Principles of Disease: Parasitology

PRINCIPLES OF DISEASE: PARASITOLOGY

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PRINCIPLES OF DISEASE: PARASITOLOGY

First published in 2026 by The University of Queensland

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ISBN: 978-1-74272-430-0

DOI: 10.14264/be72576

Please cite as: Jones, M., Beasley, A. & Knott, L. (2026) *Principles of Disease: Parasitology*. The University of Queensland. https://doi.org/10.14264/be72576

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The University of Queensland, St Lucia QLD, Australia

ACKNOWLEDGEMENT OF COUNTRY

We acknowledge the Traditional Owners and their custodianship of the lands on which this project originated. We pay our respects to their Ancestors and their descendants, who continue cultural and spiritual connections to Country. We recognise their valuable contributions to Australian and global society.



A Guidance Through Time by Casey Coolwell and Kyra Mancktelow © The University of Queensland

About the artwork

Quandamooka artists Casey Coolwell and Kyra Mancktelow have produced an artwork that recognises the three major campuses, while also championing the creation of a strong sense of belonging and truth-telling about Aboriginal and Torres Strait Islander histories, and ongoing connections with Country, knowledges, culture and kin. Although created as a single artwork, the piece can be read in three sections, starting with the blue/greys of the Herston campus, the purple of St Lucia and the orange/golds of Gatton.

The graphic elements overlaying the coloured background symbolise the five UQ values:

- The Brisbane River and its patterns represent our Pursuit of excellence. Within the River are tools used by Aboriginal people to teach, gather, hunt, and protect.
- Creativity and independent thinking is depicted through the spirit guardian, Jarjum (Child in Yugambeh language), and the kangaroo
- The jacaranda tree, bora ring, animal prints, footprints and stars collectively represent honesty and accountability, mutual respect and diversity and supporting our people.

Learn more about The University of Queensland's Reconciliation Action Plan.

INTRODUCTION

VETS2006 Principles of Disease 1

Parasitology

Introduction and Explanatory Notes

This book covers aspects of the Parasitology component of VETS2006, taught in The University of Queensland (UQ) School of Veterinary Science. The publication is freely available to UQ students and is intended to provide background information on the parasites of domestic animals, with particular reference to those of Australia.

The focus of the Parasitology module is on the parasites – their general morphology, diversity, adaptations and life cycle strategies. You will be exposed to clinical aspects of parasitic diseases in subsequent years of your veterinary professional studies.

The book is to be used as a learning tool for practical classes in veterinary professional studies and contains instructions on how to identify parasites of importance, while providing background information on a range of parasites. It will be valuable as a resource text for revision for UQ theory and practical exams and quizzes. Some of the material presented in this booklet won't be examinable. Much of the basic zoological information at the start of each chapter won't be examined, but you should still read these sections to understand the biology of parasites. **Your lecturer will give clear guidelines on which components of the module are examinable.**

The booklet has evolved over many years, with input from academics in the School of Veterinary Science at UQ. Major recent contributors are:

- Professor Malcolm Jones
- Dr Anne Beasley
- Ms Lyn Knott
- Professor Glen Coleman (Currently Deputy Vice Chancellor at Southern Queensland University).

We are grateful to Dr Tamsin Barnes for her careful review of the text. Images are either original or from cited sources.

PART I
INTRODUCTION TO VETERINARY PARASITOLOGY

1.

WHAT ARE PARASITES?

Parasites live in or on another organism and benefit at the expense of that other organism, the **host.** The host, by definition, is harmed by the interaction but is not killed immediately. The degree of harm caused by the parasite is variable. Some organisms that we consider to be parasites are more likely to be **commensals. A commensal** is an organism that lives in or on a host, and benefits from that relationship. In the association, the host receives neither benefit nor harm.

The term 'parasite' in the veterinary context, is usually reserved for any eukaryotic pathogen that has animal-like features (traditionally such features included spontaneous motility and ingestive heterotrophy). In its broadest sense, a parasite is any pathogen that displays spontaneous motility. Parasites of animals include many single-celled eukaryotes (the protozoa), helminths (worms) and arthropods. There are many other examples of parasites. There are parasitic vertebrates (e.g. vampire bats, cuckoos). Some plants parasitise other organisms. There are many species of pathogenic fungi. Fungi are eukaryotic, but were long considered plant-like organisms. Fungi are typically considered as part of veterinary microbiology.

In this module, we will examine the protozoans, helminths and arthropods; these are all eukaryotic and are the groups most commonly associated with the term parasitology.

Parasites pass much (or a significant part) of their lives **on** or **in** the body of a living host, from which they derive food in a manner harmful to the host. External parasites feed on the hair, feathers, scales, or skin of the host or suck its blood. Internal parasites may live in the various tubes and ducts of the body (i.e. digestive tract, respiratory passages or urogenital ducts) or they may live embedded in tissues such as liver, brain or muscle. Some parasites are transient visitors to their hosts. Insects like mosquitoes, sand flies, midges or *Stomoxys calcitrans* will feed on their host for only a few minutes at any one time and spend much of their time off the host.

At some point in their life cycle, all parasites must move themselves, or more often their progeny, from one host individual to another. This is seldom a simple activity, especially for internal parasites. Most larval or transmissive stages of parasites die without completing their life cycle. For this reason many internal parasites generally have a huge reproductive potential. The average *daily* egg output for the human

roundworm *Ascaris lumbricoides,* is said to range from 200,000 to 1 million eggs[1]. (Consider this – some 807 million humans are said to be infected with *Ascaris.* That is a lot of eggs excreted worldwide per day!)

Parasites and hosts evolve together. Parasites can be quite pathogenic, especially in new hosts. Traditionally, it has been considered that a dynamic balance between the parasite and host is eventually reached. The host survives without being seriously damaged and the parasite prospers well enough to produce enough offspring to continue the life cycle. This does not adequately explain the wide variations in pathogenicity of different parasites in their respective hosts. For example, parasites that lack mobility and live in more or less permanent association with the host are often quite host-specific and often inflict minimal damage on their host in normal circumstances. However, relatively mobile parasites that can survive well off the host, and that can utilise a broader range of host species are often more virulent; they may take as many nutrients from a host in as short a period of time as possible.

In spite of these considerations, it is still generally true that parasitic infection is common but **parasitic disease** is not so common. Disease may occur when:

- the host-parasite balance is upset by various factors, such as the occurrence of parasites in unusual hosts
- parasites which are relatively "new" to host species
- hosts are infected with parasites for the first time (consider coccidians in new-born animals)
- effects of domestication, including animal husbandry.

Reference

1. Wang J, David RE. Ascaris. *Current Biology*. 2020;30(10): R423-R425.

2.

TERMS USED IN PARASITOLOGY

Parasite Biology

endoparasites – live **within** the host, and are often said to **infect** a host

ectoparasites – live on the surface of the host (including in ear canals etc), and are often said to **infest** a host

facultative parasites – able to live free or as a parasite (e.g. house fly maggots on rubbish or in a wound of an animal)

diapause – metabolic quiescence (e.g. cessation of growth and metabolism) in arthropods. Generally occurs at a particular stage of development for different parasites. It is instigated by environmental conditions (i.e. assists the organism to survive adverse conditions).

hypobiosis – arrested development **within** the host. In **nematodes**, usually occurs at a time when conditions are adverse for the survival of free-living stages of the nematode – but factors influencing hypobiosis are complex! We generally do not refer to developmental arrest, or cessation of movement, of a nematode in the **non-host environment** as hypobiosis.

zoonosis – disease transmissible from animals to people

Parasites and Their Host

direct life cycle – a parasite that requires a single host species to complete its life cycle

indirect life cycle – parasite that requires at least one intermediate host species in order to complete its life cycle

host specificity – degree to which a parasite is able to survive/mature in more than one host species. Parasites with high host specificity can generally only survive in one or very few species of host. Conversely, those with low specificity can live in a wide range of hosts. Lice have high host specificity; fleas, generally, have low host specificity.

definitive host – host in which the parasite reaches sexual maturity (for veterinary parasites, this is

generally a vertebrate host). The term is also sometimes used in reference to asexual parasites (e.g. *Amoeba*) and in this case refers to the host most important to people.

intermediate host – host that is **required** for parasite development, but in which the parasite does **not** reach sexual maturity.

paratenic host/transport host – host in which the parasite remains alive and infective to another host but undergoes limited or no development. These hosts are *not required* for the parasite's life cycle but they frequently are useful in helping the parasite bridge an ecological gap.

reservoir host – host, other than those we are primarily interested in, which may harbour the parasite and serve as a source of infection.

Vectors

vector – any agent that transmits a disease organism. The term is often applied to arthropods that may transmit disease organisms between hosts. A vector may be a:

- **mechanical vector** – direct, prompt transmission of infective organism to new host, with no development or proliferation of the organism within the vector (e.g. house fly carrying worm eggs)
- **biological vector** – in which the infectious organism undergoes development and/or proliferation before being transmitted to a new host. This term overlaps with definitions of intermediate, paratenic and definitive hosts (above).

Fomites

Non-living objects capable of carrying infectious agents (e.g. shearer's clippers transferrring lice between sheep).

3.

TAXONOMY AND CLASSIFICATION OF PARASITES

There is enormous complexity of life on planet Earth. Census of Marine Life estimated that there are 8.7 million (+/- 1.3 million) eukaryotic species on Earth[1]. The vast majority of these species have not been formally described in the scientific literature.

It is estimated further that some 40% of all eukaryotic species are parasitic[2]. In fact, all species are either parasites or are parasitised by other species! Some parasites can be parasites of other parasites or at least use other parasites to further their own survival. The flagellated protozoan, *Histomonas meleagridis,* for example passes from one host, a turkey to another by hitching a ride in the eggs of a nematode *Heterakis gallinae.* These eggs are often ingested by earthworms, so that when a turkey eats an earthworm that carries ingested eggs, the turkey can be infected by not one, but two, parasites simultaneously.

In order to make sense of the diversity, we tend to categorise similar species together in a hierarchical system. The degree of similarity can be determined from morphological and/or genetic characteristics. The various hierarchies or levels of classification, are termed taxa (singular= taxon), and the science of biological classification is called **taxonomy**. The classification of parasites involves allocating them to taxa. In the table below, we present a classification of the barber's pole worm, a major parasitic pathogen of sheep and goats, and of the sheep.

Table: Hierarchical taxonomy of the barber's pole worm.

Taxon Name	
Kingdom	Animalia
Phylum	Nematoda
Class	Chromadorea
Order (SubOrder)	Rhabdita (Strongylida)
Superfamily	Trichostrongyloidea
Family	Trichostrongylidae
Genus	*Haemonchus*
Species	*contortus*
Taxonomic Authority	(Rudolphi, 1803) Cobb 1898

In the table, the Taxa (sing. taxon) are ranked from highest level (i.e. Kingdom – the broadest taxon) to lowest (species – the most restrictive taxonomic category). As more species are discovered, and as scientists try to make sense of the complexity of animal diversity, additional taxonomic levels have been added to classify groups. This is seen commonly at the levels of Order and Family. An Order can be categorised further into Suborders, Infraorders and even parvorders.

The taxonomic authority is the name of the person who first formally described the species, and the year indicates the year in which the description was published in the scientific literature. You will see that there are two names listed as authority. Rudolphi is recognised as the first person to formally name the species, but he named the species as *Strongylus contortus*. Cobb proposed the genus name *Haemonchus* in 1898 and placed this species in that new genus. Because the original name Rudolphi gave the species changed with the taxonomic revision by Cobb, we place Rudolphi and the year in brackets.

Throughout this book, we use a term '**clade**' to define groupings of organisms. A clade is any group of organisms that share a common ancestor. The word is used frequently by biologists who study phylogenetic relationships of organisms and can be used at any level of classification. A clade can be synonymous with any taxon, or it may not be related to any recognised taxon. For us, the term clade is a term of convenience and we will use the term to denote a group or related species.

The names of the genus and species are expressed in Latin, and a capital letter is assigned to the genus name. The word *Haemonchus* roughly translates to the phrase 'blood tooth', signifying the presence of a small hook in the mouth of the parasite that acts as a blood-letting tool. The species name *contortus* probably refers to the way that the red gut of the parasite twists around the white ovary in females, giving the internal structures of the worms an appearance of red and white strands twisted together. Because the genus and species names are in a foreign language, it is customary to underline or *italicise* the genus and species names, but not the names of higher taxa.

Taxonomy is a dynamic science, particularly with the molecular tools that have been developed in recent decades and which provide insight into genetic relationships between organisms. Taxonomic decisions at all classification levels are thus under more or less constant review, and not all decisions published in the literature reflect a consensus view. This can make life difficult for students and veterinary professionals who are frequently blissfully unaware of such taxonomic uncertainties but are faced with different texts recording the same parasites under different names.

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marine biodiversity knowledge, resources, and future challenges. *PLoS ONE.* 2010;5(8):e12110. doi: 10.1371/journal.pone.0012110

2. Dobson, A, Lafferty, KD, Kuris, AM, Hechinger, RF, Jetz, W. Homage to Linnaeus: How many parasites? How many hosts? *Proc. Natl. Acad. Sci. U.S.A.* 2008;105 (Supplement 1):11482-11489. doi:10.1073/pnas.0803232105

PART II
THE ARTHROPODS

4.

PHYLUM ARTHROPODA

The Phylum is a monophyletic assemblage of organisms containing some of the more obvious invertebrates observed on land and in aquatic environments. The Phylum Arthropoda is the largest animal assemblage, comprising approximately 80% of all animal species. The Arthropoda belongs to the **Clade Ecdysozoa**, an assemblage of animals that include the Nematoda and Nematomorpha, and which are all characterised by an **exoskeleton** that must be shed in order for the organism to grow. The process of shedding of the exoskeleton is called ecdysis (hence the name of the clade). The more common term for ecdysis is moulting.

General Characteristics of the Arthropoda

1. Segmentation and Tagmatisation



Centipede (Arthropoda: Myriapoda).

Image: AI generated by MS Copilot

All arthropods are segmented, that is, their bodies are partitioned longitudinally into discrete units, called segments. These are seen most obviously on arthropods like the centipede, which has a series of seemingly identical segments behind the head. Internally, segmentation is seen in organisation of discrete tissues and organs, such as branches of the nervous system, or arrangement of muscles. To get an idea of segmentation in animals, consider your own body: feel your backbone, or ribs and note that these are aligned as a longitudinal series of similar structures. The image below is an AI generation of a centipede showing the distinctive segmentation of an arthropod.

The two great benefits of segmentation are seen in the enhanced capacity for movement seen in segmented animals, and in specialisation of different regions of the body. A centipede is shown in the figure to the **left,** as an example of an arthropods with a simple form of body segmentation. The legs and wings of insects are possible because of adoption of segmentation, and the specialisation of body parts has enabled arthropods to invade many new environments and to diversify. Segmentation allows specialisation of body

parts, so that in insects, different parts of the body can be devoted to specific functions, such as locomotion or digestion or formation of embryos.

Arthropods have adapted their segmented bodies further through an evolutionary process termed tagmatization, in which body segments are fused into 'super-segments' or body regions (See figure of *Linognathus vituli* to the right). An insect has three tagmata in its body: the head, thorax and abdomen. The three tagmata have distinctive functions. The head, of course, is used for feeding and is equipped with extensive sensory structures. The thorax, is used primary for locomotion, and in insects, you will encounter the legs and wings in the thorax. The abdomen is where the insect processes food, and where organs for reproduction and excretion are found.



Linognathus vituli, a louse, demonstrating the presence of tagmata. The body segments have fused (partially) into three tagmata or body regions- from left to right, the head ,thorax and abdomen. Evidence of segmentation is observed in the presence of three pairs of legs, the segments of those legs themselves and the serial blocks of the abdomen.

Image: © Lyn Knott

2. Exoskeleton

As ecdysozoans, the arthropods have an exoskeleton. This is usually a hardened structure that covers the entire body and lines some internal structures, and is synthesised by an epithelium that lies underneath the exoskeleton. The exoskeleton is seen as a major pre-adaption that has facilitated diversification of arthropods in the terrestrial environments, for the structure provides protection against desiccation, solar radiation and predation. The exoskeleton, also called a cuticle, is made of a complex of protein and polysaccharide, called chitin.

The exoskeleton is non-expandable and so, in order to accommodate growth, arthropods undergo a series of moults, or **ecdyses**, during development. The moulting process is under **hormonal control** and the stages of the animal between each moult are referred to as **instars**.

3. Jointed Limbs (hence the name: arthro- joint; pod-foot)

All arthropods have appendages on some segments. These are often hinged to facilitate their movement and utility. Jointed legs are shown in the photo of *Linognathus* (above).

4. Dorsal Heart and Blood Vessels

This arrangement contrasts with that of vertebrates in which the heart is ventral to the nerve cord.

5. Open Circulatory System

Whereas in vertebrates blood always flows through vessels, in arthropods the vessels open into body cavities, so that tissues are bathed in **haemolymph**.

6. Ventral Nerve Cord

See point 4 above.

Arthropod Physiology

The **nervous system** consists of cerebral ganglia in the head which are joined by circumoesophageal commissures to a ventral double nerve cord that has nerve ganglia associated with each segment. Sensory receptors are often associated with highly specialised structures of the exoskeleton.

Circulatory system: The general body cavity of arthropods is filled with haemolymph and called the **haemocoele**. The "heart" is an enlarged dorsal blood vessel enclosed in a compartment (pericardium) containing holes (ostia) in its walls. As the heart beats, it sucks haemolymph in through these holes and then pumps it out into the haemocoele through short arteries (the only blood vessels).

The **gut** is highly variable but can be divided into a fore-gut, mid-gut and hind-gut.

Excretory system: Insects and arachnids have **Malpighian tubules** which are excretory organs opening into the anterior hind-gut. Arachnids also have excretory coxal glands opening on the coxae of the legs.

Gas exchange: Oxygen is delivered to the tissue by a number of different processes. Respiration may be through the **cuticle** (some mites), **gills** (larvae, nymphs, aquatic adults), or **trachea** (fine elastic conducting tubes branching among the internal organs). The trachea open at holes in the exoskeleton; **spiracles** (in insects) or **stigmata** (some acarines).

Setae: These are long, thin hair-like cuticular extensions produced by some epidermal cells (large setae may be called 'bristles' in some arthropods).

Arthropod Reproduction and Life Cycles

Development is under hormonal control; e.g. **juvenile hormone** has a "status quo" effect to maintain larval or nymphal characteristics → levels fall as development proceeds and adult characteristics appear. In the fully mature adult, however, juvenile hormone can once again be secreted by the arthropod. In the reproducing adult, the hormone has a role in reproduction.

Arthropods are dioecious, that is, the sexes are usually separate. Most arthropods are *oviparous* (egg laying).

A wide range of breeding strategies are employed and these are important in understanding the biology of parasitic arthropods.

Complex metamorphosis = complete metamorphosis (holometabolous life cycle).

Holometabolous development is seen in many insects.

- Egg develops into a **larva,** a life cycle stage structurally distinct from the adult and usually occupying a different ecological niche to the adult.
- Typically there are three or more larval stages followed by the formation of a **pupa** and structural reorganisation (metamorphosis) to form an adult.
- Examples are the fleas and flies.

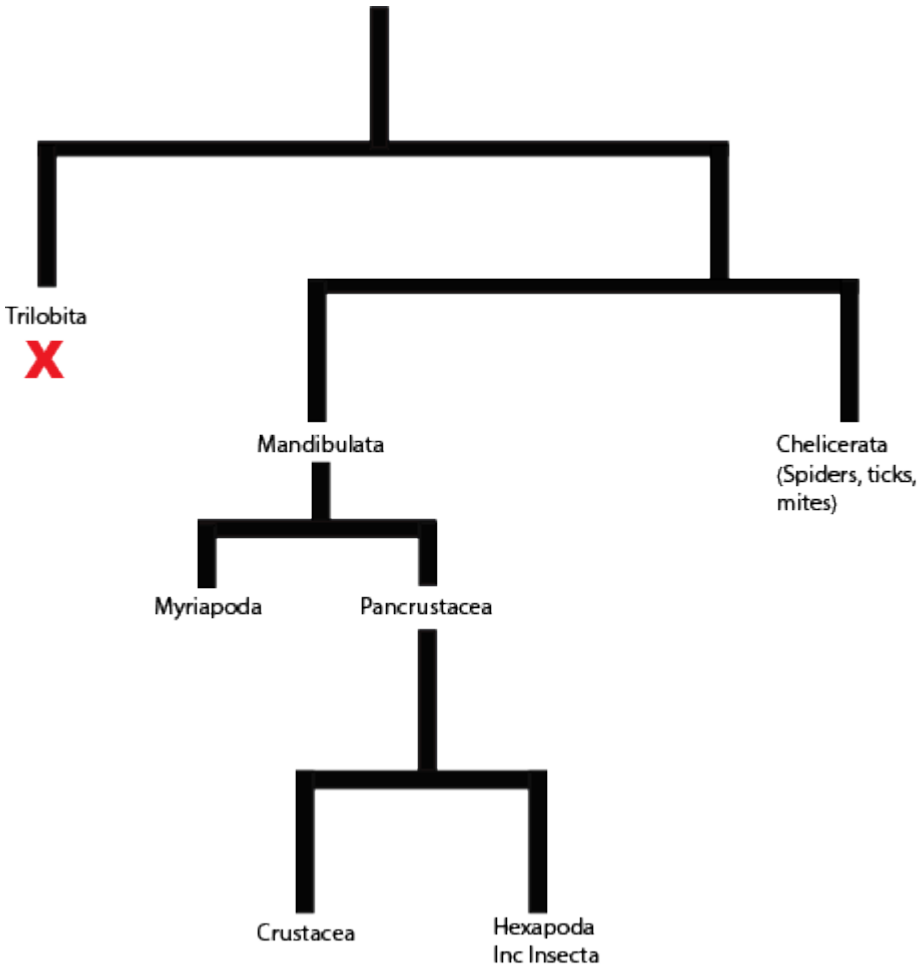
Simple metamorphosis = incomplete metamorphosis (hemimetabolous life cycle)

- In other species (such as lice), the larval instars are called **nymphs** and they gradually become more like the adult with each ecdysis.
- The chelicerates (ticks and mites) display a simple development with incomplete metamorphosis (that is, juvenile forms look much like the adult forms).

Diapause is a period of developmental arrest that allows some arthropods to withstand adverse environmental conditions. It may occur in the egg, larva, pupa or adult stages of the life cycle depending on the species and involves a slow down of physiological processes.

Classification of Arthropods

The phylogenetic relationship of the major clades of arthropods is shown in the phylogenetic tree below. For simplicity, many minor groups of arthropods are not included in this tree. The **Trilobita** was once the dominant clade of arthropods, but this class of organisms is now extinct (indicated by the red X). Of the extant (living) clades, the **Chelicerata** form a phylogenetically distinct clade to the **Mandibulata**. Chelicerates have a mouthpart dominated by chelicerae (which act as fangs, claws, toothed plates). The Chelicerata contains the spiders, ticks and mites, scorpions and many related clades.



Simplified phylogenetic tree of the arthropods. There are two major clades of living arthropods, distinguished by the structure of their mouths – the Mandibulata and the Chelicerata

The Mandibulates are arthropods with mandibles, solid structures that act in chewing. The diverse Mandibulata contains the hexapods (insects and related species), crustaceans (copepods, crabs, shrimp etc.) and the myriapods (centipedes and millipedes).

5.

THE PARASITIC INSECTS

It is estimated that there are 5.5 million insect species. There are many parasitic forms of insects but fleas, lice and flies are of particular veterinary importance.

General features of the insects are:

- **imagos** (adults) have antennae, a distinct head, thorax and abdomen, and one pair of legs on each of the three thoracic segments
- the **thorax** usually bears two pairs of wings (one pair only in flies) which are outgrowths of the tegument. The wings are supported by hollow veins (the arrangement of which is important in identification)
- most insects have a pair of compound eyes, consisting of individual lensing structures (ommatidia) and from 0 to 3 simple eyes (ocelli).
- **mouthparts structure** are mandibulate. The mouthparts shows great variation, with adaptations for chewing and biting, sponging or piercing and sucking;
    - The **labrum** (upper lip) is a hinged plate and the **labium** (lower lip) may be extensively modified
    - paired **mandibles** and **maxillae** (jaws) are adapted for cutting, slashing or grinding
    - a **hypopharynx** (~tongue) extends from the floor of the mouth and carries the opening of the salivary glands
    - palps.

Three Orders of Insects are primarily of veterinary concern:

Fleas, Lice, and Flies

Order	Common name	Body shape	Wings in adults?	Pre-adult forms	Location of pre-adult forms
Siphonaptera	Fleas	Laterally compressed	No	Eggs-larvae-pupae	Off-host (usually)
Psocodea (Phthiraptera)	Lice	Dorsoventrally compressed	No	Eggs-nymphs	On host
Diptera	Flies	Not flattened	Usually yes, 1 pair of wings	Eggs-larvae-pupae	Usually off-host, depending on species

Other groups of insects contain parasitic members. The insect order Hemiptera, best known as the bugs

that feed on plant sap, contains animal parasites. Among these bugs are the well-known bed bugs (*Cimex* species). Other bugs are agents of the zoonotic disease of the Americas called Chagas Disease. Chagas Disease is caused by infection with *Trypanosoma cruzi,* a flagellated protozoan and is transmitted to animals and humans through the bite of reduviid bugs (*Rhodnius* species). As the bugs feed on the host, they defaecate at the site of the bite and the parasites within the faeces are rubbed into the bite wound. Originally associated with South America, Chagas disease is now known to be present in the southern USA, where it infects animals and people.

Other insects may also harm animals of domestic importance but are generally not considered among the parasites. Hairy caterpillars, for example, members of the insect order Lepidoptera (moths and butterflies) can cause serious disease for horses that ingest them. These caterpillars are not parasites.

Other insects may themselves not appear as parasites but can have damaging effects on domestication animals. Filth flies, for example, may feed on liquids exuded from wounds or tear ducts. As these flies are also associated with carrion or areas of detritus or waste (rubbish bins), they may deposit harmful bacteria on hosts, leading to secondary infections.

6.

ORDER SIPHONAPTERA

The Fleas

> "The combined effects of Nero and Kubla Khan, of Napoleon and Hitler, all the Popes, all the Pharoahs, and all the incumbents of the Ottoman throne are as a puff of smoke against the typhoon blast of fleas' ravages through the ages." – B. Lehane, The compleat flea.[1]

The **Order Siphonaptera,** the fleas, are an order of small flightless insects, most closely related to the true flies and the scorpion flies and allies. There are about 2500 species of fleas found on species of birds and mammals.

The earliest use of the word 'flea' in English comes from the 12th century AD and was probably derived from the old Germanic languages. Fleas belong to the **clade** of insects that display **holometabolous** development, that is development with complete metamorphosis. Thus there are four major stages in the life cycle, the **egg, larva, pupa and adult (imago)**. The **important concept** of the flea life cycle is that the larval stage lives off the host and feeds on materials in the environment, whereas the adult typically feeds on the host.

I. Morphology

Adult Fleas

Adult fleas are **laterally compressed**, wingless, dark-brown or black insects approximately 0.5- 3mm in body length. The fleas have backwardly projecting bristles or combs that prevent the fleas from being easily removed from the host during grooming. The combs of fleas are called **ctenidia.**

Fleas have long legs, that terminate in a tarsus that can bear a single claw. The third pair of legs is much longer than the others to assist leaping. How do fleas jump so high (YouTube, 1m5s) describes how fleas jump. The scientific name of the order, the Siphonaptera, arises from the mouthparts of adults. These are elongate and are formed into a sucking tube for imbibing blood. This contrasts with the mouthparts of larvae, which are adapted to chewing, and hence the mandibles are large (relative to the size of the head).

Eggs

These are small ovate and have a cream colour. Eggs are either laid on the host and roll off into the environment (e.g. in the case of *Ctenocephalides felis*- the cat flea) or are laid directly on substrates, e.g. birds nests.

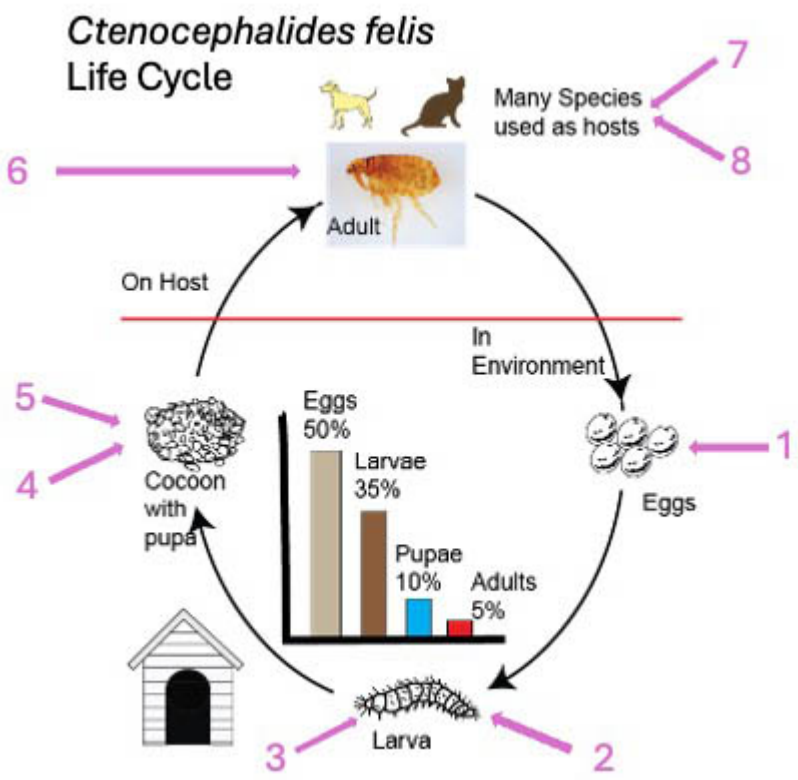
Larvae

Flea larvae are small caterpillar-like organisms, with a brown head and a cream or semitransparent body with fine setae. The head bears mouthparts that are adapted for chewing solid materials in the environment. There are three larval stages. The larvae live off the host in nests or bedding material, or in folds in furniture or cracks in flooring.

Pupae

The pupa is a resting and remodelling phase of the life cycle. The larva spins a silken cocoon around itself, moults again and then forms the pupa, which develops so that adult features (legs and other structures) are evident beneath the casing. The cocoon appears as a small ovate structure. Due to its sticky nature, the cocoon attracts small grains of sand that stick to the outside. If you were to carefully dissect the cocoon, you would see the pupa within.

II. Life Cycle



Ctenocephalides felis life cycle. Ctenocephalides felis life cycle.

Images: Adult – © Lyn Knott; Dog – Rhcastilhos, Public Domain, via Wikimedia Commons; Cat by Extreme Unction (File:Catstub.png), Chris-martin (File:Cat_silhouette.svg), modified by ToBeFree, CC0, via Wikimedia Commons

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=97#h5p-3

The general life cycle of fleas is shown in the figure above.

The duration of the life cycle of fleas varies with species and is largely dependent upon environmental conditions. For the important cat flea, *Ctenocephalides felis,* the population of fleas in an area consists of approximately 50% eggs, 35% larvae, 10% pupae and 5% adults. The primary factors influencing the life cycle are temperature, humidity of the off-host environment and the availability of appropriate food for the larva. More information on life cycle requirements are presented in the boxes in the diagram above.

Eggs, depending on species, may be stick to the host or just roll off into the environment, usually the nest. The eggs may be laid on the host, or its nest, or on the ground. Eggs are abundant usually in the rest areas of hosts. The eggs can hatch after a few days to 2 weeks.

Larvae usually live in the host's bedding/nest, although in some species they can live on the host itself. The larvae are adapted to feeding on solid material. They require humidity to survive. The larvae feed on organic debris, for example sloughed skin and hair/feathers, but they seem to require, in the case of *Ctenocephalides felis*, the small particles of dried blood excreted by adult fleas. These particles fall into the host rest areas and are a ready source of nutrition. Fleas larvae can also eat unhatched flea eggs and these may be essential dietary components for some flea species.

Pupa. The pupa occurs in the nest or rest material. The adult can develop quickly. The **pre-emerged adults** in pupal case responds, in *Ct felis* at least, to external movement. If no appropriate stimulis, adults may remain in cocoon for extended periods, up to 12 months. This is particularly important in the case of *Ct. felis* as the pupae and pre-emerged adults are relatively protected from insecticides and complicate flea control programs.

Adults. The **rapid emergence** of the young adult from the cocoon is triggered by stimuli likely to reflect the return of a host to the lair/nest, especially mechanical pressure and heat. This is seen especially in fleas of nesting birds that return to nests after prolonged periods.

Adult fleas are obligate blood feeders, but many can survive extended periods without blood feeding. During feeding, the adults excrete faeces comprised mostly of partially digested blood; these serve as an important food source for larvae

Considerable variation between species in the time spent on the host and the degree of attachment; transient feeders (*Ceratophyllus*) to prolonged associations with the host (*Ctenocephalides*) or permanent

attachment to skin (*Echidnophaga*). The Chigoe flea can burrow into the skin of the feet of animals and humans.

Adult fleas have host preferences, but are **not host-specific.**

III. Effects of Fleas on Host

Effects on the host include direct and indirect effects.

Direct effects

1. Irritation, including hypersensitivities (especially flea allergy dermatitis in dogs and cats).
2. Blood loss. This is especially a problem for young animals.

Indirect effects

1. Intermediate hosts (*C. felis* is host to *Dipylidium caninum* or flea tapeworm in dogs, cats).
2. Vectors of disease (*Spilopsyllus cuniculi* (rabbits, hares) transmit myxomatosis; most famously X*enopsylla cheopis* (black rat flea) – bubonic plague).

Control of fleas parasitising domestic animals

Fleas can be controlled on animals through the use of topical and oral insecticides. Both can be effective because the adults suck blood. Topical applications are applied between the shoulders. Although fleas can be found over the entire body, the will be commonly found around the head and neck.

The flea life cycle can be controlled in the environment. This can be done through insecticide treatments (pest control), removal of bedding and vacuuming of carpets or floors with cracks.

Important Fleas in Australia (and beyond)

Ctenocephalides felis (Cat Flea)

The cat flea, primarily infests dogs and cats but has been recorded on over 50 host species. This species may also reach large numbers anywhere where livestock are kept intensively and the environment is suitable for survival of eggs and larvae (e.g. straw bedding).

The common name, cat flea, is slightly confusing, as it implies that this species is only associated with cats. The cat flea, however, is equally common on dogs, and as stated can infest multiple species. Cat fleas can

also bite humans, although they seem to not like us very much. The cat flea originated with cats in Africa, and spread throughout the world with cats and dogs, no doubt aided by human movement of domesticated animals.

The cat flea is a major source of irritation for animals. The species causes severe irritation in animals and humans and is responsible for flea allergy dermatitis. Fleas, because they are haematophagous, can transmit microbial pathogens including species of *Bartonella,* Rickettsias. By virtue of the feeding behaviour of larval fleas, which eat detritus in the environment, including tapeworm proglottides, the species is an intermediate host of the flea tapeworm (*Dipylidium caninum).*

While oral and topical medications are now available for control of fleas on animals, there are important considerations concerning the life cycle. These include:

1. The majority of the life cycle and individuals in a population are in the environment. Thus a previously flea-free animal introduced to a place where the life cycle is maintained will be susceptible to fleas.
2. The off-host parts of the life cycles rely on humid environment with food provided indirectly by the feeding habits of adult fleas. A clean environment (for example, cleaning of old pet blankets) can remove these off-host stages.
3. The pre-adult can survive for up to 12 months in its pupal case.

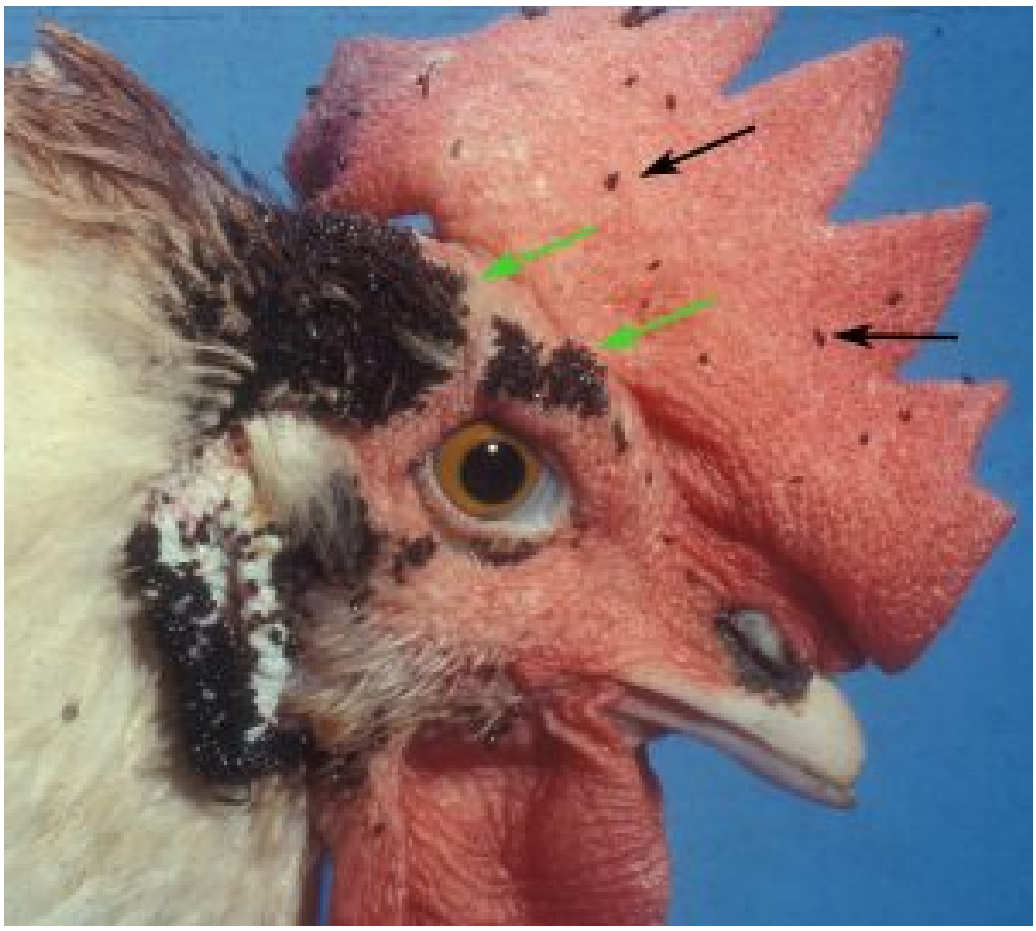
Ctenocephalides canis (Dog Flea)

The species name does not typically reflect host preference. *Ct canis* is not as common on domestic animals as *Ct felis*, but it is still present. The biology of this species is essentially the same as that of *Ct felis*.

Echidnophaga gallinacea (Stickfast or Sticktight Flea)

The stickfast flea is seen on poultry, but it has many hosts, including a wide range of domestics animals and humans. The flea is found in many parts of the world.

Adults attach to hosts in areas with few feathers or hairs, such as the combs or around the eyes of chickens. The female penetrates the skin and produces ulcers into which eggs are laid. The eggs hatch in the skin, and the larvae fall to the ground to continue the life cycle. Images of the fleas on the head of a chicken are shown below.



Echidnophaga gallinacea fleas on the head of a rooster. Individual fleas can be seen largely on the comb (black arrows), while large clumps of fleas are seen over the eye and on the ear (green arrow).

Photo: Original photo © Dr Alan Waddell of UQ (circa 1980). Used with permission.

Tunga penetrans (Chigoe Flea – not in Australia)

This South American (and African) flea burrows into the toes and feet of animals and humans. It was introduced to Africa and is a major pathogen responsible for severe pain in the feet and difficulty in walking.

Spillopsyllus cuniculi. (Rabbit Flea)

This flea is present on rabbits in Australia. The flea was instrumental in transmission of the myxomatosis virus in control strategies of rabbits in Australia.

Pulex irritans (Human Flea)

The so-called human or house flea is found on humans but infests 6 species of mammals. The flea can be found on wild pigs in Australia. *Pulex irritans* was implicated in transmission of the plague organism (*Yersinia pestis*), although experimental evidence suggests that the human flea is a poor vector. More than likely, the rodent flea, *Xenopsylla cheopis,* was responsible for transmitting the plague organism.

Identification

- Information to assist in identifying fleas

References

1. Lehane B. *The compleat flea: A light-hearted chronicle, personal and historical, of one of man's oldest enemies*. Viking Press; 1969.

7.

ORDER PSOCODEA (CLADE PHTHIRAPTERA)

The Lice

"My sooth! right bauld ye set your nose out, As plump an' grey as ony groset:
O for some rank, mercurial rozet, Or fell, red smeddum,
I'd gie you sic a hearty dose o't, Wad dress your droddum."

– Robert Burns from *To a Louse, on seeing one on a lady's bonnet, at church, 1786*[1].

(Roughly translated, Burns is saying to the louse, "I see you sticking your head out, looking like a juicy raspberry. I wish I had some smelly ointment or powder! If I did, I'd give you a serious dose of it – that would serve you right!")

The parasitic lice were previously placed in a distinct taxonomic order of the Class Insecta, the Phthiraptera. This order contained only the parasitic lice. The lice are now recognised to belong to a wider group of organisms, the Order Psocodea, which contains many free-living insects, including the book- and bark-lice. Within the Psocodea, the animal-parasitic lice form a distinct clade, called the **Phthiraptera**. This name of this clade is derived from the Ancient Greek word *phthir,* which simply means 'louse'.

Morphology of Phthirapterans

The parasitic lice are usually small (<1 cm length) **dorsoventrally flattened, wingless insects**. The heads bear a pair of short antennae containing 3-5 segments. The eyes are vestigial or absent.

All 6 legs terminate in a **single claw,** which has one or two prongs.The shape and size of the claw can be a determinant of host specificity and site specificity on the host. The abdomen of parasitic lice is enlarged and may be adorned laterally by sclerotised plates, called **paratergal** plates. Spiracles are prominent on the lateral margins of the abdomen.

Taxonomy

There are 4-5 superfamilies of lice (the taxonomy is disputed), 3 of which are of veterinary importance. The important lice, from a veterinary perspective as shown in the table below.

Clades of Lice of Veterinary Importance

The important clades of lice are shown in the Table below.

Clade	**Amblycera***	**Ischnocera***	**Anoplura**
Feeding Biology	Chewing lice; feed on skin, hair or feathers	Chewing lice; feed on skin, hair or feathers	Sucking lice; blood-feeders
Habitat on Host	Fine body hair, base of feathers	Fine body hair, base of feathers	Coarse body hair, tail, mane, face, foot
Head width	As wide as thorax, or wider	As wide as thorax, or wider	Narrower than thorax
Body Size	Usually small <3mm	Usually small, but some larger species	Usually larger up to 8 mm
Body Colour	Yellow or cream	Yellow or cream	Often black or blue (because of breakdown products of haemoglobin ingested by louse)
Antennae	4-segments, recessed in grooves	3 to 5 segments, not recessed	3 to 5 segments, not recessed
Legs	Weak (thin), claws with one or two prongs	Claws with one or two prongs	Thick, claws with one prong
Hosts	Birds and Mammals	Birds and Mammals	Only mammals
Transmission	Contact between hosts	Contact between hosts	Contact between hosts. (sometimes some lice can be transmitted on pasture or grooming equipment, shears etc).

*Traditionally, the clades Amblycera and Ischnocera had been grouped in a taxon called the **Mallophaga**, the 'wool-eaters'. This name recognises one of the most important species of louse, *Bovicola ovis,* that infests sheep. The taxon Mallophaga is not used for louse taxonomy anymore.



Bovicola, an ischnoceran louse. Bovicola ovis is the important body louse of sheep.

Photo: © Lyn Knott

In chewing lice (**Amblycera + Ischnocera**), the head is broad because it carries large mandibles of the mouth; the mandibles grind the solid food of the parasites. These lice feed primarily on keratin in feathers or hair, or sloughed epidermis and possess gut symbionts and specific enzymes to aid keratin digestion. The legs are relatively weak, and end in claws with one or two prongs (usually avian lice have claws with 2 prongs each, while mammalian chewing lice have claws with only one prong each).

Important amblycerans include parasites of birds and mammals. The genera ***Menopon* and *Menacanthus*** are important in poultry husbandry. Other important amblycerans include *Gyropus ovalis* and *Gliricola porcelli* on guinea pigs, *Heterodoxus spiniger* on dogs, and other *Heterodoxus* species on marsupials.

Ischnocerans are typically more host-specific than amblycerans. Different ischnoceran species can be found on birds and mammals. Important ischnocerans include *Goniodes* and *Goniocotes* of poultry. These have 5-segmented antennae, 2-pronged claws/leg. An important family of ischnoceran lice on mammals is the family Trichodectidae. Members of the family have 3-segmented antennae, claws with 1 prong/leg and, as stated, are found on mammals. Examples include the very important species ***Bovicola ovis*** (sheep body louse), ***Bovicola caprae*** (goat),***Bovicola bovis*** (cattle), ***Felicola subrostratus*** (cat) and ***Trichodectes canis*** (dog).

Anoplurans suck blood and have reduced mouthparts, which results in a much narrower head in these organisms. The sucking mouthparts form a terminal sucking tube, or proboscis which can be retracted into the head. The proboscis is formed from maxilla, hypopharynx and labium, which are produced into long, thin stylets. This proboscis is introduced directly into blood vessel when feeding. **Anoplurans only infect mammals**; two thirds of known species occur on rodents.

Important genera include ***Haematopinus*** (species on cattle, pigs, equines), ***Linognathus*** (species on cattle, sheep, goats, dogs), ***Pediculus*** (on people, vector of epidemic typhus) and ***Pthirus*** (on people, "crabs").



Haematopinus from mammals. This genus belongs to the Anoplura, and contains large sucking lice, found on the faces or feet of mammals.

Photo: © Lyn Knott.

Life Cycle

Lice are **hemimetabolous.** The entire life cycle is spent on the host. **Eggs are cemented to hairs or feathers of their hosts.** The eggs of the human head louse are called nits. From the egg hatches a nymph, a juvenile form similar in structure to adults except that it is smaller and lacks obvious reproductive organs. The egg casing of lice is highly protective of the embryo, and is resistant to insecticides (some new insecticides can traverse the casing, however and can kill the developing nymph).

Lice display a relatively low reproduction rate. Low mortality of immature stages in favourable environments (due in part to cementing of eggs in place) leads to rapid expansion in susceptible animals.

Direct **contact** between animals is needed for transmission of lice (most lice die within a day or so once removed from the host).

Populations often increase during autumn and winter, then fall in spring/summer (partly due to temperature, also shedding of coat).

Host Specificity

Those commonly encountered on domestic mammals (i.e. anoplurans and ischnocerans) **have extremely high host specificity,** that is a louse species will only infest a single host species. Each louse species can only exist within a certain band of temperature and humidity. The following table shows some biological characteristics of the chewing (Amblyceran and Ischnoceran) and sucking (Anopluran) lice.

Important Lice in Australia

Bovicola ovis, the sheep body louse, is responsible for major economic damage in the wool industry. Infested sheep have a decreased wool yield, and by rubbing the fleece infested animals damage the wool resulting in a lower price.

Important Aspects of Biology of *Bovicola ovis*

- Useful information can be found in the Lice Boss Website[2]. Distribution on body affected by temperature at surface of body, and the presence of fibres of a suitable diameter to attach eggs.
- The life takes 34-36 days from laying of egg until the louse becomes an adult. The eggs hatch 10 days after laying. These eggs are resistant to many insecticides, so remember- use a residual insecticide (one that remains on body for >10 days) or treat twice.
- This species can live off hosts for 10 days.
- Populations of *B. ovis* on sheep are **highest in autumn/winter.**
- Hot temperatures in summer can kill the lice.
- Heavy rainfall and wet wool can drown lice.
- Shearing (spring/summer) lead to drops in populations of louse. Thus, populations are lowest 30 days after shearing but the populations increase with highest numbers seen 5 months after shearing.
- Although populations are lowest after shearing, transmission by contact is greatest when wool is short.
- Yards, pens and shearing sheds are important sites for contact transmission.
- If the surface of sheep is warm and shaded for longer periods of time, the lice are more likely to migrate to the surface of the wool, at which point they may transfer between individuals.

Watch Checking sheep for lice (YouTube, 57s). It shows how one should check sheep for the presence of lice.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uq.pressbooks.pub/principles-disease-parasitology/?p=99#oembed-1

Other lice

Most of the other lice genera or species described below are encountered occasionally (dog and cat species) or commonly (bovine parasites) in practice, but have less impact.

Menacanthus stramineus, the fowl body louse is an important species, generally in free-range farms. This louse can cause skin irritation due to its feeding and excretions. If populations are large, the lice may abrade the skin causing blood to pool at the surface. This blood is then also ingested. Thus, this chewing louse can become a **facultative** blood-feeder. This louse is thus also able to eat blood, although it does not have sucking mouthparts.

The **crab louse, *Phthirus pubis,*** is a parasite of great apes and humans and infects the hair of the genitals,

eyelashes and eyebrows. Clients have been known to bring a sample of this louse to their veterinarian, claiming that they found the louse on their pet. If you are ever asked to identify this louse in a veterinary context, don't be fooled (although be sensitive), *Phthirus pubis* does not infect dogs or cats. The louse sample probably came from the client.

Effects on Hosts

It is often difficult to ascertain effects on the host unless the infestation is in wool-producing animals or free-range poultry. In non-wool producing animals, disease is often mild to moderate unless the host is debilitated and unable to groom properly.

Effects on the host include:

- irritation producing hide and fleece damage and/or decreased feed intake;
- blood loss (sucking lice, uncommon to be clinically significant);
- vectors of disease (e.g. typhus and trench fever in humans transmitted by *Pediculus humanus humanus*)
- intermediate hosts for parasites (*Trichodectes canis* for the tapeworm *Dipylidium caninum*).

Control

A louse problem may reflect other, more significant problems. Therefore, in cases of lousy animals, you should look for other problems (check husbandry, nutrition, other diseases etc). Host nutrition has been implicated in severity of louse infestations/disease. The cat louse (*Felicola subrostrata)* is usually controlled by cats through self-grooming. Older cats no longer able to groom themselves, or with other conditions, may display severe infestations with this louse.

An **important concept of louse control** is that the **egg stage can be considered a protected stage**. This, together with the propensity for contact transmission between hosts of the same species, means that when treating lice one should:

- treat ALL animals in a group. For sheep, be aware of strays that have missed treatments. Practice quarantine, especially when breeding (that is ensure that rams introduced to a flock are louse-free). Sheep are best treated when the wool is short (fewer lice are present, and the insecticide can disperse more readily across the body.
- **Importantly**:
    - use a **residual treatment** that kills active population at treatment, **AND** also the nymphs that will emerge after 10-14 days from the protective eggs;
    - or **treat animal twice**, at an interval of 10-14 days depending on louse species.

Identification

- Identifying lice of domestic animals

References

1. Burns R. To a Louse. Accessed February 27, 2025. https://www.bbc.co.uk/arts/robertburns/works/to_a_louse/
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8.

ORDER DIPTERA

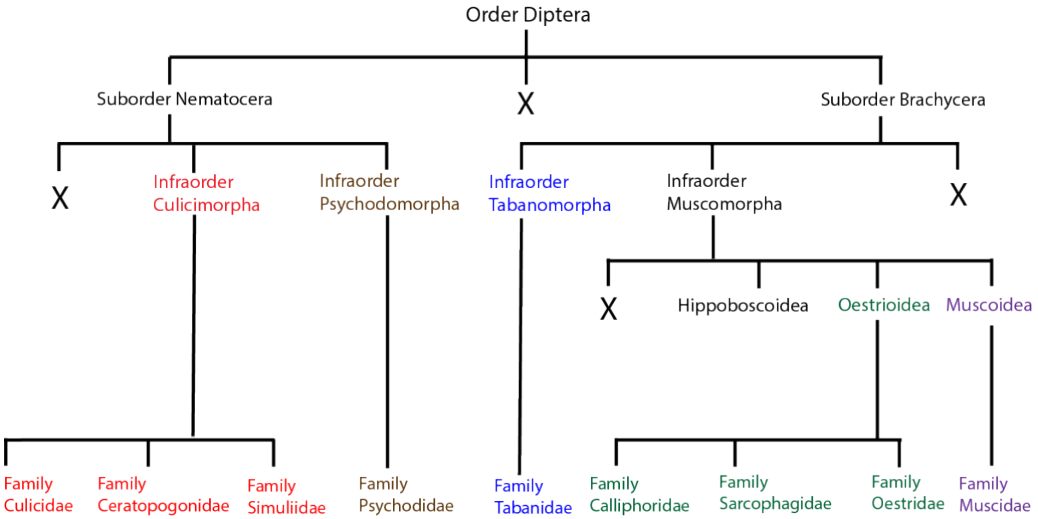
The Flies

"God, in his wisdom, made the fly, and then forgot to tell us why." – Ogden Nash, *Good Intentions*[1].

The Order Diptera is a large order of some 150,000 described species. The scientific name for the order is derived from Ancient Greek, 'di'- two and 'ptera'- wings. All winged flies have only a single pair of wings, while winged insects from other orders have two pairs of wings (in some of these 4-winged insects, the first pair can be modified – the hard shields of beetles are actually their first pair of wings). In dipterans, the second pair of wings has been replaced by sensory and balancing organs, the **halteres.** Some flies, such as some parasitic hippoboscids including the sheep ked, have lost wings altogether.

The head of flies is often mobile and the flies are often characterised by the possession of large compound eyes. Taxonomy of flies is based on the structure of the mouthparts, the arrangement of head sutures, eyes, antennae, wing venation, tarsi and placement of bristles on the body.

While the vast majority of fly species are free-living, the order includes some important parasites of humans, domestic animals and wildlife. A taxonomic arrangement of the Diptera is shown in the figure below. The flies of veterinary importance belong to two clades – the Nematocera (slender flies with multi-segmented antennae) and the Brachycera (stout flies, with antennae with relatively few segments). The dipterans that are of veterinary importance belong to the families shown in the **bottom line** of the figure below. Note that there is well over 100 families of flies that have no relevance to veterinary medicine, and not all species in the listed families are of veterinary importance.



Taxonomy and relationships of the flies of veterinary importance. Most flies in the Order Diptera are not of any veterinary importance. Various 'branches' of the fly groups that are not of significance here, are indicated with the letter 'X' in this tree. These branches may contain one or more clades of flies and many species, and are indicated solely to remind us that there are many species of flies with different characteristics and biology.

General Life Cycle Considerations

Dipterans are holometabolous and their larvae occur in a range of environments. For some species of veterinary importance, the adults only are parasitic, whereas for others the larvae are parasitic. (In some rare instances, both stages are parasitic). For the flies, it is important to recognise three forms of egg laying. Adult female flies may be:

- **Oviparous.** The female **lays** batches of **eggs** that undergo a period of maturation in the environment or on a host before larvae hatch from them.
- **Ovoviviparous**. In some families, (e.g. Sarcophagidae), the **eggs hatch in the oviduct** of the adult fly just before they are laid. The fly thus gives birth to active 1st stage larvae.
- **Viviparous.** In the Families Hippoboscidae and Glossinidae, **larvae hatch and are nourished within the female**, and deposited when almost ready to pupate.

The last two strategies have been developed in instances in which the adult is the primary feeding phase. In the sheep ked, for example, the adult fly is a wingless louse-like fly that feeds on blood. The larval phase is retained in the uterus of the adult female for its entire development.

Dipterans of Veterinary Importance

- Suborder Nematocera
  - Family Culicidae
  - Family Ceratopogonidae
  - Family Simuliidae
  - Family Psychodidae
- Suborder Brachycera
- Infraorder Tabanomorpha
- Infraorder Muscomorpha
  - Family Muscidae
  - Family Calliphoridae
  - Family Sarcophagidae
  - Family Oestridae
  - Family Hippoboscidae

1. Suborder Nematocera (Mosquitoes and Midges)

> "If you should have to build near a river, do not construct your house so as to face it, for it will be very cold in winter and unhealthy in summer. See if there be any swampy land near, for certain tiny animals, invisible to the eye, breed there, and being carried through the air, may reach the inside of the body, causing diseases hard to cure."
>
> – Marcus Terentius Varro, about 120 BC in De Re Rustica[6].

Nematocerans (slender flies, the taxonomic name means thread-horns, which describes their generally long multi-segmented antennae) are typically small, delicate insects with long antennae with many similar segments and long narrow wings. While most nematocerans are free-living, some have adapted to blood feeding in adult stages. These blood-feeders will also feed on nectar. Females of the parasitic species will feed on blood, using their mouthparts to pierce skin and to then suck blood. The male counterparts of these parasitic females only feed on nectar and are not attracted to animals or humans.

The life cycles are typically holometabolous and larvae develop in a range of environments. The larvae of nematocerans are maggot-like, and have prominent heads. Some larvae are aquatic and have adaptations to enable the to access air for respiration while under the water.

Nematoceran Families

Family Culicidae (Mosquitoes)



An adult female mosquito feeding on the finger of Mal Jones, Minjerribah, Qld 2022.

This important family contains the mosquitoes, a group of organisms adapted to blood feeding in adult females. The mosquitoes use the rich protein source in blood meals for egg production and feed on blood at least twice in their adult lives. The figure to the left shows a female culicine mosquito feeding on the finger of one of the authors. Mosquitoes are quite adept at feeding on animals, and will either feed from exposed skin or force themselves into the fur to feed, often around the neck of the animal. Mosquitoes can feed on all classes of terrestrial vertebrates.

Mosquitoes show host preferences. Mosquitoes are attracted to their hosts through exhaled carbon dioxide, other specific odours, colour, body size, animal density and heat[2]. There is evidence that mosquitoes are able to learn and will respond to positive or negative experiences during their feeding. The positive experiences could explain why they are adept at transmitting pathogens. Negative experiences can explain why the use of insecticide-treated bed nets can show variable success in controlling mosquitoes. Mosquitoes that survive exposure to the bed nets may learn to avoid landing on these barriers when seeking blood again[2]. Mosquitoes will bite at different heights on the body and the bites can be often painless. Some mosquitoes can emit that annoying ringing/buzzing sound as they fly, while others fly without making a noise perceptible by humans.

Mosquitoes are classified into two sub-families, the Anophelinae and Culicinae. The former family includes the genus *Anopheles*, which transmits human malaria. The Culicinae includes a wide range of genera including *Culex* and *Aedes.* These transmit a wide range of pathogens, especially the arboviruses, yellow fever virus, dengue virus, West Nile virus, Ross River virus, chikungunya virus, among many others. Mosquitoes also transmit filarial nematodes, especially the canine heartworm *Dirofilaria immitis* and bacterial pathogens.

The life cycle can take anywhere from 2 weeks to a year to complete. Rapid build-up in numbers is dependent on the availability of aquatic habitats and warm temperatures.

Female mosquitoes lay their eggs on the surface of water, on floating vegetable matter, at the water-land interface, or on a moist surface. Different species have different breeding sites: *Aedes aegypti* and *Aedes notoscriptus* can breed in containers in back-yards filled with rain water, *Culex annulirostris* in fresh water swamps, lagoons or shaded water holes. *Aedes aegypti* is the notorious agent of human dengue. The predilection of this mosquito species for breeding in small containers filled with water is one factor in transmission of the disease.

Larval mosquitoes feed on algae, decaying organic matter and microbes in the water. The larvae pupate in water. The pupa is aquatic and motile, but does not feed. When the adult is ready to emerge from its pupal case, the organism floats to the surface of the water body and the adult emerges through a split in the dorsal lining of the pupal exoskeleton.

Significance of Mosquitoes in Australia

Mosquitoes are:

- **intermediate hosts** for filarioid nematodes, especially heartworm, *Dirofilaria immitis* and various blood-borne protozoa (including, in the case of *Anopheles*, **malaria** in people)
- **vectors** for viruses – Japanese encephalitis, bovine ephemeral fever or "3-day", Ross River Fever, fowl pox
- cause **irritation ("fly worry")** in livestock
- **allergic skin condition** in allergic cats and dogs. Visit Insect bite dermatitis in dogs, cats, horses, and rabbits.

Control of mosquitoes can be difficult due to (a) widely dispersed immature stages and (b) restrictions on insecticide use in the environment.

Family Ceratopogonidae (Biting Midges)

This family of nematocerans contains the biting midges, also called 'no-see-ums.' The biting midges are minute, pestiferous, biting flies. Their bites can be painful and can cause hypersensitive skin responses.

The adult flies can be identified by their small body size, multi-segmented antennal and relatively short mouthparts (see figure below). Midges are found in many environments but their distribution is limited by the requirements of their larvae. The midges do not 'like' wind and thus are particularly annoying on warm still days, biting usually at dawn and dusk.

The adults do not fly far from sites in which they breed, but they can be carried on winds. Thus, biting midges are a problem in **warm, wet summer months** in **northern Australia.**

All midges require moist environments for their larvae to develop and individual species display high specificity to their breeding sites. Some midge species breed in intertidal regions, estuarine swamps, moist leaf litter, or moist faeces of large animals.

Culicoides is the most important parasitic genus in Australia. The most important species in Australia is *Culicoides brevitarsis*, which breeds in moist faecal pats of (especially) cattle, and is confined to northern Australia.



Biting Midge. Adult whole mount. Note the short mouthparts but long antennae, the haltere just behind the wing and the parasitic mite attached to the abdomen.

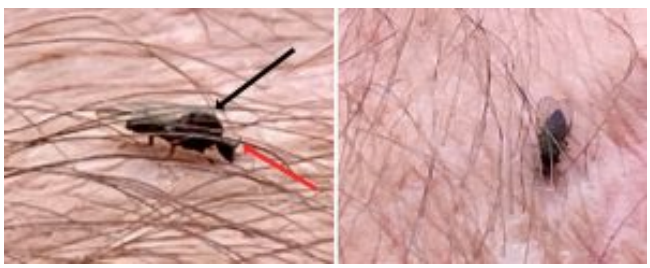
Photo: © Lyn Knott.

Significance of *Culicoides* species in Australia

Australian midges can be:

- **Vectors of arboviruses** (arthropod-borne viruses). Examples include bovine ephemeral fever ("3-day"), akabane virus, bluetongue virus. Knowledge of *Culicoides* biology is essential in understanding these important viruses. For example, Bluetongue virus is an arbovirus that produces disease by attacking endothelial cells and is more pathogenic in sheep than cattle. In Australia, there are 13 serotypes of the virus, but disease is rare. *C. brevitarsis* and *C. wadai* are often implicated in transmission of bluetongue virus in Australia but these species only occur in low numbers in sheep-rearing districts, and prefer not to feed on sheep.
- **Queensland Itch** in hypersensitive (i.e. allergic) horses (especially *C. brevitarsis*).
- **Fly worry**, especially in summer.
- **Intermediate hosts** for some filarioid nematodes of minor to moderate significance (e.g. *Onchocerca* in cattle and horse. See Phylum Nematode for more information).

Family Simuliidae (Black Flies)



Austrosimulium sp from West Coast, South Island of New Zealand, biting a human hand. Note the humped thorax (black arrow) and the short antennae (red arrow).

These small thick flies are biting flies with a prominent hump on the dorsal aspect of the thorax (see figure). In adults, both the antennae and mouthparts are shorter than the thorax, although the antennae have multiple segments. Larval development requires **running, well-oxygenated water**, so adults are generally found near flowing rivers and streams. Eggs are laid on partially submerged vegetation or rocks and can survive long periods of drought, hatching after

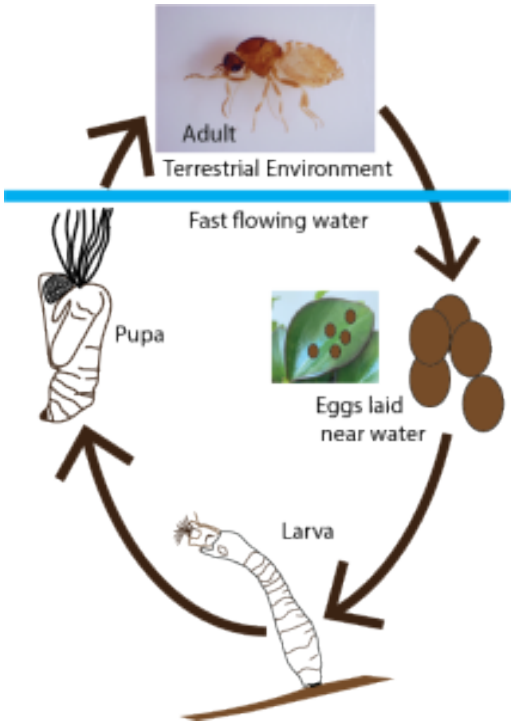
rainfall and when water begins to flow. The larvae and pupae are found in fast-flowing water. Larvae attach to the substrates with posterior hooklets. Pupae are found in a silken cocoon and have long branching gills for respiration within the water. To escape the cocoon, the pre-adult fills the pupal casing with air and floats to the surface, and the adult escapes into the atmosphere.



Adult *Austrosimulium pestilens.*

Photo: © Lyn Knott.

Multiple species of black fly are found in Australia. In northern Australia, from the Gulf of Carpentaria to north-western NSW, a dominant species is ***Austrosimulium pestilens.*** This species can be found in very large numbers, especially after flooding of inland waterways. Due to their aggressive feeding biology, their painful bites and the secretion of anti-coagulants during feeding, black flies can cause intense irritations to livestock. *Austrosimulium pestilens* **does not disperse far from waterways** and adults can be found on trees along the water edge. The flies thus form large feeding swarms near waterways. These feeding populations can be so intense that livestock may stampede to escape the incessant biting. For this species, fly attacks occur 6-12 days after the onset of heavy rains that have resulted in minor to major flooding [2]. A suitable strategy to minimise effects on animals would be to move stock away from paddocks that border on flowing rivers.



Life cycle of *Austrasimulium pestilens*. The larva and pupa are aquatic. Adults live near water courses and lay eggs on objects near the water.

Images: "Adult" © Lyn Knott. Other images by authors.

A less common, but more widespread species, is *Austrosimulium bancrofti*. This species is able to disperse over wider areas than *A. pestilens*. *Austrosimulium bancrofti* does not usually feed on livestock or humans[3].

In Australia, black flies can be intermediate hosts of some minor blood-borne parasites of birds and reptiles, and possibly some *Onchocerca* species.

Family Psychodidae (Sand Flies)

These are hairy flies with long stilt-like legs, wings held at 60° to the body at rest, and cutting mandibles. Although not laid in water, eggs need moist conditions for survival. Adult females feed at night. This family contains the primary **vectors** of *Leishmania*, an important genus of flagellated protozoan. *Phlebotomus* spp. are present in Australia but are not major pests of domestic animals. The one known species of *Leishmania* in Australia is found in kangaroos, in which it causes cutaneous lesions on the tail. That *Leishmania* is thought to be transmitted by biting midges, not phlebotomines.

2. Suborder Brachycera – **Infraorder** Tabanomorpha

The suborder is a large group of flies, of which one family, the Tabanidae (**March/marsh flies**, horse flies and deer flies) is parasitic. Adult males and females are primarily nectar feeders. The females require a blood meal as a source of protein for egg formation. The flies are distinguished from the nematocerans by the reduced number of antennal segments. Tabanids are large flies and vary in their host-finding behaviours. Some are 'clumsy' flies and buzz or hum as they fly, while others are silent. The flies can have large, often coloured, compound eyes that cover the front of the head. Female tabanids have slashing sponging mouthparts that cut the skin of their hosts to form a pool from which the fly then draws the blood. Bites from a tabanid can be painful, having been likened to having 'minor surgery without local anaesthesia'. The mandibles and maxillae are adapted to form a group of stylets that cut open the skin and lacerate blood vessels to form a pool. A labium has an absorbent pad at its distal end, and this is inserted into pool of blood in a lapping motion.

Their wings are strong and flies may disperse many kilometers from the breeding areas. Tabanids are most active on hot, sunny days.

Their eggs are laid on vegetation or stones near water. The larvae fall into water or moist soil. All tabanid

larvae are carnivorous and eat worms, small crustaceans or other insects they encounter. After development, larvae migrate to drier regions to pupate.

Veterinary Significance

Tabanids are **efficient vectors** of disease. They can be mechanical vectors or biological vectors. Mechanical vectors simply carry pathogens from the bite wound of an infected animal to a new animal. Often the pathogens will be carried on the outside of the mouthparts. In biological vectors, the pathogen is internalised by the fly and develops within the vector.

There are three genera of veterinary significance: *Tabanus* (horse flies), *Haematopota* (not in Australia) and *Chrysops* (deer flies).

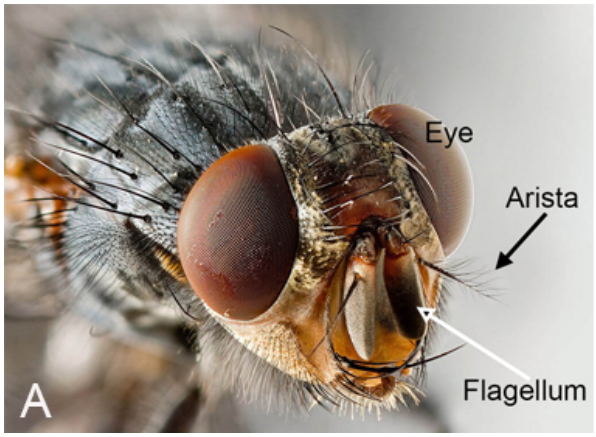
In Australia, tabanids are known to transmit equine infectious anaemia virus.

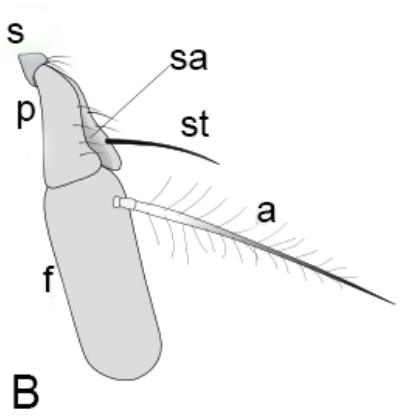
Overseas, tabanids are known to transmit flagellated protozoans of the genus *Trypanosoma.* Of these, the agent of the animal disease surra (PDF, 274KB), *Trypanosoma evansi*, is transmitted by members of the genus *Tabanus.* The protozoans survive in the gut of tabanids and are regurgitated into a bite wound as the fly feeds.

3. Suborder Brachycera – Infraorder Muscomorpha

The Muscomorpha contains organisms we might call the true flies. Muscomorphans of veterinary significance include flies we call commonly **house flies, blow flies, filth flies, flesh flies, coffin flies** and **bot flies.** These common terms are interchangeable and may not follow strict taxonomic sorting of the flies, but these are pesky flies we encounter around animals, farm buildings, in homes or in rotting cadavers or rubbish bins. The group contains many important parasites that affect animals as adults (that is by biting or worrying animals), and as larvae. The muscomorphans contain many agents of **myiasis**.

Muscomorphans can be distinguished from other flies, in part, based on size (muscomorphans of veterinary relevance are typically small-to- medium-sized flies) and by the structure of their antennae. These flies have short three-segmented antennae, the last of which bears a feather-like attachment, the **arista** (see figure below).





A. Head of muscomorphan fly, showing the arista emerging from the flagellum of the antenna. **B.** Antenna of a muscomorphan fly showing the arista. Legend: a: arista; f: first flagellomere; p: pedicel; s: scape; sa: antennal seam; st: bristle.

Images: **A.** Creative Commons BY-SA 4.0 licence. Modified from an original image by JJ Harrison, CC BY-SA 1.0 via Wikimedia Commons. **B.** Creative Commons BY-NC-SA 4.0 licence. Adapted from "Antenna aristate on a blow-fly" by Giancarlo Dessì, under Creative Commons BY-NC-SA 3.0 licence.

The arista (pl. aristae) is an important identifying feature of the flies of this group. Aristae are feather-like projections from the terminal segment (or flagellum) of the antenna. The arista have sensory components and are thought to sense airflow and possibly some odours.

In many species the mouthparts are adapted to sponging or lapping food. In a house fly, for example, the prominent component of the mouthparts is the labium, with a sponge-like labellum at the end. This is pushed against the food. Flies will often regurgitate stomach content onto food, moistening it to allow for absorption. This regurgitation process is part of the reason that some blow flies and house flies are called filth flies, the other reason being that they can feed in a variety of places, including rubbish bins, animal carcasses, and diseased areas on animals. These flies can only drink liquids through their labellum.

Watch House fly eating (YouTube, 1m3s).

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uq.pressbooks.pub/principles-disease-parasitology/?p=104#oembed-2

Some of the flies have become adapted to drinking host blood. In these biting flies, the mouthparts are adapted to puncturing skin and drinking blood (e.g. buffalo flies, stable flies). Instead of possessing a soft terminal labellum, the labium is formed into a stiffened rod that is pushed through the skin.

Watch Stable Fly (YouTube, 21s). It shows the mouthpart of *Stomoxys calcitrans* in lateral view, with the prominent labium shown. As you watch the video, make sure you also identify the arista emerging from the terminal segment of the antenna.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uq.pressbooks.pub/principles-disease-parasitology/?p=104#oembed-3

Life Cycle Concepts

Most muscomorphans lay eggs although some are ovoviviparous or viviparous. The eggs hatch into a larva with a poorly defined head and with no legs. These larvae are often referred to as **maggots**. The mature larva pupates on the ground within a hard pupal case.

Muscomorphan Families

We will now consider some important flies of this group.

Family Muscidae (Biting and Nuisance Flies)

Muscids are medium-sized flies which, unlike other flies, such as members of the family Calliphoridae (below), have a dull colouration. The mouthparts are well developed in muscids and contain either a soft jointed labium with a sponge-like labellum or a hardened rigid labium:

- **Sub-family Muscinae** with fleshy labella evolved for lapping include the house fly (***Musca domestica***), the bush fly (***M. vetustissima***) and species of the genus *Hydrotaea* (these flies are widespread nuisance flies in farming regions).
- **Sub-family Stomoxinae** are blood suckers with an elongate proboscis. Important members include

the stable fly (***Stomoxys calcitrans***) and the buffalo fly (***Haematobia irritans exigua***).

Muscids in Intensive Management Systems: (*Musca domestica* & *Stomoxys calcitrans*)

Muscid flies are important in different situations. Two flies are of importance in intensive systems and homes.

Musca domestica, the house fly, is a **synanthropic** species, and has a worldwide distribution. The fly is a **filth fly,** feeding in areas of discarded foods, faecal wastes with feeding on foods. The fly carry a wide range of bacterial pathogens and parasites on its body or in its foregut. The house fly is attracted to wounds and lesions as a source of liquid food, and can cause secondary infection and irritation. The flies prefer warmer weather and are active during the day.

Stomoxys calcitrans, the stable fly, is a biting muscid with a preference for horses and other large mammals. The small dull fly looks like a housefly but can be recognised by the distinctive hardened and needle-like proboscis (labium) that is used for blood sucking. The fly gives a painful bite, usually on the hind legs. The species name is derived from the same word origin as 'calcitrant', which means 'kicker', indicating the response of animals to the painful bite. The fly often prefers to bite dogs on the pinnae.

S. calcitrans is often found around farm buildings; prefers strong light and rests on walls, posts etc during the heat of the day.

The bites of *S. calcitrans* can cause distress to animals, leading to weight loss, loss of yield of milk, as well as foot lesions. The fly is a vector for viral, bacterial pathogens and pathogens. A peculiar but common phenomenon is SE Qld is that of cutaneous habronemiasis in horses. This is caused by skin infections of horses with larvae of the habronematid nematodes *Draschia* and *Habronema*, that use the fly as an intermediate host (more on their life cycle can be found in the chapter on the Nematoda).

Life cycle of muscid flies

Eggs of both species are laid in rotting, moist organic matter, especially if there has been faecal and/or urine contamination. The life cycle may be short in warm, wet months (8 – 14 days for *M. domestica*, 20 – 30 days for *Stomoxys calcitrans*), resulting in **rapid build up in fly numbers.** Large numbers of these flies in intensive management systems is indicative of poor husbandry, that is lack of cleaning of stables, presence of spilled feed and poor effluent disposal.

Muscids in Extensive Management Systems

Haematobia irritans exigua (Buffalo Fly)

The buffalo fly is a sub-species of ***Haematobia irritans,*** a widespread fly thought to have originated in Java. It is a major pest of cattle in northern Australia. *Haematobia irritans exigua* is closely related

to the **horn fly *Haematobia irritans irritans,*** a fly of Europe that has spread to the Americas. *Haematobia irritans* resembles the stable fly in morphology, but is smaller (up to 4.0mm). Its colouration is usually grey with several dark stripes on the dorsal thorax. Like *Stomoxys*, the proboscis is held forward but the buffalo fly also has **stout palps** which are as long as the proboscis. Buffalo flies are of major importance to the northern cattle industry in Australia. Watch the videos below to observe the irritant effects the bites of the flies have on cattle. Note that the animal in the foreground has many hundreds of flies resting on the body.

Buffalo flies rising in a cloud then returning to settle on an animal (YouTube, 34s).

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uq.pressbooks.pub/principles-disease-parasitology/?p=104#oembed-4

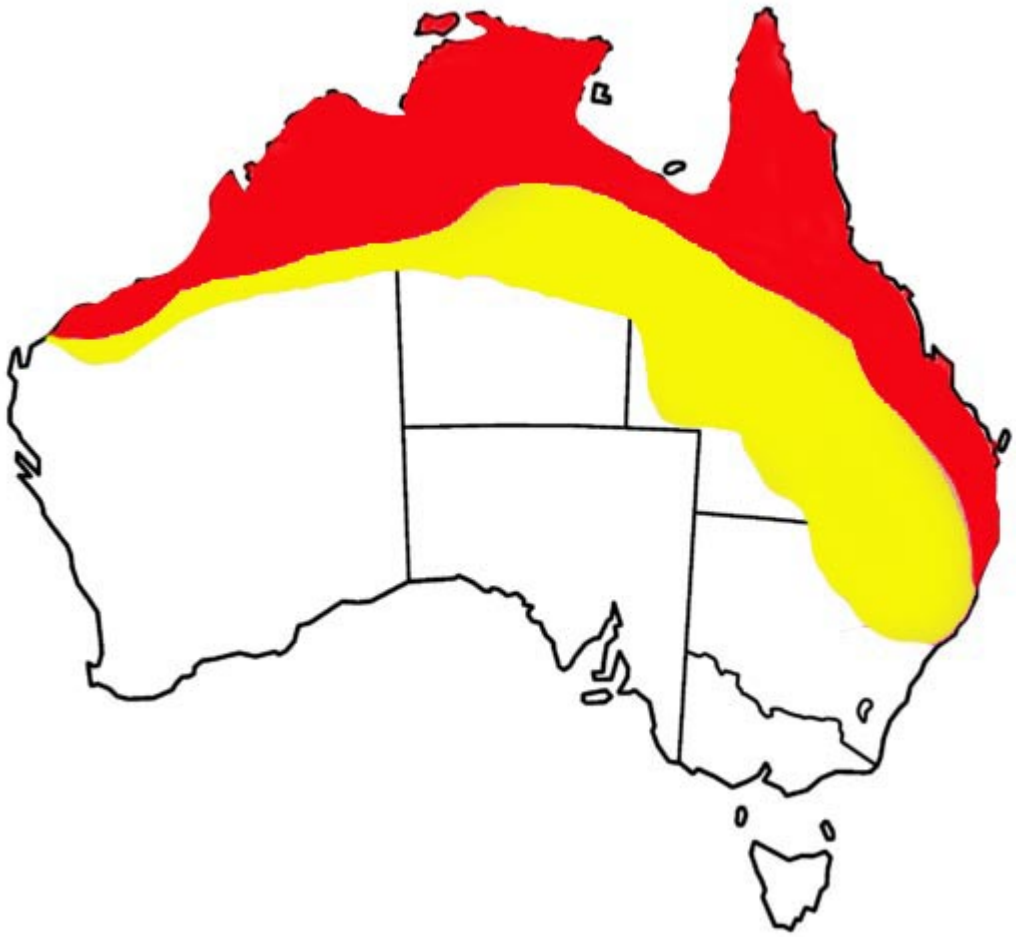
The buffalo fly is a parasite of cattle. The specificity to cattle is high and they do not thrive away from cattle. The fly is essentially a permanent parasite along the flanks and back line of cattle, only leaving the host to lay eggs in freshly passed dung. Larvae and pupae develop in and under cattle dung. Adults do not thrive away from cattle. Bulls, dark-coloured animals and those in poor condition have more flies (although cattle host predilection is an area of active research).



Fly worry caused by buffalo fly in northern Australia

Image: © Anthony Feez, School of Veterinary Science, UQ. Used with permission.

Buffalo flies are found across northern Australia and down the east coast to northern NSW. The range extends in warm, wet summer months. Buffalo flies breed in cattle dung.



Distribution of buffalo flies in Australia. The regions in red shows the permanent distribution of the species. The region in yellow shows area of incursion in seasons favourable to the fly.

Image: Creative Commons BY-SA 4.0 licence. Adapted from Flies: Buffalo flies by Meat and Livestock Australia; "Map" by Golbez, modified under a CC BY-SA 3.0, via Wikimedia Commons

Significance of Buffalo fly in Australia

- Bites of the fly are painful, causing irritation, decreasing production and damaging hide. Large numbers of the fly cause intense irritation of an animal, causing the animal to rub itself vigorously.
- A population of 1000 flies, each biting 30-40 times per day results in constant daily aggravation of the cattle.
- Moderate infestations of dairy cattle are estimated to reduce milk yields by 0.5L/day[4].
- The fly can be a possible intermediate host for Australian species of *Stephanofilaria* nematodes in cattle.

Control options include insecticides, traps, back rubs, ear tags. Dung beetles also help to reduce fly numbers as the beetles disperse faecal masses reducing the available space for maggots to breed.

Musca vetustissima – Bush flies or Australian bush fly

Watch Annoying bush flies (YouTube Shorts, 23s).

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This is an exceedingly pestiferous fly that crawls across the face of people and animals. This native fly is present for much of the year over northern Australia, and may be carried huge distances by winds (e.g. repopulate more southern areas each spring).

The fly breeds in animal dung and human faeces. The fly causes irritation and delayed wound healing in sheep (for example, after castration, tail docking or mulesing).

Family Calliphoridae (Blow flies)

These are medium to large flies, usually with a bright metallic colour with distinct bristles on dorsal thorax. The arista is plumose to beyond halfway and mouthparts are of the lapping type. Identification of calliphorids depends partly on the identification of characteristic wing venation (We will not cover details of wing venation in this book, although one important feature of wings is used to distinguish genera of the Calliphoridae – see the keys to adult flies).

Life Cycle of Calliphoridae

The larvae (maggots) feed on organic material of animal origin and are useful in breaking down carrion. The Calliphoridae are typically the first flies to arrive at a dead animal, and flies will aggregate around orifices, laying eggs that hatch into maggots. Typically, there is an ecological succession of maggots in a body, with different flies laying either eggs or active maggots at different stages of the decomposition process. Maggots of different species of fly are identified and distinguished from those of other species by the number of segments in the body, the structure of the exoskeleton of the mouthparts and pharynx, and the size and arrangement of spiracles on the posterior stigmatic plates (1st stage larvae have one slit in their spiracles; 2nd stage larvae have two slits; 3rd stage larvae have 3 slits).

The ecological succession of maggots in a dead body or lesion has two points of significance. First, as fly maggots appear at different times in a rotting carcase, the time of death of that animal can be predicted from the species of maggots present in carcase. This knowledge has been used in forensic medicine around the world[5]. Second, the ecological succession is important to understanding the ecology of **blow fly strike in sheep**.

Sheep Blow fly strike

Blow fly strike is a form of **myiasis**. The formation of a strike wound is not random and relies on a specific

sequence of flies becoming attracted to the sheep and depositing offspring onto the body of the living sheep. We categorise fly species, the maggots of which are found in sheep strike lesions as:

- **Primary strike flies** – These **initiate** strike in sheep. The flies set up the lesions and in early stages of infestation their maggots cause minimal damage. As the maggots moult to later instars, they become more invasive. The important primary strike fly is ***Lucilia cuprina***. This fly was transported to Australia, possibly from Africa in the early days of European settlement. The fly has become a virtual obligate parasite of sheep. Another primary strike fly is the congeneric species *Lucilia sericata*. This latter species is also common in south-eastern Queensland, where its maggots are adapted to developing in carrion, but occasionally it can also initiate strike. Some other flies species can also initiate strike (see below).
- **Secondary strike flies** invade and extend areas made suitable by the invasion of primary flies but cannot initiate strike. These flies are attracted to the struck sheep. The maggots (and flies) tend to be larger and the flies may be **ovoviviparous** or **viviparous**. The maggots are invasive and **extend the lesion**.
- **Tertiary strike flies** are also attracted to struck sheep. These feed within the lesion but typically are not very invasive and do not act to extend lesions. Examples of tertiary strike flies include *M. domestica* and *M. vetustissima* (Muscidae-above) and *Sarcophaga* spp (Sarcophagidae-below).

Some common species involved in sheep blowfly strike are shown in the table below. Some illustrations of flies causing sheep blowfly strike, with some identifying features are shown in the figure to the right.

Colour	Family	Species	Role in Strike	Comments
Green Adults	Calliphoridae	*Lucilia cuprina*	1º	introduced to Australia- 90% of strikes
Green Adults	Calliphoridae	*Lucilia sericata*	1º	introduced to Australia- predominantly urban areas rarely 1º
Green Adults	Calliphoridae	*Chrysomya rufifacies*	2º	native - sometimes 1º
Green Adults	Calliphoridae	*Chrysomya varipes*	2º	native
Brown species	Calliphoridae	*Calliphora albifrontalis*	2º	native- WA - sometimes 1º
Brown species	Calliphoridae	*Calliphora noctiva*	2º	native- WA - sometimes 1º
Brown species	Calliphoridae	*Calliphora stygia*	2º	native - sometimes 1º
Brown species	Calliphoridae	*Calliphora augur*	2º	native - sometimes 1º
Black species	Calliphoridae	*Ophyra* spp.	2º	native
Blue species	Calliphoridae	*Calliphora vicina*	2º	introduced - urban areas
Flesh flies- stripes on thorax	Sarcophagidae (see below)	*Sarcophaga* spp.	3º	native

Important Calliphorid Blowflies in Australia



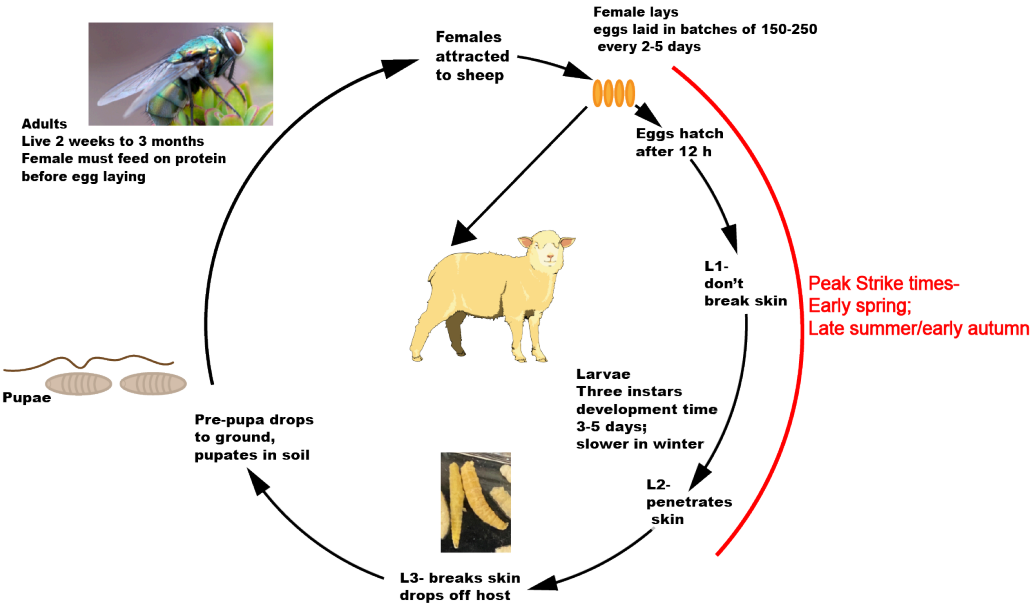
Australian sheep blowfly.

Photo: "*Lucilia cuprina*" by Graham Wise, shared under CC BY 2.0 via Wikimedia Commons

Lucilia cuprina is an introduced fly, and is the most important primary strike fly in Australian sheep. The fly has a wide distribution and is thought to have originated in tropical Africa. Perhaps it was carried to Australia from Africa on ships carrying sheep during the early European colonisation of Australia. The fly is fecund and can produce 300 eggs per reproductive cycle and lay eggs every 2-5 days. The fly initiates over 90% of all strikes in Australia and is regarded as an obligate parasite of sheep.

Lucilia cuprina females are wide ranging and can fly up to 10 km. The females are attracted to sheep by bacterial activity on contaminated or soiled wool. There are two primary stimulants. Sulphur-rich compounds attract the fly to the site of the lesion. These compounds are released through bacterial

degradation of skin and wool because of the cysteine-rich keratin present. Ammonia-rich compounds induce oviposition.



Life cycle of Lucilia cuprina in Australia.

Images: Adult fly by Graham Wise, shared under a CC BY 2.0 via Wikimedia Commons; Sheep by Rhcastilhos, Public Domain, via Wikimedia Commons. Other images by authors.

Calliphora spp. are native blowflies, that occasionally act as primary strike flies, or invade pre-existing wounds (i.e. in the latter case, act as secondary strike flies). ***Calliphora augur*** is most important in eastern states; the adult has a yellow-brown abdomen with a broad, blue-green median band on the dorsal surface. In Western Australia, some species of *Calliphora* can be primary strike flies.

Chrysomya rufifacies (hairy maggot blowfly) is the most important secondary strike fly, especially in hotter areas of Australia. ***Chrysomya megacephala*** is a fly native to Australia. The maggots mostly feed on carcasses. The fly and maggots are similar to those of *Chrysomya bezziana*, the Old World Screwworm fly.

***Chrysomya bezziana* (the Old World screw worm fly)** and ***Cochliomyia hominivorax* (the New World screwworm fly)** are two important exotic species, the former of which is present in Papua New Guinea. *C. bezziana* is medium-sized, blue-green with an orange-yellow face and burgundy eyes, and glassy wings.

The Old World screw worm fly occurs in Asia, tropical Africa and PNG. The New World screw worm fly lives in South America. A sterile-male release program has been implemented across southern North America to prevent invasion of the USA.

Screw worm flies are obligate parasites of mammals. The maggots are laid on living skin, and mucous membranes, usually near wounds. The wounds can be as small as an insect or tick bite. *C. bezziana* is not in Australia, but continued surveillance is maintained to prevent incursions. There have been intercepted cases in humans, but no evidence of spread of the fly in tropical mainland Australia.



Maggots of the New World Screwworm fly, in a cattle leg, southern Brazil

Image: © The University of Queensland Veterinary School

Australia: Visit Monitoring for screw worm fly for information on surveillance for Old World Screwworm fly in Australia.

North America: Visit New World Screw worm for information on surveillance and control of the New World screwworm fly.

Family Sarcophagidae (Flesh or Coffin Flies)



Sarcophaga sp. from Gatton campus. The fly is 1 cm long. Note the stripes on the thorax and the chequerboard patterning on the abdomen.

Photo: © Malcolm Jones

These are medium to large, thick-set flies. Adult females are either viviparous or ovoviviparous. These strategies allow the laid maggot a competitive advantage in the mass of maggots within carrier or a struck animal. Members of the genus *Wohlfahrtia* species can produce serious myiasis in people and animals. In Australia, the sarcophagids are of minor importance, and are tertiary strike flies in struck sheep. *Sarcophaga fusicaudia* is common in Brisbane.

Family Oestridae (Bot Flies)

The common name 'bot' comes from an original name meaning 'maggot.' The formal names 'Oestridae' and '*Oestrus*' come from an Ancient Greek word meaning frenzied and was used in ancient times to describe both the fly and behaviour changes in animals in oestrus.

Bot flies larvae (bots or maggots) are internal parasites of the sinuses, anterior gastro-intestinal tract or the skin of mammals. The adults are large (bee-like) with **vestigial** mouthparts, small eyes and are usually covered in bushy setae. The adults do not feed, and are short-lived. The adults are erratic fliers and some species annoy their hosts.

The larvae (**bots**) are obligate parasites which are **highly host-specific** and **site-specific** within host. Some important bot flies are described below.

Sheep nasal bot (*Oestrus ovis*)

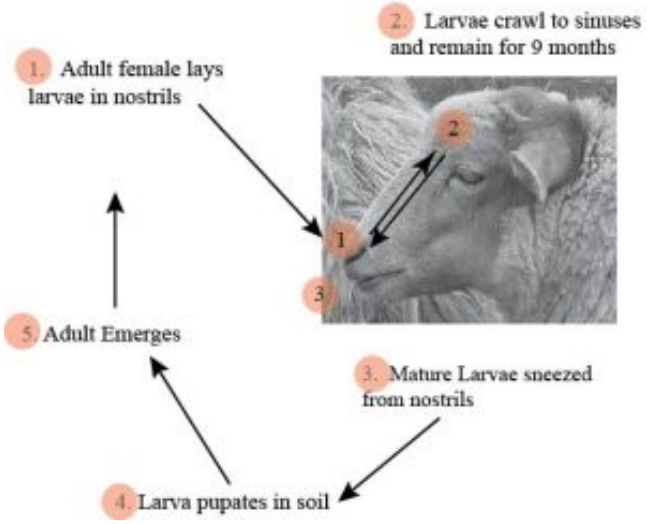
The sheep bot is specific to sheep and goats, and is found worldwide. On rare occasions, bots can be found in other animals including dogs and humans. The bot flies are a brown fly about the size of a bumble bee. The adults are active in the warmer months, particularly in the heat of the day.

Bots of *O. ovis* have well-developed mouth-hooks (see photo- the hooks are shown to the right of the organism) to anchor themselves in nasal passages and sinuses.



Oestrus ovis larva, showing prominent mouth hooks

Image: © Lyn Knott



Life Cycle of *Oestrus ovis.*

Image: Sheep head, Public domain

Pathogenic effects on sheep are minor. The female flies can irritate the fly when depositing larvae as they are quite aggressive. The bots can cause rhinitis (nasal inflammation) but generally the bots have no affect on productivity.

Equine bot flies (*Gasterophilus* species)

Three *Gasterophilus* are found in Australian horses. The on-host life-cycle characteristics of the species are shown in the Table below.

Species	Site of egg deposition	Site of infection in the equid host
Gasterophilus intestinalis	Front legs	Mouth for first stage larva, followed by squamous stomach
Gasterophilus nasalis	Between rami of mandibles	Mouth for first and second stage larvae, then pylorus of stomach and proximal duodenum
Gasterophilus haemorrhoidalis	Near lips	Mouth for first stage larva, then fundus and pylorus of stomach

After completing development in the host digestive tract, the maggots move with food flow caudally and are eventually defaecated onto pasture, where they pupate. As they pass through the tract, they may reattach to the mucosa (*G. haemorrhoidalis* can attach near the rectum). The maggots develop in the mouth for about 3 weeks. They will then grow in the stomach for periods of up to 10 months. The pupal stage lasts for 10 weeks and adults survive for a period of weeks.

Adult bots can be worrisome and persistent flies, annoying both horses and owners. They are very agile flyers and can avoid 'swatting'. *Gasterophilus nasalis* first-stage larvae will burrow through the oral mucosa. Generally, however, bots are not highly pathogenic.

Family Hippoboscidae – Keds and Louse Flies

The hippoboscids are parasitic flies that have adapted to permanent or semipermanent life on their hosts. Hippoboscids have leathery, dorso-ventrally flattened bodies and their legs have strong claws on the feet allow them to cling to feathers or hair. The species are blood-sucking parasites of birds and mammals. Adults either lack wings (as in the sheep ked) or remain on the host for extended periods. This video, Hibboboscid flies, shows some hippoboscids from a dog in India.

Important species in Australia include:

Melophagus ovinus. This is the sheep ked, and economically important, but fortunately rare, species in Australia. ***Hippobosca equina*** feeds around the perineum & groin of horses (occasionally cattle). There are many other species found on wild birds and a few on wallabies. Apart from the pigeon, domestic birds are spared hippoboscid attention.

Family Glossinidae – Tsetse Flies (Not in Australia)

- *Glossina* are the tsetse flies, important vectors of *Trypanosoma* protozoa (including agent of sleeping sickness in Africa).
- *Glossina* flies are narrow, 6-15mm in length and have a long, rigid, forward projecting proboscis. The M1+2 vein follows a characteristic path to produce a first M2 cell which is said to be cleaver or hatchet-shaped (cleaver cell).

Identification

- Information to assist in identifying adult flies
- Information to assist in identifying maggots

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9.

THE PARASITIC ARACHNIDS

Class Arachnida

Members of the arthropod **Class Arachnida** include spiders, scorpions, ticks and mites. Among these groups, the important parasitic forms are placed within two superorders, the Parasitiformes and the Acariformes.

Unlike insects, the mouths of the arachnids are chelicerate, that is the primary segmented mouth appendages are structures termed **chelicerae**. These can be modified as fangs (in spiders), or grasping 'claws' (scorpions) and into elongate cutting plates (ticks and mites). The chelicerae are flanked in ticks and mites by a pair of sensory **pedipalps** (often called palps).

Arachnids differ fundamentally in structure to insects. Firstly, antennae, wings and compound eyes are absent in arachnids. Some may have simple eyes and in eyed ticks, the simple eyes may appear on the lateral margins of the body. The bodies of ticks and mites especially are divided into two regions, the **gnathosoma** (head region) and the **idiosoma** (body region). The idiosoma contains a thoracic region, which carries the legs and an abdominal region, but the two regions are difficult to distinguish. An important distinction of arachnids from insects is that typically, adults and nymphs of the arachnids bear **4 pairs of legs**.

Ticks and Mites

Parasitic arachnids belong to two **Superorders** — the **Superorder Parasitiformes (ticks and larger mites)** and the **Superorder Acariformes (tiny mites)**. Until recently, the ticks and mites were classified together in a single taxon, the Acari. This taxon is no longer supported by modern molecular phylogenies.

The Parasitiformes contain all of the ticks (**Order Ixodida**) and a group of usually large mites, the **Order Mesostigmata**. Some important mesostigmatid mites are the red chicken mite (*Dermanyssus gallinae*), and the **varroa mite**, an important pathogen of the honey-bee. The **Superorder Acariformes** contains the small mites infecting animals, such as the scabies mite, *Demodex* mites, the fur mites and many others. Some characteristics of the Ixodida, Mesostigmata and the Acariformes groups are presented in the table below.

Characteristics of Parasitic Arachnids

	SuperOrder Parasitiformes Order Ixodida	**SuperOrder Parasitiformes Order Mesostigmata**	**Superorder Acariformes (Order Sarcoptiformes and Trombidiformes)**
Habit	All species parasitic on vertebrates (reptiles, birds mammals)	Mostly free-living, some parasites on reptiles, birds, mammals and arthropods	Many species free living, but several groups of important animal and human parasites.
Size	Macroscopic 2-7 mm before feeding	Microscopic- small size (0.5-1.5 mm long)	Microscopic (0.3-1 mm long)
Dorsal Surface	Idiosoma either leathery and covered in pustules (soft ticks), or a hard scutum (male hard ticks), or a small scutum and body capable of gross engorgement (female hard ticks)	Idiosoma with dorsal surface either soft and rubbery, or hardened, and lined with setae.	Idiosoma with dorsal surface either soft and rubbery, or hardened, and lined with setae, or spines
Mouthparts	Basis capitulum with pointed hypostome bearing several rows of retrorse teeth, paired dorsal chelicerae, and lateral sensory pedipalps present.	Basis capitulum, consisting of hypostome lacking teeth, paired chelicerae and lateral pedipalps.	Carried on a basis capitulum, consisting of paired chelicerae, non-toothed hypostome and lateral pedipalps. Pedipalps may be modified as leg-like structures in some species
Spiracles	Spiracle a large plate posterior to legs 4 (in hard ticks- Ixodidae) or a simple opening between legs 3 and 4 (in soft ticks- family Argasidae)	Spiracles open between legs 3 and 4. In non-parasitic forms, peritremes of the spiracles are well developed.	Spiracles anterior (between chelicerae-most Trombidiformes), or not present (Sarcoptiformes)
Legs	All 4 legs in anterior half of body. Legs not sunken into body, coxae move freely	All 4 legs in anterior half of body. Legs not sunken into body, coxae move freely	Legs in anterior half of body, or legs 1 and 2 anteriorly and Legs 3 and 4 posterior. Base of legs sunken into body

Mouthparts are modified for specialised feeding.

The 'head' region, the gnathosoma bears a basal region, the basis capitulum. This carries a pair of dorsal **chelicerae** (cutting tools, highly variable in form between species and therefore useful in identification), a pair of lateral **pedipalps** (generally sensory but also variable in form and function) and a median, ventral **hypostome** (helps to anchor the parasite in position and bears a dorsal groove to permit the flow of saliva and host blood). A rostrum or tectum extends dorsally over the mouth. Some hard ticks produce a cementing substance. This cement assists to anchor the parasite to the host and, in the case of the cattle tick, may lead to skin irritation and loss of value for severely affected hides.

In ticks, palps grasp a fold of skin while the chelicerae cut through it. As cutting progresses, the **hypostome**

is thrust into the wound, and its teeth help anchor the tick to its host. Blood and lymph from lacerated tissues seep into the wound and are sucked up.

In the following accounts of the ticks and mites, we shall first consider the ticks in their own chapter, as ticks comprise a cohesive taxonomic group. The subsequent chapter considers the Mesostigmatid mites with the Acariformes mites. Although mestostigmatids are more closely related to ticks, the distinction is made for convenience.

10.

SUPERORDER PARASITIFORMES: IXODIDA

The Ticks

> "Among the enemies.... in these rich, coast lands, is the Wattle Tick, a hard flat insect (sic) of a dark colour, about the tenth of an inch in diameter, and nearly circular, in the body; it insinuates itself beneath the skin, and destroys, not only sheep, but sometimes foals and calves. Paralysis of the hind quarters often precedes death in these cases. Sometimes it occasions painful swellings, when forcibly removed from the human body, after having fixed its anchor-like head and appendages in the skin." – James Backhouse[1]

The ticks are ectoparasitic arachnids of mammals, birds and reptiles. There are 73 species of ticks in Australia, of which 50 species are unique to the country. New Zealand has 12 species of tick. The ticks of Australia and New Zealand belong to two families, the Ixodidae (hard ticks) and the Argasidae (soft ticks).

For quick reference, some important ticks in Australia are:

Hard ticks

Ixodes holocyclus– paralysis tick

Rhipicephalus australis– cattle tick

Rhipicephalus linnaei– tropical brown dog tick

Haemaphysalis longicornis– bush tick

Soft ticks

Argus persicus– fowl tick

Morphology

All ticks are external parasites of terrestrial mammals, birds and reptiles. The ticks feed on blood.

Ticks have generally rounded to ovate bodies. The mouthparts are borne on an anterior plate, the basis capitulum. The legs are prominent and emerge laterally in hard ticks, or ventrally in soft ticks. The integument is relatively thick and respiration is via spiracles (usually only one pair) and trachea.

Eyes, when present, appear as rounded structures at the lateral margin of the scutum on the dorsal surface, approximately opposite the coxa of the second leg.

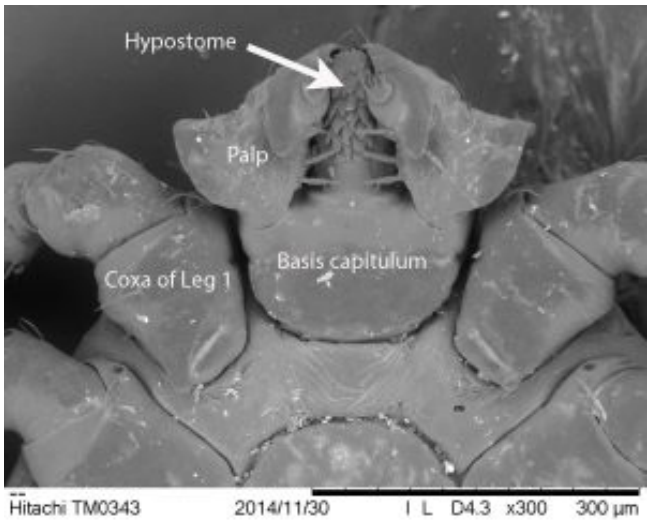
Larval ticks have only 3 pairs of legs while other stages have 4 pairs of legs. The nymphs are similar in morphology to adults, but lack a genital aperture, which in adults occurs on the ventral surface of the tick, approximately level with the second pair of coxae.

The table below shows characteristics of the two families of ticks, the Ixodidae (hard ticks) and the Argasidae (soft ticks):

	Hard ticks (Fam. Ixodidae)	**Soft ticks (Fam Argasidae)**
Basis Capitulum	Terminal (anterior) & visible from dorsal surface	Subterminal and not visible from dorsal surface
Scutum	Present; covers entire dorsal surface of adult ♂ but only partially covers adult ♀, larvae and nymphs (allow engorgement)	Absent
Eyes (if present)	On scutum	Supracoxal fold
Palps	Rigid	Freely articulated (leg-like)
Porose areas	Present	Absent
Spiracles (stigmata)	Behind 4th pair of legs	Behind 3rd pair of legs
Sexual Dimorphism	Marked (size & colour)	Minimal
Nymphal instars	Only one	From 2-8
Number of hosts	1-, 2- or 3- host ticks	Many hosts
Feeding behaviour	In parasitic phases, the tick remains permanently attached and feeding on host.	Feed intermittently, rest away from host between meals (for example, nests, cracks and crevices)

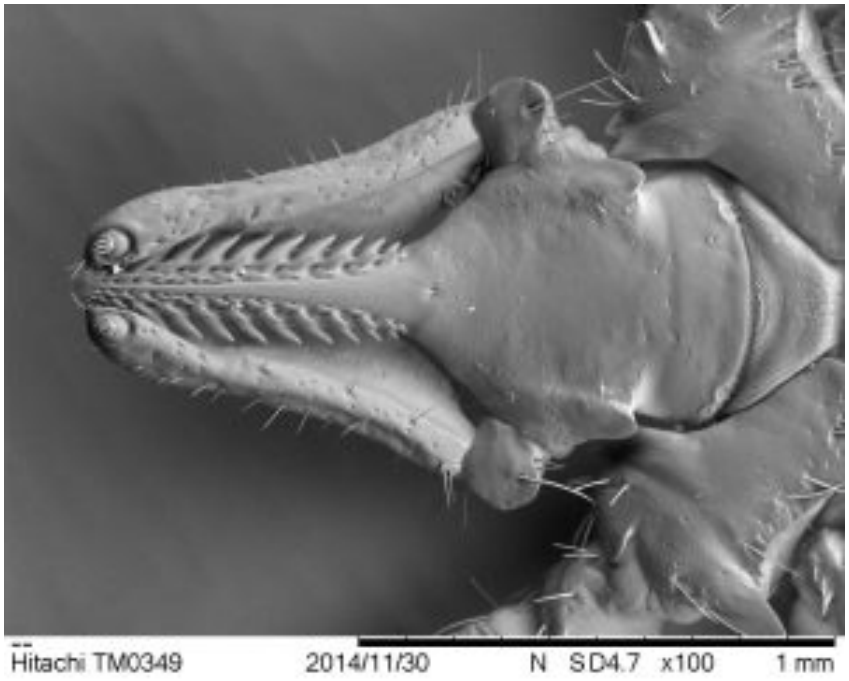
Mouthparts of Hard Ticks

The mouthparts of *Haemaphysalis bancrofti* and *Ixodes holocyclus* are shown below. The two images are taken by scanning electron microscope and show the toothed hypostome flanked by the palps (pedipalps).



Head region of the hard tick *Haemaphysalis bancrofti* from a kangaroo, ventral surface

Image: © Lyn Knott



Head region of *Ixodes holocyclus*, ventral view

Image: © Lyn Knott.

Life Cycle

Ticks vary in their host specificity. Some species show an extremely wide host range, but most occur on a limited range of host species. Their life cycle involves simple development, without complete metamorphosis seen in some insects. The generalised life cycle has the following features.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=139#h5p-39

A female tick must feed on blood prior to egg production. Males, when they encounter a female of the same species, will grasp the female with its legs. Males may locate the females in the environment or on the host. In some species, the males will parasitise the female for its blood meal, after which it will copulate with the female and drop from the host. Some female ticks are parthenogenetic (i.e. no male is involved in reproduction). After feeding, females will drop to the ground, seek a sheltered position and lay a batch of eggs. This process of feeding and egg-laying will occur multiple times for adult soft ticks, but only once for female hard ticks, which will die after oviposition.

Many hard ticks will use a behaviour called '**questing**' to gain access to a new host. The **video** below shows a question tick. In this, an infesting stage will climb to the tip of a plant, rock or other object and wait, with their first legs extending vertically. Once they detect the presence of a host, the tick will wave its legs rapidly for some seconds and if they make contact with the host with use the terminal structures of the legs to grasp the surface of the host.

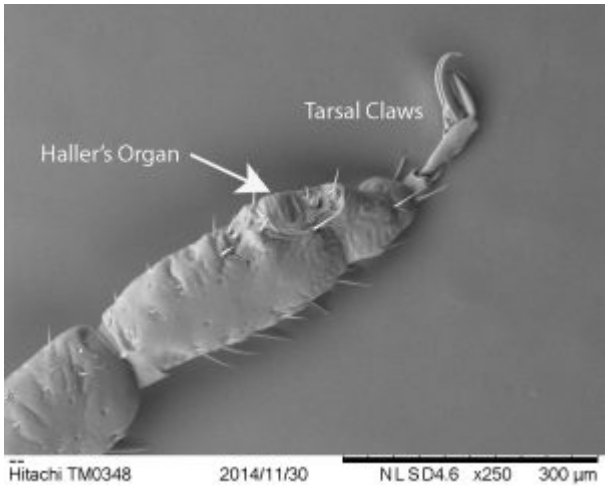
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Watch Questing adult tick (YouTube, 42s).

The tick will then wander across the body of its host across the body until it locates a suitable site for blood feeding. Such sites are often areas that the host cannot groom readily, behind the neck, external ear canals. However, when you suspect a case of tick paralysis, **ensure you perform a thorough examination of the host**, as ticks can occur anywhere on the body.

Ticks use a range of sensory organs to respond to host stimuli and find a location to penetrate the skin. A prominent sensory structure involved in this is the Haller's organ, a complex sensory organ on the first pair of legs of ticks (See figure below). The Haller's organ is used for host- and mate-seeking.

Ixodid ticks are described as being either **1-host, 2-host or 3-host ticks.** The numbers of hosts refer to the number of host individuals a single tick must use to complete its life cycle.



Haller's organ of *Haemaphysalis*

Image: © Lyn Knott.

The most important **1-host tick** in Australia is *Rhipicephalus (Boophilus) australis*, the Australian cattle tick. In this species, tick larvae attach to one animal and moult from the larval to nymph stage and later from the nymph to adult stage on that single host individual.

Many ticks are **3-host ticks**. Important 3-host ticks in Australia are *Ixodes holocyclus*, the paralysis tick, *Rhipicephalus linnaei,* the brown dog tick and *Haemaphysalis longicornis.* In these species, the parasite drops off of the host to moult from larva to nymph, from nymph to adult, and to lay eggs.

Some ticks are **2-host ticks.** In these species, the ticks parasitise one host individual during their larval and nymphal stages and then another host during their adult stage, or conversely, use one host individual for larvae only and a second for nymphs and adults.

This categorisation of ticks bears little relationship with the **host specificity** of tick species. *Ixodes holocyclus* is a 3-host tick that displays low host specificity. The tropical brown dog tick (*Rhipicephalus linnaei*), however, is a 3-host tick displaying high host specificity.

Soft ticks may feed intermittently on different host individuals and so are defined as **many-host ticks.**

Off-host stages, including the engorged females prior to egg-laying, eggs, larvae and off-host moulting stages, are most susceptible to environmental conditions. Ticks are especially sensitive to temperature and relative humidity. In warmer conditions, development of off-host spaces may be faster but survival may be shorter. The duration of the off-host stages of the life cycle is the most variable component of the tick life cycle; life cycles may be as fast as 6 weeks or up to 3 years depending on the species of tick and the environmental influence on off-host development.

Effects on Host

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https://uq.pressbooks.pub/principles-disease-parasitology/?p=139#h5p-5

Important Ticks in Australia

Ixodes holocyclus (Paralysis Tick)

This species is native to Australia. *Ixodes holocyclus* is a member of a large genus of ticks with many species worldwide and 22 species in Australia. *Ixodes holocyclus* is the most notorious of all species in the genus **as an agent of tick paralysis.** The species occurs along the eastern seaboard of Australia (see the distribution map below). The requirement for warmth and humidity restricts the distribution of *I. holocyclus* to these regions. Other species, including *I. cornuatus,* may also induce paralysis in domestic animals and humans. *Ixodes cornuatus* is restricted to Victoria and Tasmania (see map).

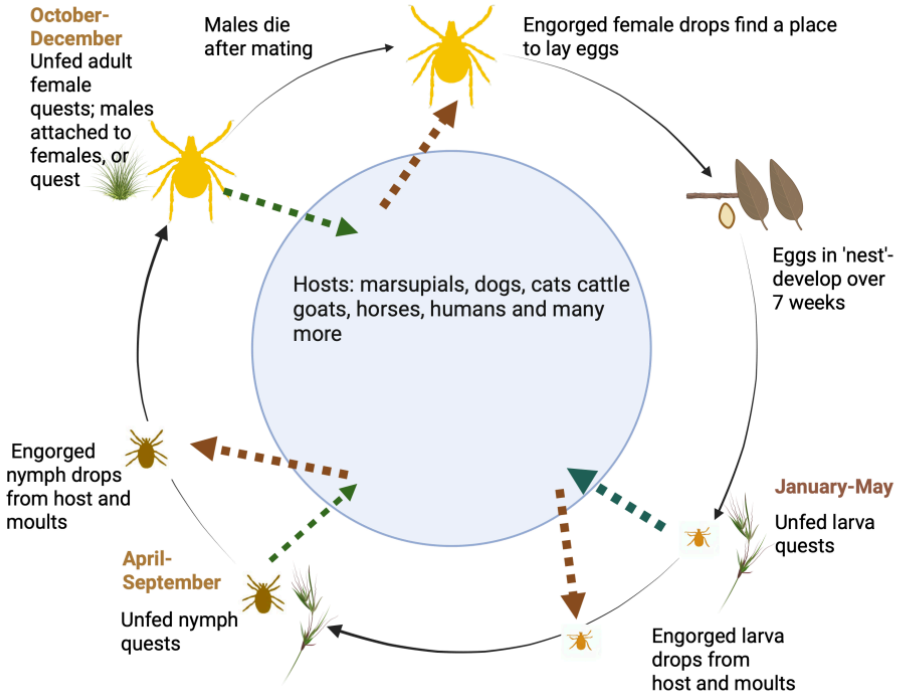


Distribution of paralysis ticks in Australia (based on Barker and Barker[1]). Ixodes holocyclus (green) is the primary agent of paralysis and is distributed in coastal regions from Queensland to north eastern Victoria. Ixodes cornutaus (pink) is found in eastern Victoria and Tasmania.

Image: Creative Commons BY-SA 4.0 licence. Adapted from "Map" by Golbez, CC BY-SA 3.0, via Wikimedia Commons

Life Cycle

Ixodes holocyclus is a 3-host tick that displays low host specificity. Barker and Barker[2] report that this tick has been found on 55 species of mammals and 7 species of birds. In northern Queensland, *I. holocyclus* is reported to parasitise flying foxes. While *I. holocyclus* can develop on many different species of hosts, its life cycle is evidently sustained by native mammals, notably bandicoots (genera ***Isoodon and Perameles*** **)** within its range**.** Around Brisbane, possums and koalas can be used as hosts.The life cycle is presented in the figure below:



Ixodes holocyclus, life cycle.

Image: Created in BioRender. Jones, M. (2026) https://BioRender.com/ago5lwu

The life cycle is heavily dependent on climate (e.g. 240 days may be fairly typical but environmental contamination may persist for over 740 days). Veterinarians will report annual fluctuations in the numbers of tick paralysis cases brought to their clinics.

Significance

Tick paralysis caused by *Ixodes holocyclus* is the most serious form of paralysis produced by any tick. Tick paralysis is complex, potentially fatal syndrome of **paralysis and cardiopulmonary problems** in dogs, cats and young farm animals. Many animals die from respiratory issues.

The toxic compounds appear to be from a family of peptides found in tick saliva. While adult females are primarily responsible for envenomation of animals, it appears that all stages, including larvae produce the toxin[2]. Life cycle attributes, including the size of females and volume of toxin released into the host, and the length of feeding times of different stages, are important determinants of whether paralysis will occur. Some animals can develop immunity to the tick and paralysis.

Hypersensitivity (allergic) reactions are common in people and horses, especially during times when larvae are abundant. Overseas, other species of *Ixodes* transmit the agent of Lyme disease (affects people). The **status** of Lyme disease in Australia is **unclear and controversial.** Most research suggests that Lyme disease is not present in Australia, but the debate continues. *Ixodes holocyclus* has been associated with Queensland Tick Typhus (caused by a *Rickettsia)* and Q fever (*Coxiella burnetti).*

A condition known as mammalian meat allergy or alpha-gal syndrome was first described for human patients from Sydney. This delayed-type sensitivity reaction is now known to occur after the bites of many tick species.

Rhipicephalus australis (Cattle Tick – previously known as *Boophilus microplus*, *Rhipicephalus microplus*)

Recent phylogenetic analyses of ticks based on mitochondrial sequences have led scientists to re-evaluate the taxonomic position of the tick formerly known through out northern Australian cattle industry as *Boophilus microplus.* The species is now established to belong to the genus *Rhipicephalus,* originally called *Rhipicephalus microplus,* but now it is called ***Rhipicephalus (Boophilus) australis.***

Don't be put off if you see or hear the cattle tick referred to as *Boophilus microplus* or ***Rhipicephalus microplus***.

Rhipicephalus australis is found in northern Australia in a band extending from north-eastern New South Wales to north-eastern Western Australia. Factors governing the distribution of the cattle tick in these regions are:

- The presence of bovine hosts.
- Areas with sufficient moisture (over 500 mm annual rainfall)
- Temperature. In southern regions, temperatures lower than 16°C over 4 months cannot sustain survival of the ticks.



Distribution of *Rhipicephalus australis* in Australia (red band). Adapted from Barker and Barker[1].

Image: Creative Commons Attribution-ShareAlike 4.0 licence. Background map by Golbez, modified under a CC BY-SA 3.0, via Wikimedia Commons

While the Australian cattle tick is closely associated with cattle, the tick can cause heavy infestations on horses, sheep, deer and wild buffalo, and may be found on marsupials, humans, goats, cats, feral pigs and dogs[2].



Rhipicephalus australis ticks on ear of bovine.

Photo: © Anthony Feez. Used with permission.

Life Cycle

Rhipicephalus australis is a 1-host tick and thus larvae initiate infestation. The on-host life cycle of a female, from the time it attaches to the host as a larva until the female drops from the host, is 21 days. The developing stages moult on the same host, presumably remaining attached at the bite site during the moult. Engorged females drop to the ground and lay eggs in protected space on the ground. Egg development and hatching is dependent on temperature, so that development is quicker in warmer months and slow in winter. The result of slow development of larvae in cold months in southern Queensland results is severe infestations in early spring, with the life cycles repeating in the spring and summer months.

Significance

The cattle tick is the most important parasite in the cattle industry in Queensland. The Queensland cattle regions are divided by Biosecurity Queensland into 'cattle tick infested zones' and all regions outside of the infested zones. Stringent requirements are in place to prevent transport of ticks outside of infested zones. The importance of the Australian cattle tick arises directly and indirectly. Cattle ticks are also important internationally, including in the USA.

Direct effects, that include **tick worry**; loss in production due to irritation and decreased food intake, **anaemia** due to blood loss, and **damage** to hide.

Indirect effects include the transmission of tick-borne diseases. The Australian cattle tick is vector for three agents of **tick fever**; due to the protozoan organisms ***Babesia bovis*** and***Babesia bigemina,*** and the rickettsial organism, ***Anaplasma marginale.*** The species is a major economic burden for the cattle industry, with major cost of control for farmers and government (e.g. maintenance of tick line). The tick is resistant to many **acaricides**, especially in the dairy industry.

One strategy for control of the cattle tick in Australia has been the introduction of *Bos indicus* and other partially resistant breeds into northern Australia. *Bos indicus* breeds appear more resistant to ticks, while *Bos taurus* breeds are less resistant. Some tropics-adapted taurine breeds (Southern African Sanga breeds, West African humpless breeds and Criollo breeds of South America) perform better in tick areas of northern Australia than temperate breeds of taurine cattle.

Visit Additional considerations – ticks in cattle for other control strategies for the Australian cattle tick.

Rhipicephalus linnaei (Tropical Brown Dog Tick)

The tropical brown dog tick has a complex taxonomic history. Until very recently, the species in Australia has been known as ***Rhipicephalus sanguineus***, but recent studies have clearly identified all ticks of this species complex in Australia as belonging to the species ***Rhipicephalus linnaei.***



Distribution of Rhipicephalus linnaei in Australia (in Brown), as proposed by Teo et al[4].

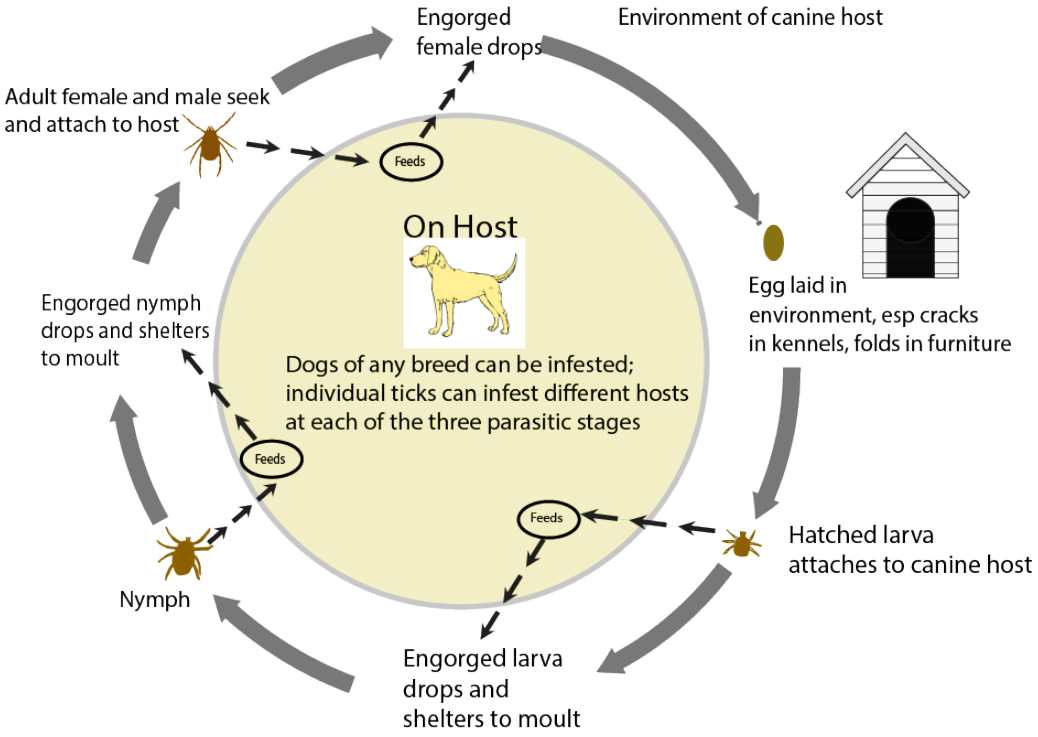
Image: Creative Commons Attribution-ShareAlike 4.0 licence. Background map by Golbez, modified under a CC BY-SA 3.0, via Wikimedia Commons

Rhipicephalus linnaei is an introduced tick with comparatively low moisture requirements widespread in Australia. This tick occurs throughout the northern parts of Australia, from the northern rivers in NSW to Carnarvon in Western Australia, and to the Great Australian Bight in southern Australia. Incidental findings have been reported for southern NSW, Victoria and Tasmania. These occurrence of the tick species in southern parts of Australia is thought to occur due to the transport of infected dogs from endemic regions into non-endemic regions/. .

Life Cycle

The tick is specific to domestic dogs, but can be found on wild dogs and occasionally cattle. The tick is common around the neck, head and ears of dogs its infests.

The tick has a 3-host life cycle and is generally host-specific for dogs. Under optimum conditions, the life cycle can be completed in 10 weeks, and multiple cycles can be completed within a year. The tick is highly adapted to living in dog kennels and human houses, in which off-host stages may be found in cracks and crevices and within furniture. *Rhipicephalus linnaei* is thus a common problem in kennels and refuges.



Life cycle of Rhipicephalus linnaei.

Image: Dog from Rhcastilhos, Public Domain, via Wikimedia Commons. Other images by authors.

Significance

In Australia, *Rhipicephalus linnaei* transmits the rickettsial organism *Ehrlichia canis*, the agent of canine ehrlichiosis (or canine tropical pancytopenia). After its discovery in Western Australia in 2022, the agent of canine erlichiosis was subsequently found to occur in the Northern Territory and Mt Isa in Queensland. It is suggested that *Erlichia canis,* was present in Australia well before its discovery[4]. *Rhipicephalus linnaei* may also transmit the apicomplexans *Babesia vogeli* and *B. gibsoni,* as well *Hepatozoon canis.*

Haemaphysalis longicornis (Bush Tick)

Originally described in Australia, ***Haemaphysalis longicornis*** is an 3-host introduced tick, probably originating in Asia. The species is called the bush tick in Australia, the cattle tick in NZ, and in other parts of the work, including the USA, may be called the Asian longhorned tick. The tick was first discovered in the USA in 2017.

The preferred host of the tick is cattle, although the species can occur on other domestic animals (dogs horses, goats and cats), humans and many native species.

A related tick, the wallaby tick ***Haemaphysalis bancrofti*** , a parasite of native marsupials, especially macropodids, can also be found on cattle and other domestic species.



Distribution of Haemaphysalis longicornIs in Australia (yellow) (Adapted from Barker and Barker[1]).

Image: Creative Commons Attribution-ShareAlike 4.0 licence. Background map by Golbez, modified under CC BY-SA 3.0, via Wikimedia Commons

Life Cycle

Haemaphysalis longicornis is parthenogenetic, and studies reveal that the population consists of one male for every 400 females. The tick has a 3-host life cycle and each stage will remain on the host for periods of 1-2 weeks. The life cycle is regulated by time of development of the off-host stages, and the process of moulting may take days to weeks to complete under circumstances. Eggs take approximately 1 month to mature.

Significance

The primary focus for disease associated with *Haemaphysalis longicornis* in Australia is transmission of bovine theileriosis to cattle. Bovine theileriosis is a disease caused by blood infection with strains of the apicomplexan *Theileria orientalis.* In Australia, the distribution of *H. longicornis* matches that of bovine theileriosis almost exactly[2]. This protozoan infects cattle and can be responsible for disease in young calves, late-pregnancy and early lactating cattle.

Other Ticks of Importance in Australia

Amblyomma spp.

These hard ticks are commonly found on reptiles and birds. Barker and Barker[2] note that there are 14 species in Australia. ***Amblyomma triguttatum***, the ornate kangaroo tick, is a 3-host tick. This species is an important cause of damage to kangaroo hides and may be found on horses, feral pigs, cattle, sheep and dogs. *Amblyomma triguttatum* has been implicated in transmission of *Coxiella burnettii* the agent of Q-fever, and *Rickettsia gravesi,* an agent of a form of spotted fever.

Important Soft Ticks (Family Argasidae) in Australia

Argas persicus

This soft tick, commonly called the fowl tick, is naturally parasitic on rooks in Asia. In Australia, the most common host is the domestic chicken. There is a suggestion that the parasite can also infest wild birds in this country. The body has a distinct flattened margin (like a pie-crust) retained as a lateral ridge when engorged. As with all soft ticks, ***Argas persicus*** is a transient multi-host feeder. Females drop from the host, laying 20-100 eggs after each feed. Off-host stages remain in cracks and crevices in poultry houses or environment. Large numbers of the parasite can cause anaemia in chickens resulting in reduced egg production. In Australia, the tick is said to transmit the rickettsia *Aegyptianella pullorum,* agent of a febrile disease of chickens, and the spirochaete *Borrelia anserina, a*gent of avian spirochaetosis.

Ornithodorus gurneyi

This species is the kangaroo soft tick. The tick may be found in areas where macropodids rest typically in desert. Other hosts include horses, dogs and people, and a range of native hosts, including lizards. Although humans and domestic animals rarely encounter the tick, due to its distribution in arid regions, there are reports of severe reactions to the bite of the tick in humans, with localised swelling at the bite, headaches, impaired vision and temporary blindness.

Identification

- Identification of ticks of domestic animals

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11.

SUPERORDER PARASITIFORMES, ORDER MESOSTIGMATA, AND SUPERORDER ACARIFORMES

The Mites

> "A mite makes the seas roar" – Richard Feynman, in a speech to the US National Academy of Sciences, 1955[1]

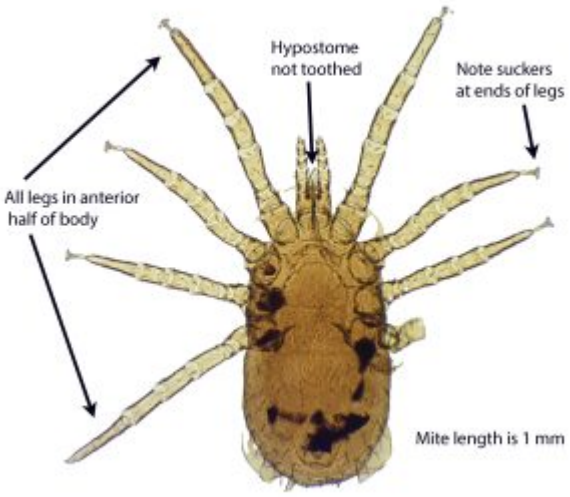
In this chapter, we will consider the mites that parasitise domestic animals. Mites are **small arachnids**, usually smaller than ticks. The organisms that are considered to be mites come from two distinct groups, the Superorders Parasitiformes and Acariformes. The two groups are not closely related to each other in a phylogenetic sense, and thus the term 'mite' describes different groups of organisms. Nevertheless, members of both groups appear 'mitey', and we will consider them together in this chapter. The keys we will use will also assist you to identify mites from both groups of importance in parasitology.

Visit chapter The Parasitic Arachnids for the characteristics of the Orders Parasitiformes and Acariformes.

Superorder Parasitiformes

Order Mesostigmata

These are generally large mites (0.5-1.5 mm in body length). Most mesostigmatids are free-living and predatory. One parasitic example of this group is *Dermanyssus gallinae*, which is pictured below (note that the mite in the picture is missing a leg!). The hypostome, situated between the longer palps, is not toothed. The lack of hypostome teeth is one characteristic that separates the mesostigmatids from the ticks. The mesostigmatids have a single pair of lateral spiracles, situated near the third pair of legs (that is about halfway along the idiosoma, or body). **All of the legs emerge from the anterior half of the body**, that is, their **coxae** attached in the anterior half of the idiosoma.



Dermanyssus-gallinae , ventral view. Note that leg 4 on the mite's left side is missing.

Image: © Lyn Knott

Varroa Mites

Varroa destructor and *V. jacobseni*

These mites are not traditionally considered a veterinary concern, but you may be asked about the varroa mites by clients who maintain introduced honey bees *(Apis mellifera).* The varroa mites can cause the total collapse of a bee hive in a few years after the first infestation. The population growth may be less if the initial infestation of a colony is large. The varroa mites attach to bees while the larvae are developing in the brood chambers. The mites remain attached throughout the life of the bee, feeding on haemolymph, thereby shortening the life-span of infested bees.

The mite does not infest hives of Australian native bees, while Asian honey bees (*Apis cerana*) have evolved strategies to control the mite populations.

Dermanyssus and *Ornithonyssus* spp.

These are large mesostigmatids with coxae grouped together and chelicerae modified for piercing host tissues and haematophagy. Species of these mites are seen on birds, and can infest humans and mammals for short periods of time.

Dermanyssus gallinae (Red Poultry Mite)

This mite feeds on blood of domestic poultry. The mite appears red only after a blood meal. The lancet-like chelicerae (not depicted in the figure above) are pressed into the skin to rupture capillaries. The mites usually feed around the breast and legs, although they may also feed around the cloaca. There are two nymph stages and adults and nymphs will emerge to feed on birds, mostly at night. The adults have been shown to survive for up to 10 months in empty poultry enclosures.

This species can readily infest other animals, including dogs, cats and people. The mite has been implicated as a vector for a wide range of bacterial and viral diseases, including *Salmonella* (serovars *Salmonella* Gallinarum and *S.* Enteriditis), *Erysipelothrix rhusiopathiae,* fowl pox and avian influenza[2].

Ornithonyssus spp. (Northern Poultry Mite, Tropical Poultry Mite, Tropical Rat Mite)

Ornithonyssus bursa (northern fowl mite/starling mite) and *O. bacoti* (tropical rat mite) are present in Australia and can spread in homes where the natural hosts have nested. These mites occasionally bite people and pets. *Ornithonyssus bursa* is most likely to enter homes with commensal or **synanthropic** birds, usually sparrows or starlings, usually with birds nesting in the roof cavities of homes. *O. bacoti*, however, parasitises rodents, and can occur in older building that may be prone to rodent infestation. Members of the genus can also be found on caged and wild birds and can be inadvertently introduced into veterinary clinic with these hosts.

The biology of the mites is similar to that of *Dermanyssus,* although the mites spend their life cycle on the hosts and may only survive for a short period (about 10 days) away from the host.

Superorder Acariformes

Go to The Parasitic Arachnids for the characteristics of the Superorders Parasitiformes and Acariformes.

These mites are called here the **mange** mites. They are characterised, among other features, by having legs that are partially sunken into the body, so that the legs may appear short and stubby. There are two orders with parasitic members, the Trombidiformes and the Sarcoptiformes. Many species of mites cause chronic and disseminated infestation of the skin, provoking intense reactions. Such conditions caused by mites are known collectively as **mange**.

Life cycle

Acariform mites show a simple form of development, with simple metamorphosis. As with the ticks and mesostigmatid mites, the larval stage is 6-legged, while later stages have 8 legs.

With the exception of harvest mites, parasitic acariform mites are parasitic throughout their life cycle and will lay eggs on the host. Thus, in mites that are always parasitic, transmission is through **direct contact** between hosts**.** Once infection is established, pathogenic populations can build up on an animal without further acquisitions. The ability of mites to survive off the host is variable between species.

Order Trombidiformes

Sub-Order Prostigmata

In these organisms, the spiracles are located between the chelicerae or on the dorsal margin around the mouthparts. We use the occurrence of feathered **setae** to identify this group and to distinguish them from other mites.

Demodex spp. (demodectic mange)

Mites from this genus have a distinctive worm-like shape and live in hair follicles and sebaceous glands of their hosts. The mites are highly host specific. Infestation with these mites can be diagnosed through a skin scraping, but the mites may desiccate quickly once removed from the host.



Demodex canis mites in a skin scraping from the shoulder blades of a dog. The dog was suffering from hair loss in the region of the scraping.

Photo: © Dr Karen Jackson. Used with permission

Various species of *Demodex* live as commensals in the skin of most mammals. In some species, the mites may proliferate and cause disease and this may occur in dogs. It is important to remember that virtually all dogs are infested with *Demodex* mites, but only a small minority of dogs will develop disease.

Life Cycle

The mites live on hair follicles and sebaceous glands of animals. Mites take from 18-35 days to develop into adults, and stages consist of egg, larva, nymph and adult. While the mites are restricted to follicles and sebaceous glands, they may migrate short distances on the body surface at night.

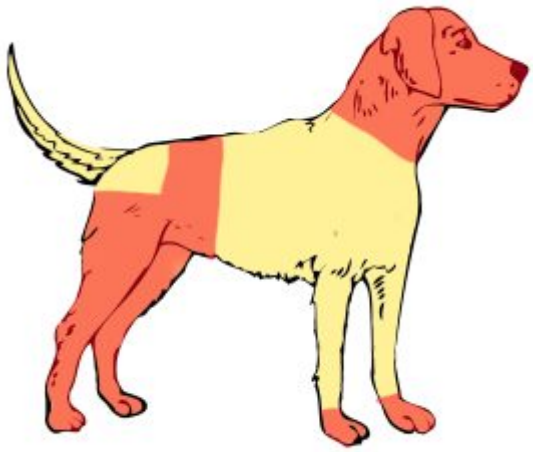
Demodex mites are transferred primarily from dam to pups during nursing in the first 72 hours after birth. The mites may also transfer between pups of the same litter over the same period. The mites are generally thought to **not transfer between animals after** these early stages of life. *Demodex* species do not readily transmit between species, that is, they display high host specificity.

Disease

The agent of canine demodicosis in dogs is *Demodex canis*. Dogs can harbour other species of *Demodex,* but little is known about the pathogenic potential of any species. Demodicosis is also called **demodectic mange** or **red mange** and can be diagnosed by the demonstration of an abundance of mites in skin scrapings of lesions.

Localised demodicosis occurs when there are four or fewer localised lesions on the body, but most commonly on the face.

Generalised demodicosis is much more serious (but very rare) and occurs when there are more than four lesions, often disseminated in the regions shown on the figure. Demodicosis can be associated with reddening of the skin, pustules or swellings of the skin, hair-loss and scaling of the skin. The lesions may become secondarily infected with bacteria and folliculitis may occur.



Dermogram showing regions of body where demodicosis may be evidenced in a dog. Regions where lesions occur most commonly are shown in red. Based on data in Thomson et al.[3].

Image: Adapted from "Dog" by Rhcastilhos, Public Domain, via Wikimedia Commons.

Demodicosis occurs in younger dogs and appears to have a genetic basis. Certain breeds, among them various terrier breeds (Boston Terrier, Jack Russel Terrier, Scottish Terrier, West Highland White Terrier), as well as Boxer, Bulldog, Chihuahua, Dalmatian, Dachshund, Doberman pinscher, Great Dane, Afghan, Alaskan Malamute, German Shepherd, Shar-pei, Weimaraner, show a greater predisposition to disease[3]. Deficiencies in the adaptive immune response, and notably function of T-cells, are thought to be related to susceptibility of dogs to the mites.

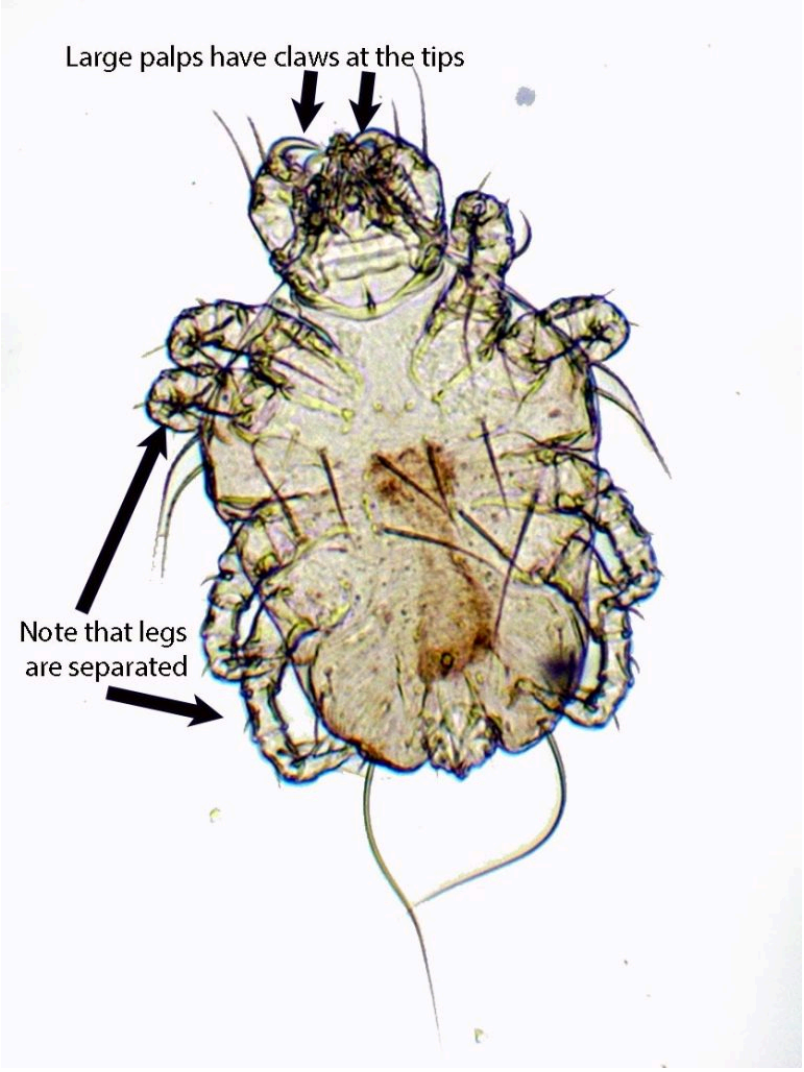
Spot-on treatments and injected anti-parasitic compounds have been used to treat severe demodicosis. It is important that owners bring their pets for regular checkups. The vast majority of dogs will carry *Demodex* mites without showing any clinical signs and it is not necessary to treat these animals.

Cheyletiella spp

These mites are fur mites, living within the fur of animals, but migrating onto the skin surface to feed. There are three species of veterinary importance, affecting dogs, cats and rabbits.

The mites can produce a mild form of mange characterised by dandruff and mild/moderate pruritus in young animals. The mites are large and can be seen with the naked eye. This gives rise to the common name for these mites – **"walking dandruff".**

Cheyletiella transfer readily from pets to owners and often produce more severe pruritus and lesions in the owners than in the young dog or cat. Humans heal spontaneously once animal infection is cleared up.



Cheyletiella mite from domestic animals.

Image: © Lyn Knott

Psorobia ovis (previously Psorergates ovis) (Sheep Itch Mite)

These are small non-burrowing mites of sheep. Adults live on the superficial layers of the epidermis but larvae and the first nymph stage often live under the thickened cornified layer and scaly or scurfy skin is one feature of infection. *Psorobia ovis* is important as a cause of **fleece derangement** and therefore lower wool prices.

The mites are spread by direct contact, especially in sheep with short wool (ewe to lambs or between animals in yards after shearing). The mites typically spread very slowly through a flock.

Psorobia ovis was introduced to Australia with the transport of sheep from the United Kingdom. The species is said to have been eradicated from Australia in the late 1800's, but there are still reports of the parasite being present in Western Australia.

Trombiculids

Members of this family of mites are peculiar in that only larvae are parasitic. Nymphs and adult forms are free living on pasture. In the United Kingdom, the mites are called harvest mites, because larvae appear around harvest time. In North America, the mites are called chigger mites, while in Australia a species *Eutrombicula hirsti* is called the scrub-itch mite. *Eutrombicula hirsti* is associated with bandicoots, and a range of other marsupials.

Larvae occur in clusters on the host and in addition to having only 3 pairs of legs, are red-orange in colour. The mites cause mild to intense itching on the host. The mites stay attached to the skin and release digestive enzymes to break down the skin. The action of parasite molecules and breakdown products causes itching.

Order Sarcoptiformes (Astigmata)

This large order of mites has 15,000 species, classified into 230 families. While most sarcoptiforms are free-living, there are many parasitic species that infest a wide range of vertebrate and invertebrate species.

The sarcoptiform mites have short legs and lack spiracles, respiring through simple pores or across the exoskeleton.

Two families are of major significance in veterinary medicine – the **families Sarcoptidae and Psoroptidae.**

Family Sarcoptidae

The Sarcoptidae are tiny mites that have short legs. The first two pairs of legs (Legs 1 and 2) emerge anteriorly and the other pair (Legs iii and iv) emerge posteriorly. Typically, **Legs 3 and 4 do not extend beyond the abdomen**.

Representative genera are:

- *Sarcoptes*
- *Notoedres*
- *Trixacarus*
- *Cnemidocoptes.*

These mange mites are **highly contagious and produce marked pruritus.** In some, especially *Cnemidocoptes* and *Notoedres*, hyperkeratosis (excessive production of keratin) is a feature. Hyperakeratosis also occurs in some cases of infestation with *Sarcoptes*, including in humans, foxes and wombats.

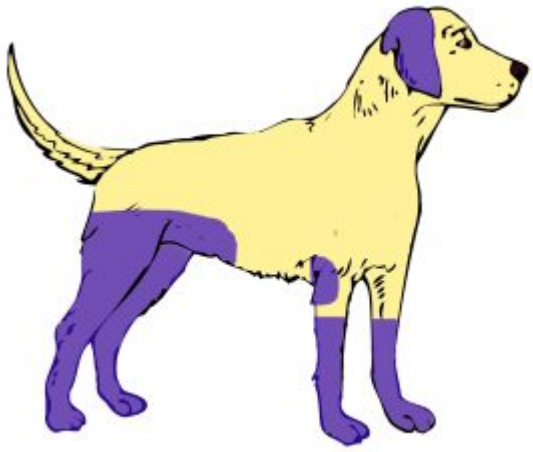
Sarcoptid mites are generally host specific, but may transiently infest in-contact animals of other species. For example, a person with a dog with sarcoptic mange may develop lesions and pruritus but the mites cannot reproduce on the person and once infection is eliminated from the infected dog, its owner's lesions will also resolve.

Control of sarcoptid mites generally relies on treatment of affected animal with acaricide plus all in-contact animals of same species plus cleaning of bedding, resting areas, grooming tools etc (mites do not survive long off the host but may persist for a day or two).

Sarcoptes scabiei – sarcoptic mange or scabies

This is a widespread species, occurring on almost 150 different host species worldwide. Across this wide host range, the scabies mite is regarded as a single species, with host-specific variants of the mite parasitising different host species. The variants are usually named for the host from which the variant is obtained (eg *S. scabiei* var *canis).* The parasite variants are host-adapted, and do not transfer in the long-term between species (as mentioned above).

Females form burrows and tunnel through the through stratum corneum of the skin, laying eggs as they migrate. Larvae hatch from eggs and migrate to hair follicles, where they moult to become nymphs. Females have two nymph stages, whereas males have only one. The females require about 17 days to complete development. The general distribution of *Sarcoptes scabiei* on a dog is shown in the accompanying illustration. Evidence of the presence of the mites includes the presence of papules, boils and hyperkeratosis. The parasite can generate extensive and severe responses even when few mites are present.



Dermogram of *Sarcoptes scabiei* distribution on a dog. Based on data in Thomson et al.[3].

Image: Adapted from "Dog" by Rhcastilhos, Public Domain, via Wikimedia Commons.

Affected animals can mount a delayed-type hypersensitivity to the parasite. It is thought that secretions

from saliva and mouthparts of the mite generate the immune response. Transmission of mites from host to host is by **direct contact**. Although the mites may die rapidly off the host, there are records of the mite surviving on fomites for 10-17 days under conditions of increased humidity and warm temperatures.

Notoedres cati – cats

This species is responsible for notedric or face mange in cats, but can be transmitted to dogs, ferrets and people. Hyperkeratosis is a feature of infestation. The mite can be distinguished from *Sarcoptes* in having an anus that opens dorsally.

Trixacarus caviae – guinea pigs

This species occurs on guinea pigs and is a cause of pruritis. *Sarcoptes scabiei* and *Notoedres muris* may also be identified on rodents (although this is not very common now). In *Trixacarus*, the anus is dorsal in males but ventral in females, and the dorsal surface has sharp spines. In addition, *Trixacarus caviae* and *Notoedres cati* are smaller than *Sarcoptes scabiei*.

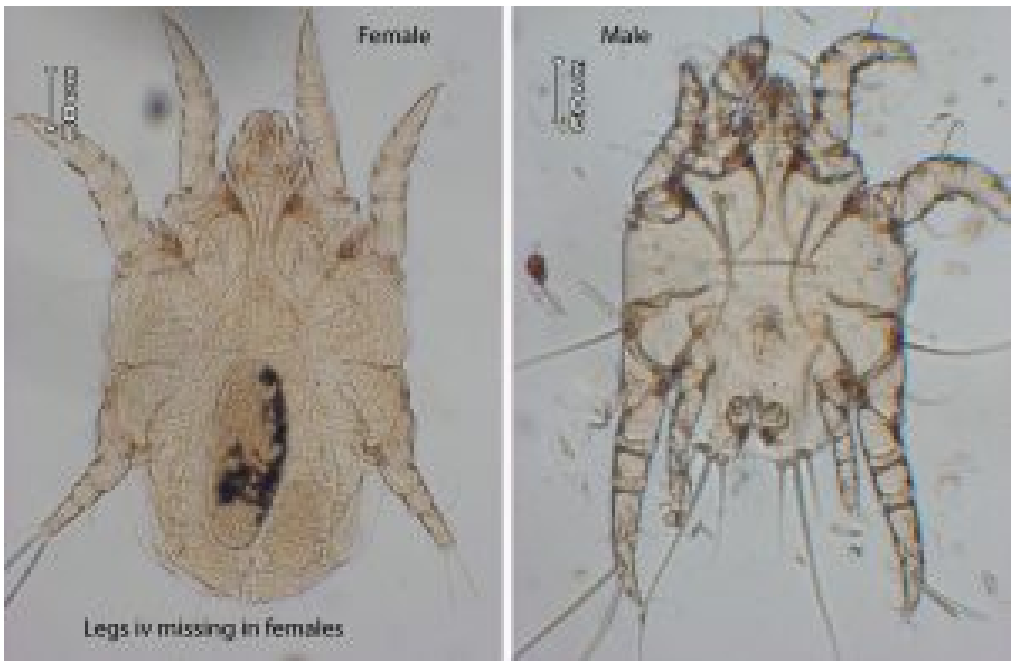
The pruritus in guinea pigs arising from infection makes this mite one of the most common reasons for guinea pigs being presented to vets (chewing lice *Gliricola porcelli* and *Gyropus ovalis* will often be found on infected animals, but *Trixacarus* is more likely to produce severe pruritus).

Cnemidocoptes spp – poultry and caged birds

In budgerigars, canaries and finches, this species may produce scaley face or scaley legs – characterised by honeycomb-like hyperkeratosis of the skin of the face and/or legs.

Family Psoroptidae

Psoroptid mites differ from sarcoptid family mites in that Legs iii and iv are longer and extend beyond the abdomen.



Otodectes cynotis, female and male.

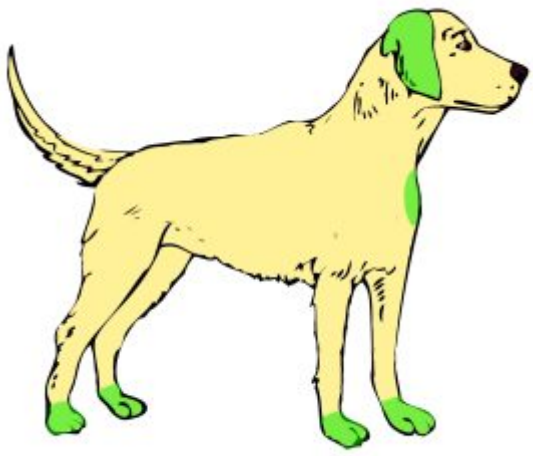
Images: © Lyn Knott.

Ear mites of dogs and cats (*Otodectes cynotis*)

Otodectes cynotis is a highly contagious surface-dwelling mite from the ear canal of young cats and dogs.

This species is considered by some people to be a **commensal** in cats, as so many animals are infected without showing clinical signs, but can be an of inflammation and disease in the external ear canal (**otitis externa**) of both cats and dogs.

As shown in the dermogram (image of dog below), some mites migrate onto the general body surface; need to treat ears, feet AND body fur.



Dermogram of *Otodectes cynotis* on dog. The distribution of the mite is shown in green. Based on data in Thomson et al.[3].

Image: Adapted from Dog from Rhcastilhos, Public Domain, via Wikimedia Commons

This is a very contagious mite. As some animals show no clinical signs when infested, it is important to treat all in-contact dogs and cats as well as the animal with otitis externa.

Different species of mite are responsible for ear infections in other animals. Such species of mites include *Raillietia* sp. in ruminants and *Psoroptes* sp. in rabbits, horses and goats. The Psoroptid mite *Psoroptes ovis* is particularly interesting as it is responsible for severe mange of sheep. The mites form large populations on the backs of sheep, causing sheep scab, a source of intense irritation and pain for sheep. The same species of mite is now known to cause infections in sheep, goats, cattle and horses and ear infections in sheep and rabbits. Different variants of the mites seem to be site and possibly host-specific.

While the variant responsible for sheep scab has been eradicated from sheep in Australia, a variant that infests ears (*Ps. ovis* var *cuniculi)* is present in this country in sheep, goats and rabbits.

Identification

- Identification of mites of domestic animals

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PART III

THE HELMINTHS

12.

THE HELMINTHS (WORM PARASITES OF ANIMALS)

The term 'helminth' is an ancient word that signifies 'worms'. We use this term to refer to parasitic worms. There is a range of worm phyla that includes members that are parasitic, but the two major phyla are the Platyhelminthes (flatworms) and the Nematoda (roundworms).

The two phyla can be readily distinguished from each other. The nematodes have tubular bodies and the surface is distinctly delineated from surrounding media due to the generally smooth edge of the exoskeleton. Flatworms are soft and fleshy organisms with a somewhat leathery appearance.

Other helminths

Other helminths not considered elsewhere in this book are the thorny headed worms, the Phylum Acanthocephala. These worms are characterised by the presence of an anterior eversible proboscis. The proboscis of acanthocephalans has retrose hooks that anchor the proboscis in the wall of the intestine of the host. Pigs are infected with an acanthocephalan called *Macracanthorhynchus hirudinaceus,* by eating infected beetles. Wild cats in Australia carry the acanthocephalan *Oncicola* sp. The life cycle of *Oncicola* is not fully known, but the second intermediate hosts are passerine birds. Cats become infected with *Oncicola* by preying and ingesting the native birds.

All domestic animals are susceptible to parasitism by leeches. These helminths belong to the Phylum Annelida. Leeches have mouths with cutting plates. Leeches are capable of imbibing large amounts of blood relative to their body sizes and are often not detected by their hosts during their transient parasitic phase.

The table below describes the features that differentiate cestodes, trematodes and nematodes. This table is a much simplified aid to identifying the helminths we commonly encounter in parasitology courses.

Helminth Differentiation Table

This Table is a simple tool to assist you to quickly differentiate various helminths.

Appearance	Grouping	General Information	Further Identification
Flat and leaf-shaped with suckers	Trematode (Liver fluke)	Lifecycle - complex Intermediate host - mollusc Hermaphroditic 2 suckers Soft-bodied	Trematodes
Pear-shaped with suckers	Trematode (Stomach fluke)	Lifecycle - complex Intermediate host - mollusc Hermaphroditic 2 suckers Soft-bodied	Trematodes
Flat with proglottids	Cestode Various genera	Lifecycle - complex 1, 2 or 3 intermediate hosts Hermaphroditic No alimentary tract	Cestode identification
Cylindrical - definitive head and tail	Nematode Various superfamilies	Lifecycles - simple OR complex Separate sexes Morphology - mouth, pharynx, gut, cloaca, tail	Nematode superfamily identification

Lyn's master Table

13.

PHYLUM PLATYHELMINTHES

The Flukes and Tapeworms

> "But, from this plant, through its corruption of the liver, is engendered a kind of worm which, through rotting, lives and eats and corrupts the entire liver of the animal...[...]..And this disease of ...[..].. animals can linger and linger in sheep for a year or more; but, in the end, they must die from it. For the worm destroys the liver, and the liver is one of the three principal organs where life resides, after the heart and the brain; and therefore, the ...[..]. sheep cannot live....." – Jehan de Brie[1].
>
> de Brie did not actually describe the liver fluke, but did describe the pathologic effects of liver rot caused by the fluke. He was even correct about how *Fasciola hepatica* infects its mammal hosts. de Brie's observations were made some 500 years before the life cycle of the parasite was formally described!

Contents

- Class Trematoda (The Flukes)
  - *Fasciola hepatica*
  - Family Paramphistomidae (Stomach Flukes)
  - Identifying fresh water snails
- Class Cestoda
- Family Taeniidae
  - *Echinococcus granulosus*
  - *Taenia* species
  - *Dipylidium caninum*
  - Family Anoplocephalidae
  - *Spirometra erinacea*

The **Phylum Platyhelminthes** belongs to a clade of animal phyla called the Spiralia, one of the three major lineages of animals. The Spiralia also includes the molluscs and earthworms, as well as the rotifers, and

the parasitic acanthocephalans that were mentioned in the previous chapter. Spiralians are characterised by a particular form of embryological development. The Spiralia is one of three important clades of animals. The other two clades are the Ecdysozoa (which includes the nematodes and arthropods) and the Deuterostomia (which includes the vertebrates).

Parasitic platyhelminths differ from other animal parasites in having the characteristics listed below (click on the headers to read more about the characteristics of flatworms).



An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=171#h5p-7

The Phylum Platyhelminthes is arranged into four classes (click on the headers to read some of the characteristics of the classes):



An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=171#h5p-6

The two groups of primary veterinary significance are the **trematodes and cestodes**. We will not consider the other two classes here. People with special interests in aquaculture will need to develop knowledge of the pathogens of farmed fishes; good starting points are any general texts on Aquaculture, or the MSD Veterinary manual.

Class Trematoda (The Flukes)

The Class Trematoda is divided into two subclasses. Of these two, the Subclass Digenea contains species of veterinary significance. The name Digenea refers to the occurrence of at least two hosts in the life cycles of these parasites. One of these hosts is almost invariably a mollusc, typically some species of gastropod (snail). The other host is almost always a vertebrate species. Within the vertebrate definitive host, digeneans may occur in a variety of sites, typically in the small intestine. The two dominant groups of flukes infecting animals in Australia, however, are peculiar in that they occur in diverse sites- *Fasciola hepatica* occurs in the hepatic bile ducts of ruminants and other herbivorous hosts, while members of the Family Paramphistomatidae are stomach flukes of ruminants.

The liver flukes and stomach flukes are easily distinguished from each other. The liver fluke lives in the bile

ducts, and has a large leaf-like and flattened body with an anterior conical region. The anterior-most region contains the oral sucker, which encloses the mouth. This leads to a blind gastrodermal tract that ramifies throughout the body. A ventral sucker, used for movement of the fluke, lies in the midline of the body, and immediately behind the anterior cone.

Stomach flukes (Family Paramphistomatidae), by contrast are found in the rumen of ruminant hosts. Juvenile forms will develop for a short period of time in the duodenum. Unlike the flattened liver fluke, paramphistomes are gourd-like, appearing like mini-'butternut pumpkins'. Their ventral sucker is displaced to the posterior-most region of the body.

Flukes feed on a range of materials. Liver flukes are blood-feeders as adults, while juvenile flukes in the host are feed on tissues. Adult liver flukes can be responsible for chronic anaemia in ruminant hosts. The stomach flukes appear to feed on stomach contents of their hosts, although there is some evidence that the adults may feed on host gut lining and may even ingest host blood[2]. Absorption of nutrients may also occur through the tegument ("skin").

While the adults can be easily distinguished by site specificity and morphology, their eggs are quite similar.

The eggs of the two groups of species can be distinguished by colour and side, as described in Helminth eggs and Protozoan cysts.

Life Cycles

Apart from the schistosomes (blood flukes), flukes are hermaphroditic and have indirect life cycles, with a mollusc intermediate host. The mollusc host is a critically important host. The flukes display high host specificity to their molluscan hosts.

Furthermore, the mollusc serves as a host in which extensive clonal reproduction occurs. A ciliated larva, the **miracidium (plural = miracidia),** hatches from the egg. This free-swimming larva live for 24-48 hours and swims towards the intermediate host (usually a snail). The miracidium is exquisitely adapted to seeking a snail host, and is highly specific to that host. It is thought that the miracidium is attracted to specific molecular 'signatures' in mucus released by snails. Once it locates a snail, the miracidium will penetrate the body wall of head-foot region of the snail. Some penetrate through the eye stalks of the snail.

During penetration, the miracidium discards the ciliated epithelium and assumes a simple, sac-like form. This first parasitic stage is called a **sporocyst**. At some stage, the parasite will migrate to the digestive gland of the snail digestive tract. The sporocyst is an elongate worm, lacking a mouth and gut, absorbing micronutrients across its body wall. Generative tissues within the body of the sporocyst will form the next stage through a process of asexual development.

The stage that develops within the sporocyst is a distinct offspring of the sporocyst and is called the **redia (plural=rediae).** The redia contains a mouth and gut and feed on snail tissues. More asexual reproduction

occurs within the rediae to produce the next larval stage, the **cercaria (plural=cercariae)**. The cercariae actively emerge from the snail (typically they possess a tail to aid swimming) before shedding their tails and encysting on vegetation as **metacercariae**. The encysted metacercaria is then infective to the definitive host. (In some flukes, the cercariae may be consumed directly by a definitive host or they may penetrate and encyst in a second intermediate host – but neither of the two important flukes in Australian animals adopt either of these strategies).

Important species in Australia

Fasciola hepatica

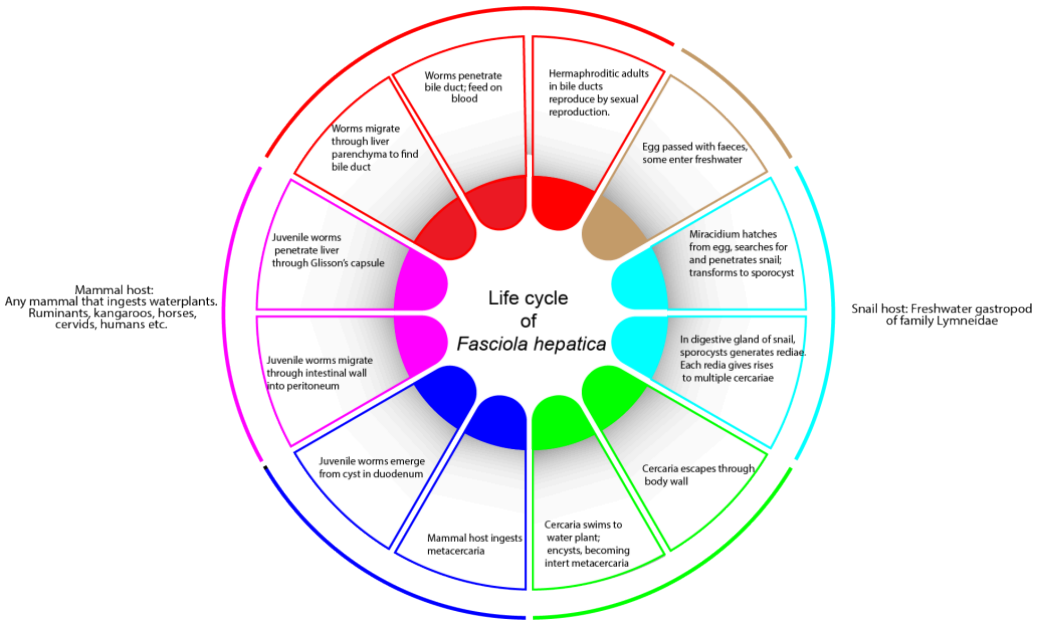
Adults of this parasite occur in the hepatic bile ducts of a range of species, particularly sheep, cattle and goats, but also pigs, macropodids, rabbits, alpacas, horses[3], and humans. Internationally, the parasite is recognised as an important pathogen of humans. This is the only adult worm found in the bile ducts of domestic Australian animals. Adults are 2-3 cm long and leaf-shaped.

Life cycle

Fasciola hepatica is highly fecund. The hermaphroditic adults can produce up to 20,000 eggs per fluke per day. The eggs are fabricated in a specialised region of the reproductive tract, call the ootype or egg mould. This ootype can process only 1 egg at a time, that is one egg every 4.3 seconds! Coupled with this reproductive output is the rampant asexual reproduction in sporocysts and rediae in the snails. A snail is typically infected with 1 miracidium, but through the multigenerational reproductive behaviours of the parasite in the snail, this miracidium can potentially give rise to 1000s of cercariae.

As mentioned, this parasite displays relatively high specificity to its snail hosts, and will only develop in some, but not all species of the aquatic gastropod family, the Lymnaeidae. A primary factor in the distribution of the liver fluke, particularly in Australia, is the presence of suitable snail hosts. The distribution of the snails is driven by non-biotic factors in the environment, such as the presence of bodies of water able to sustain the snails.

Snail hosts of *Fasciola hepatica* live in low-lying swampy areas with slow moving water. The life cycle is further sustained by the presence of water plants in proximity to the snail habitat, for the cercariae that emerge from the snail will encyst on this plant material. Snail populations in various locations will vary from time to time. Under favourable conditions, populations of snails can increase rapidly. Excessive rainfall, snails carried with birds, animals or floods can cause the range of the snails and consequently the parasite to change over time.



Life cycle of *Fasciola hepatica.*

> *An interactive H5P element has been excluded from this version of the text. You can view it online here:*
> *https://uq.pressbooks.pub/principles-disease-parasitology/?p=171#h5p-2*

The parasite is found in locations where there is the combination of the following biotic and abiotic factors.

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> *https://uq.pressbooks.pub/principles-disease-parasitology/?p=171#h5p-40*

Development of *Fasciola hepatica* in the definitive host

There remains controversy around details of the development of *Fasciola* in its hosts. The following is the most accepted developmental pathway. Juveniles emerge from the metacercarial cyst in the duodenum of the host. The cyst wall is digested through the action of enzymes and other components of the stomach and small intestine. After emergence, the newly emerged juveniles follow a rather strange pathway to the bile ducts, migrating through the small intestine wall into the abdominal cavity. The larvae migrate typically in a cranial direction until they encounter Glisson's capsule (the external lining of the liver). Their behaviour then abruptly changes, as they invade the liver parenchyma. The juveniles migrate through the parenchyma for 5-6 weeks, eventually reaching a bile duct, which they penetrate. In the bile duct the flukes commence

feeding on blood through the wall of the ducts, and will begin to lay eggs after a few weeks of development. The **pre-patent period** is 8-10 weeks in sheep and cattle, longer in humans.

Watch Life cycle of the Liver Fluke: Fasciola hepatic (YouTube, 4m6s).

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Pathogenesis

Fasciola hepatica causes acute and chronic disease in its hosts.

Acute disease is due to the destruction of liver parenchyma by large numbers of immature flukes. The condition is sometimes known as liver rot. This disease is most commonly seen in sheep (rare in goats and cattle) and arises from the ingestion of large numbers of metacercariae and the concurrent migration of the newly emerged juveniles into the liver. Liver rot can lead to sudden death, oedema, and anaemia, due to acute liver failure and haemorrhage into the abdomen.

Infectious necrotic hepatitis is caused by the invasion of the liver by the bacterium *Clostridium novyi* type B. This pathogen appears to be introduced by migrating juvenile flukes.

Chronic disease arises from continued activity of adult flukes in the bile ducts and the host response to the parasites. This is the more common form of disease in sheep, goats and cattle and arises from the ingestion of small numbers of metacercariae over a long period of time. Signs of chronic disease include weight loss, hypoalbuminaemia (bottle jaw), anaemia, and decreased production.

Paramphistomes (Stomach flukes)

Members of the Family Paramphistomidae are parasites of domestic and wild ruminants. Species in Australia are *Paramphistomum ichikawai, Calicophoron calicophorum, and Orthocoelium stretocoelium.* These paramphistomes are common parasites of stomachs of ruminants in coastal and sub-coastal districts of eastern Australia and north west Western Australia.

The adults are found in the rumen and reticulum of sheep, goats and cattle. The name paramphistome is derived from the peculiar arrangement of the oral and ventral suckers, which gives the appearance of having two mouths, one at each end of the body. The adults are 1-2 cm in length appearing as pear-shaped flukes. The worms attach to the mucosal surface of the rumen by means of their larger posterior sucker, leaving their anterior ends projecting into lumen of stomachs.

Life cycle

The environmental phase of the life cycle of paramphistomes is similar in most respects to that of *F. hepatica*, except in the choice of snail hosts, and migration and sites of infestation in the definitive hosts. The paramphistomes utilise species of planorbid snail as intermediate hosts. Each Australian species has a different snail species of host, so their distribution is largely governed by the availability of those snails in the environment.

After ingestion of water plants by the definitive host, the metacercariae will emerge from the cyst in the duodenum. There, they will attach to the intestinal mucosa and will migrate anteriorly to the rumen or reticulum after 6-8 weeks. The pre-patent period is approximately 7-13 weeks.

Pathogenesis

Adult flukes in the stomach do not cause disease.

The juvenile stages may cause damage to the intestinal mucosa through erosion of the lining due to their attachment by the posterior sucker. This erosion will be noticed in the duodenum and sometimes the ileum, depending on the population size of the immature parasites, and is associated with reduced food intake, increased liquid intake and severe diarrhoea. The damage may precede generation of the characteristic eggs of the parasites, which can render diagnosis difficult.

Other Flukes

Flukes are common parasites of all major groups of vertebrates and are specially common in fish. Most species are found in the small intestines of their hosts and are of minor significance.

The schistosomes (genus *Schistosoma*) are important flukes of the blood system of a wide range of hosts, but are notable as parasites of humans and domestic and wild mammals in tropical regions[4]. Relatives of the schistosomes are found in birds in Australia and are agents of a condition called **cercarial dermatitis**. In this, cercariae of the parasites actively and indiscriminately penetrate the skin of hosts. In aberrant hosts, such as humans, they will die and host responses to the dead parasites give rise to inflamed skin lesions[4].

Members of the genus *Opisthorchis* and *Clonorchis* belong to a group of organisms that infest the bile ducts of their hosts. Unlike *Fasciola hepatica* , these flukes utilise freshwater fish as intermediate hosts. The parasites are ingested by humans, usually in salads containing uncooked fish. Among these flukes, *Opisthorchis viverrini* is associated with cancer of the bile ducts of humans and is listed as a carcinogen[3].

Identification

- Identification of adult flukes of primary veterinary importance in Australia
- Identification of trematode eggs

Identifying Freshwater Snails in Pastures

If faced with an outbreak of fascioliasis or paramphistomiasis, it may be necessary to investigate the local epidemiology of the disease. An important part of this can be to identify the location of the intermediate hosts, so that control through exclusion or snail treatment may be performed.

Australia has a very large fauna of freshwater snails. Probably all of them act as intermediate host to some species or other of trematode. (Remember that our wildlife are full of worms!) It is thus important to be able to identify the important species of snails.

Pulmonate Snails

Most freshwater snails belong to this major group of lunged snails. They lack gills and need access to air to breathe. There are a number of families of pulmonate snails of relevance, including the **Lymnaeidae** and **Planorbidae.**

Family Lymnaeidae

This family includes the intermediate hosts of *Fasciola hepatica*. There are 6 species present in Australia of which 3 act as intermediate host to *Fasciola* (susceptible snails highlighted in red). Lymnaeids are recognisable as **"dextral"** or right-handed shells (see illustration of dextral snails). They are delicate and lack an operculum (trapdoor). In dot point below, we list a range of lymnaeid snails that may be encountered in Australia. Those shown in red are susceptible to infection with *Fasciola hepatica*.

- ***Austropeplea tomentosa*** – (SA, Vic, Tas, NSW, ACT) a native species and the most important host of *Fasciola hepatica* in Australia.
- ***Austropeplea lessoni*** – (Qld, WA, SA, Vic, Tas, NSW, ACT, NT) the most common lymnaeid around Brisbane; not a vector of *Fasciola*.
- ***Austropeplea viridis*** – (New Guinea, Qld) introduced species with potential to extend *Fasciola*

into tropical Australia.

- ***Peregriana peregra*** – (Tas) introduced from northern Europe, not an important host of *Fasciola*.
- ***Lymnaea stagnalis*** – (Vic, Tas, NSW, WA, SA) introduced from Europe, not an important vector of *Fasciola*.
- ***Pseudosuccinea columella*** – (Vic, NSW, WA) introduced species, potentially important vector of *Fasciola*.

Family Planorbidae

This is the largest family of freshwater snails in Australia. Its members are important in that they can be confused with Lymnaeids. This applies to genera such as *Physastra* and *Physa*. These snails are similar to the lymnaeids but are **left-handed** (the scientific word is **"sinistral"**).

The Planorbidae also includes several "**planispiral"** (flat-spiral) snails. Three of these species act as intermediate hosts (one species distinct for each) to the three species of paramphistomes present in Australian ruminants.

Order Prosobranchia (Prosobranch Snails)

These are gilled snails and are, generally speaking, the group to which marine shells belong. Prosobranch snails are not susceptible to infection with *Fasciola hepatica*. Their interest in the context of trematode parasites of sheep and cattle is that, because they are dextral, they may be confused with lymnaeid hosts of *Fasciola*. However, they may be distinguished by the presence of an **operculum (trapdoor)**. In addition their shells are usually thick whereas those of lymnaeids are thin and fragile.

Identification

- Identification of freshwater snails relevant to transmission of liver and stomach flukes in Australia

Class Cestoda (The Tapeworms)

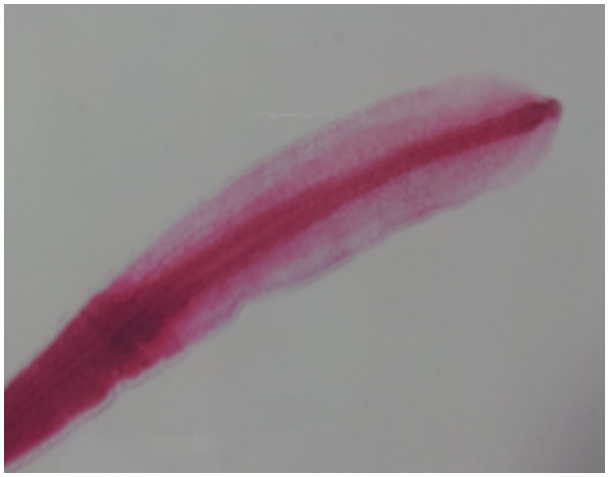
> "In a rich bath of pre-digested soup, warm in the pulsing bowel, safely shut from the bright ambient horror of sun and air, his slender segments ripening loop by loop, broods the voluptuous monarch of the gut, the tapeworm, the prodigious solitaire" – Alec Derwent Hope, *The Kings*[5].

Cestodes are endoparasitic worms with no alimentary canal. The body of a tapeworm is elongate and flattened. The name cestode is derived from 'kestos' (Greek meaning 'a girdle'). The anterior attachment organ or holdfast, is known as the **scolex**, and the 'tape' is known as the **strobila.** The strobila is usually divided into proglottids. This process of proglottid formation gives the tapeworms the appearance of being segmented, but they are not so. Different species of tapeworms differ greatly in size. Some, like *Echinococcus granulosus,* are small worms with relatively few (2-3) proglottids. Others, such as species of *Taenia* are exceptionally long, sometimes spanning many metres, with many thousands of proglottids.

The worms can live for several years. The worms must absorb nutriment through the tegument as they have no internal gastrointestinal tract. Tapeworms are hermaphroditic, normally with both male and female gonads in each proglottid. Male organs often develop before the female.

Taxonomy

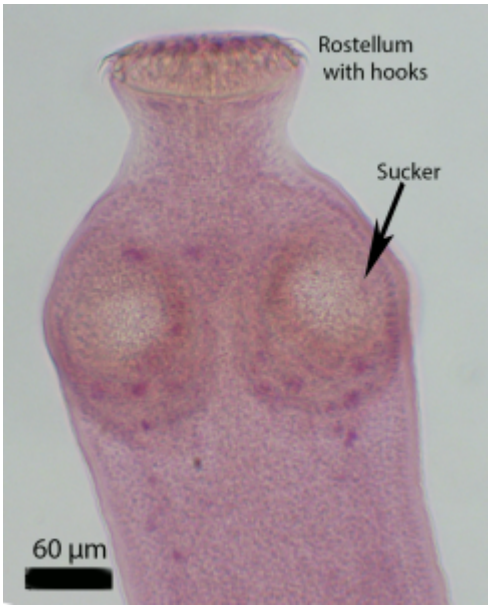
There are many orders of tapeworms. The different orders are distinguished from each other on the basis of the morphology of the **scolex.** The cestodes infecting animals of veterinary importance belong to two orders, which can be distinguished from each other by the structure of the scolex and by the variations in the life cycles.



Scolex of the pseudophyllidean tapeworm Diphyllobothrium latum, showing the slit-like bothria.

Image: Diphyllobothrium latum scolex by 커뷰, shared under a CC BY-SA 3.0, via Wikimedia Commons

Order Pseudophyllidea with slit-like bothria (two long grooves with muscular walls), no hooks. In proglottids (the reproductive units of the tapeworm body), the genital pore opens on the flat surface of the worm. There is only one species of significance to domestic animals in Australia, *Spirometra mansoni.* This tapeworm is found in carnivorous mammals (dogs, cats, foxes).



Scolex of Echinococcus granulosus, from stained whole mount.

Image: © Lyn Knott

Order Cyclophyllidea, with four cup-like or round suckers on the scolex. The apical region of the scolex may bear a region armed with hooks or adhesive glands. This apical organ, the **rostellum**, is also used for attachment. In proglottids (the reproductive units of the body), the genital pore opens at the lateral margins.

Cyclophyllidean cestodes are common parasites of mammals and birds and many species affect domestic animals and humans. Some of the most notorious pathogens of domesticated animals and humans belong to the Order Cyclophyllidea.

Other cestodes

There are many other groups of cestodes, mostly parasitising fishes. Sea mammals are parasitised by a distinct order of cestodes that resemble cyclophyllideans in many ways, but have strictly aquatic life cycles.

Order Cyclophyllidea

This order is the most important group from animal production, disease and public health aspects. The scolex consists of four suckers, and many species have an accessory attachment device at the apex of the scolex. This eversible conical structure, the rostellum, contains hooks and exocrine glands.

The life cycle of cyclophyllideans involves two hosts, a definitive host, in which the adult tapeworm lives, typically in the small intestine, and an intermediate host, in which the developing stages (generically termed

metacestodes) live with the body cavity or solid organs. A feature of cyclophyllidean life cycles is that transmission is always **passive** on the part of the parasite-the parasite must be ingested by a new host for the life cycle to proceed. This contrast with the life cycles of the trematodes, in which larvae actively migrate through the environment and penetrate the host. Thus, in cyclophyllidean cestodes, the larva in the egg does not hatch until the egg is ingested by a suitable intermediate host.

The eggs are usually round in cyclophyllideans or ovate in pseudophyllideans. The egg contains a 6-hooked embryo (**hexacanth** or **oncosphere**), surrounded by a thick radially striated "shell" (**embryophore**) and an outer, delicate membrane. For cyclophyllidean cestodes, the egg envelopes are susceptible to digestion by enzymes present in the intermediate host.

Families of Cyclophyllidean cestodes of primary veterinary concern

Family Taeniidae – Generally large tapeworms (except for members of the genus *Echinococcus*), with 4 prominent cup-shaped suckers and a hooked rostellum on the scolex. The life cycle is unique in that both the definitive hosts and intermediate hosts are mammals.

Family Dilepididae – This is a very diverse group of tapeworms, primarily occurring as parasites of birds. The scolex has 4 suckers and a rostellum. Some mammal parasites are known, with one a very common parasite of dogs in Brisbane. Dilepidids use arthropods as intermediate hosts.

Family Anoplocephalidae – The anoplocephalids are a diverse group of cestodes occurring in birds and mammals. The scolex has four suckers, but a rostellum is absent. The intermediate hosts are always arthropods. Some important anoplocephalids are found as parasites of ruminants and horses.

Family Hymenolepididae – The hymenolepids are parasites of birds and mammals. The species typically have an armed rostellum and 4 cup-shaped suckers in the scolex. Species of hymenolepidids of mammals are commonly found in rodents and small marsupials. Those from rodents have zoonotic potential. The intermediate hosts are species of arthropods. This family will not be covered further here.

Family Taeniidae

Definitive hosts of taeniid cestodes are carnivorous mammals or people. Unlike nearly all other cestodes, the intermediate hosts are **mammals.** This is a **primary distinction** between taeniid life cycles and those of other cyclophyllidean cestodes. In other cyclophyllideans, an invertebrate is used as an intermediate host. The scolex has a non-retractable rostellum armed with hooks (in most species). Their proglottids have only a single genital pore.

The eggs of taeniids are small and the 6-hooked larva is surrounded by an embryophore that is thick and striated. The eggs are embryonated when they pass from the host (they are thus infectious as soon as passed) and may survive over one year in the environment and are tolerant of cooler conditions. The eggs are susceptible to desiccation. The tiny size of the egg allows them to disseminate through the environment so

that one infected definitive host, such as a wild dog, can allegedly contaminate thousands of hectares. There is a report of eggs of *Taenia ovis* being carried from the main islands of the United Kingdom to a remote island. The island has the intermediate host (sheep) but not the definitive host (dogs). It is thought that the eggs are carried by sea birds that pass between the main islands and smaller islands.

Life Cycle

The life cycle of taeniid cestodes always requires a definitive host, in which the adult worm lives in the small intestine, and an intermediate host, in which a developmental stage, termed the **metacestode stage,** lives in some body organ or organ system**.** Transfer between the two hosts is always **passive**, that is, the parasite always 'waits' to be ingested (contrast this with the life cycle of *Fasciola hepatica.* Thus, in taeniid cestodes, an intermediate host is infected after ingesting unhatched eggs from the environment. A definitive host is infected by ingesting live metacestodes from the tissues of an intermediate host.

Taeniid Metacestodes

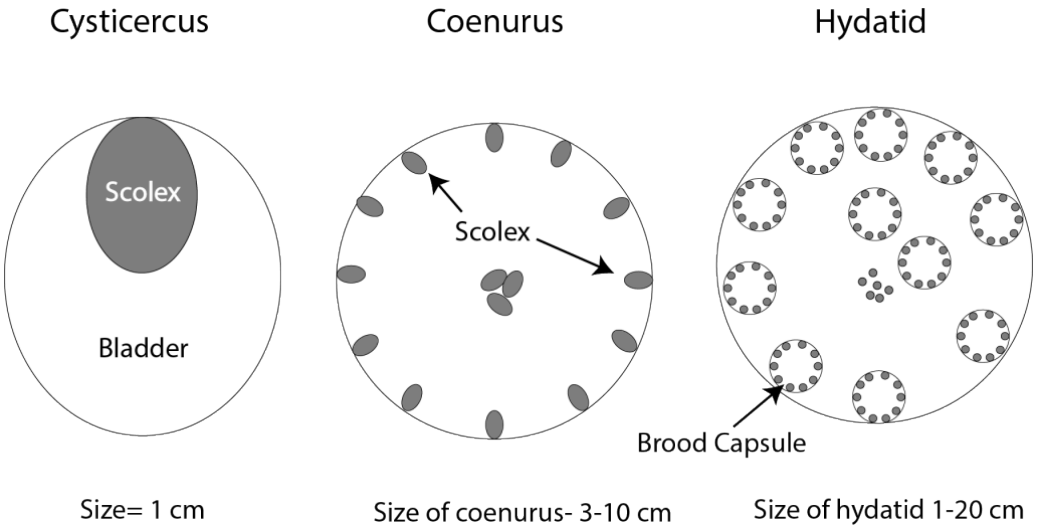
The metacestodes can resemble large bladders. The scolex, the region that will become the adult worm in the intestine of the definitive host, lies ***invaginated*** within the cyst. When the metacestode is consumed by the definitive host, most of the bladder is digested, leaving the scolex, which evaginates and attaches to the small intestine of the definitive host.

Important Aspects of the Taeniid Lifecycle

- The life cycle of taeniids always requires a **mammal intermediate host** and a **mammal definitive host.**
- All other cyclophyllidean cestodes use a non-mammal host as intermediate host and most often use an invertebrate.
- Adult taeniids are found in the **small intestine of mammal hosts.**

Forms of Taeniid Metacestode

Taeniid metacestodes take different forms, depending on the **species of parasite**. Common forms of taeniid metacestodes are shown in the figure below.



Primary forms of metacestodes of taeniid cestodes (stylised drawings). One form of metacestode, the strobilocercus is not shown. The scolex (plural =scoleces), the holdfast of the future adult in its definitive host, sits within a fluid filled cavity in all of these metacestodes. In the hydatid, the brood capsules contain multiple scoleces.

Cysticercus

The simplest form of taeniid metacestode is the **cysticercus** (see stylised figure above). This form can be called a bladder worm, signifying that the scolex of the metacestode is **invaginated** into a larger and soft bladder-like posterior region. Thus, the cysticercus can appear like a small and flaccid cyst. The cysticercus is found in members of the genus *Taenia*.

Each cysticercus contains a single scolex. When a definitive host ingests a cysticercus, it will be infected (potentially) with one scolex that grows to become an adult tapeworm. One species of *Taenia* has a somewhat bizarre cysticercus, which we call a **strobilocercus**. The strobilocercus begins its development as a cysticercus with an invaginated scolex in the bladder. At some point in development, but the scolex evaginates (folds outwards) from the bladder. The scolex then starts to develop a chain of proglottids, so that it looks like a juvenile tapeworm, with the terminal section being the bladder.

Hydatid

A hydatid (see figure above, structure should on the right) is a complex cyst that forms the metacestode of *Echinococcus granulosus*. The hydatid consists of a germinal membrane, a proliferative structure of the hydatid that buds inwards to form small chambers, called brood capsules. The germinal membrane is surrounded by a complex layer, termed the laminated layer, which is made of overlapping extracellular sheets of tissue of parasite origin. The germinal membrane itself surrounds a fluid filled cavity. The fluid of the hydatid is often held at high pressure. When the hydatid ruptures, the fluid explodes out into the

mouth of the canid host. Veterinary professionals should be aware of this pressure – cutting the cyst may cause the contents to squirt out, possibly into the eye of the professional!

The brood capsules, as mentioned above, are small chambers that bud into the fluid cavity. Each brood capsule will generate up to 12 tapeworm protoscoleces (presumptive adult tapeworms). Often the brood capsules will break free from the germinal membrane, and will sink to the bottom of the cyst. The brood capsules may also rupture, liberating individual protoscoleces. This mix of small tapeworm particles is called the **hydatid sand**.

Hydatids may rupture in a host and their contents will be disseminated throughout the abdominal cavity. Small parts of living tapeworm tissues from the original cyst may form new secondary cysts.

A host that eats a hydatid can potentially be infested with thousands of protoscoleces. It is not uncommon to encounter a dog that has been infested with well over 100,000 *Echinococcus* adults.

Coenurus

The coenurus (see figure above) is a form of metacestode that is intermediate (in terms of reproductive potential) between the cysticercus and the hydatid. In the coenurus, the germinal membrane buds inwards to form individual invaginated scoleces. A coenurus will produce 12-24 scoleces.

All forms of these taeniid metacestodes are found in Australia. Refer to the Table of Taeniid cestodes from Australia to assist you to identify which species you may have encountered. Note that the metacestodes of taeniid tapeworms (except for *Echinococcus granulosus)* are strictly host and organ-specific. If you find a metacestode in a host and in a specific location, then you can be almost certain that you have identified the species of tapeworm.

Clinical Significance of Taeniid Cestodes

Adult taeniids in the definitive hosts generally do not induce clinical signs or produce only minor signs.

The metacestodes will generally have little effect on animals, although whether there is a fitness loss remains uncertain. It may be that infected individuals may be more prone to predation or are lost from the population. Animal products infested with metacestodes will be condemned at the abattoir.

When **humans** act as intermediate host for *Echinococcus granulosus* or *Taenia solium*, the infection can result in severe disease. Hydatids of *E. granulosus* usually lodge in the liver or lung, although virtually any tissue can carry the cyst. The cysts may result in tissue-occupying lesions. Anaphylaxis may occur if the hydatid should rupture.

While humans are definitive hosts for *Taenia solium,* it is common for humans to also carry the metacestodes (that is, to act as intermediate host). In humans, the metacestodes of *T. solium* may develop in the brain. *Taenia solium* is not endemic to Australia, although it is present in neighbouring countries.

Important Taeniid Species

Echinococcus granulosus

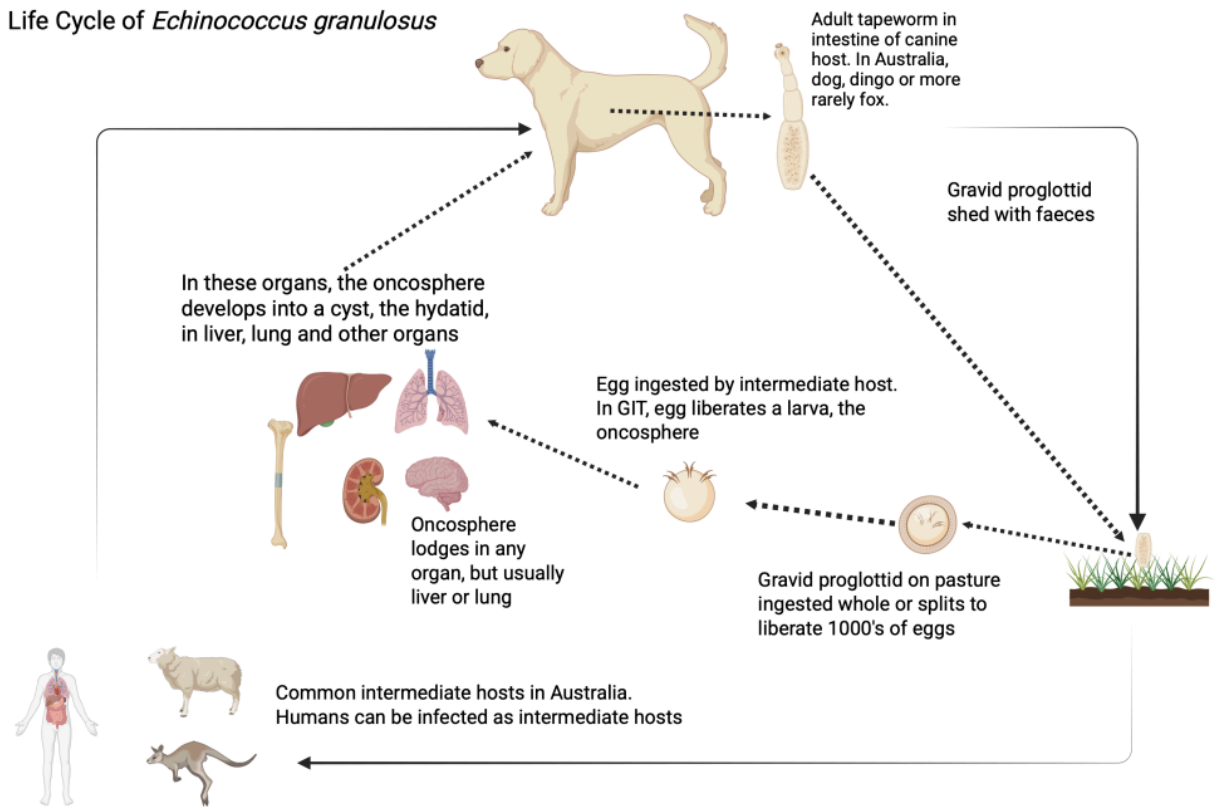
This is the most important tapeworm in Australia, as it is an important zoonotic species. The life cycle always involves dogs or dingoes (and to a lesser extent foxes). A wide range of mammal species can be intermediate hosts. Humans can act as intermediate hosts, becoming infected by ingesting a tapeworm egg.

Unlike the other taeniids, adult hydatid tapeworms are only a few mm long and have no more than four proglottids at one time. When a canid is freshly necropsied, the worms are not observed, as they are nestled between the villi of the duodenum. After about 15 minutes, the worms expand and can be seen to swell beyond the villi. The prepatent period is approximately 6 weeks.

Two major cycles exist in mainland Australia. There is a **domestic** involving dog and sheep, although this is often well-controlled. There is also a **sylvatic** cycle, in which the parasite cycles between wild dogs (dingo or feral dogs) and macropod marsupials. This sylvatic cycle complicates control as wild dogs can encroach on farmland and into periurban regions.

Many mammal species in Australia can act as intermediate hosts. Sheep, macropods and other species can be infected with hydatids. In Australia, cattle and pigs can also carry hydatids, usually in their livers, but the cysts are not fertile (that is, the cysts do not produce protoscoleces) and do not contribute to the life cycle. Cattle and pigs are more properly termed "**sentinel hosts**"- the presence of infertile cysts in these hosts indicate that the life cycle is active in the area the animals inhabit.

Life Cycle of *Echinococcus granulosus*



Life cycle of Echinococcus granulosus in Australia. Solid arrows depict the host used in the life cycle. The dashed arrows shows development of the parasite in the hosts.

Image: Created in BioRender. Jones, M. (2026) https://BioRender.com/7a6lu4m

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Taenia species

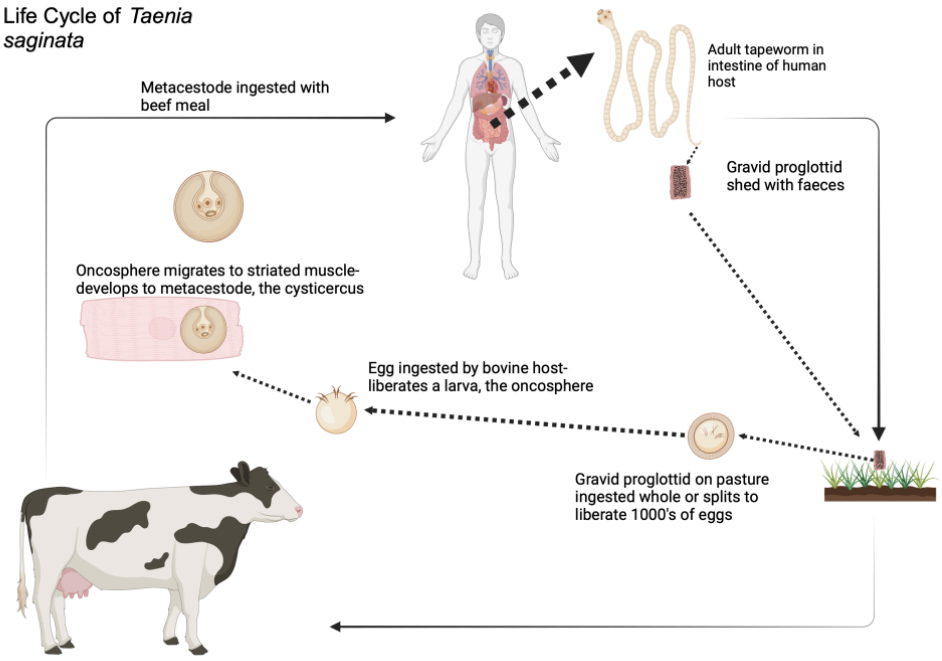
The genus *Taenia* is widespread and abundant. The adult worms are large, are parasites of carnivores or omnivores, and typically have squared or rectangular proglottids. Important species **in Australia** include:

Taenia ovis – agent of sheep "measles". The metacestode (historically called *Cysticercus ovis*) forms cysticerci in the striated muscle of sheep. The cysticerci can be abundant, and when observed in abattoirs, will lead to condemnation of the meat. The adult tapeworm is carried by dogs and can be controlled through treatment of the dogs and ensuring that domestic dogs do not eat sheep flesh. Wild dogs will carry this worm.

Taenia taeniaformis – This species is transmitted between cats or foxes as definitive hosts and rodents as intermediate hosts. The metacestode is a strobilocercus in the liver of the intermediate host.

Important members of the genus **internationally** include:

Taenia saginata – Known as the beef tapeworm, this species is transmitted between humans as definitive host and bovids as intermediate host. Cysticerci are found in the muscle of the bovine hosts. The species is rarely encountered in Australia, and may enter with tourists and immigrants. Similarly cattle exposed to human waste may become infected, but this is usually rare.



Life cycle of *Taenia saginata*.

Image: Created in BioRender. Jones, M. (2026) https://BioRender.com/g5pfd4t

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Taenia solium – This is an important species and highly pathogenic species to humans. The species does not occur in Australia. This species is known as the pork tapeworm. Adult tapeworms are parasites of humans and cysticerci are found in striated muscle of pigs. Humans become infected by eating uncooked pork. *Taenia solium* has a strange aspect to its life cycle in that humans are also able to act as intermediate host! A human that ingests eggs is can have cysticerci develop in their tissues. Often in humans, the cysticerci will develop in the central nervous system. Neurological disorders, including epilepsy, ongoing

headaches, partial blindness and other phenomena, can be associated with infection with the intermediate stage infections in humans.

Family Dilepididae

Dipylidium caninum

There is one species of this family of veterinary relevance, Dipylidium caninum. This tapeworm is a parasite of dogs, cats, foxes and humans. The tapeworm is known commonly as the **flea tapeworm**. Often this species is called the "cucumber" worm, because of the shape of the proglottids that pass with the faeces. The middle of the proglottid is wider than the anterior and posterior ends, thus giving the appearance of a cucumber seed.

The worm is largely harmless in the definitive host, but its gravid proglottids have the ability to move as they are passed from the hosts. Clients may be concerned with small, white or yellowish pulsating objects on the surface of their pet's faeces, or on the perianal region of the animals. They may identify the objects as maggots. Careful observation of the objects will reveal that they are indeed proglottids. One way of confirming the identity is to rupture the proglottid and examine the contents with a compound microscope. The presents of characteristic egg capsules will confirm the identity of the species.

The intermediate host is a flea, commonly *Ctenocephalides felis.* It is thought that chewing lice on dogs may also become infested. Flea larvae are infested when they eat the eggs that end up in animal bedding. The infested larval flea will metamorphose, eventually becoming an adult and will attach to and feed on the host. While grooming themselves, the host may accidentally swallow an infested flea, thereby leading in infection in that mammal host.

Clinical significance of *Dipylidium caninum* infection

Usually there is no harm caused to the mammal host. Owners, however, don't like seeing the proglottids on their pet's faeces or anus. Infected dogs may scoot, although this is more likely to be due to impacted anal glands.

Family Anoplocephalidae

These cestodes have a scolex lacking a rostellum or apical hooks, although they have four cup-shaped suckers forming the scolex. The proglottids are markedly wider than long. Anoplocephalids are commonly seen in ruminants and horses. The intermediate hosts of the anoplocephalids are typically soil- or pasture-dwelling arthropods (e.g. pasture mites).

The tapeworms of ruminants belong to the genera *Moniezia* and *Thysaniezia*. These are long parasites with many proglottids. Horses are infected with members of the genus *Anoplocephala,* which are typically short stout cestodes. Anoplocephalids are very common parasites of marsupials and birds.

Clinical significance of anoplocephalid infestation

Usually the tapeworms have no impact on their hosts. *Moniezia* is common in young ruminants but the species has no impact on production. ***Anoplocephala perfoliata*** adults form clusters at the ileo-caecal junction in horses and are implicated in the causation of **colic** and other gastro-intestinal disturbances.

Order Pseudophyllidea

Pseudophyllideans are cestodes, with a partially aquatic life cycle. Most definitive hosts of pseudophyllideans are fish, but a few species infest mammals and birds. Tapeworms in this group have a scolex bearing two longitudinal grooves (bothria) rather than suckers (see figure at the beginning of the section on cestodes).

The shell of the egg is thick, brown and unlike the cestodes described above, is operculate (that is it has a 'trapdoor' at one pole of the egg through which the larva, a ciliated **coracidium**, hatches from the egg). Unlike other tapeworms we consider, the larvae of pseudophyllideans have a brief free-living phase, which ends when the coracidium is eaten by the first intermediate host (or the larva dies). Two intermediate hosts are required in the life cycle of *Spirometra mansoni*.

Spirometra

Tapeworms of the genus *Spirometra a*re common in cats, foxes and dogs in Australia, predominantly in coastal regions.

The identity of the Australian species of *Spirometra* has, until recently, been uncertain. Extensive surveys demonstrated that the species in Australia is *Spirometra mansoni*[6].



Proglottids of Spirometra mansoni from southeast Queensland. The parasite was expelled from a dog. Note the longitudinal band in the mid-line of the worm. This band is made up of the uteri and uterine pore of each proglottid. Each uterus carries 100's to 1000's of eggs.

Spirometra has a simple scolex, with two slit like suckers. The tapeworm differs from other species in that its genital pores are mid-ventral. The uterus becomes filled with yellow-brown eggs and forms an elongate band that runs along the midline dorsally to the pores. The net effect of this is that the worms have an appearance of a zipper, which can give rise to the common name 'zipper-worm'. The operculate fluke-like eggs are passed unembryonated in faeces.

Life cycle of *Spirometra*

Adult parasites are commonly seen in the intestines of cats, dogs and foxes. Eggs will pass in faeces. The larva, a coracidium, does not hatch from the egg until the egg reaches freshwater. The coracidium is a round, ciliated, organism that actively moves in freshwater. The larva is eaten by copepods. After being eaten the larva burrows into the body cavity of the copepod and grows to become a larva, termed a procercoid.

To continue the life cycle, the infected copepod must be eaten by a second intermediate host, which usually is an amphibian, a tadpole. Within the body cavity of the tadpole, the procercoid develops into the next stage, a plerocercoid. This stage carries the scolex of the adult worm, but does not have an proglottids. The plerocercoid remains in the body cavity as the tadpole metamorphoses into a frog. A definite host will become infested after eating an infested frog or any number of paratenic hosts (see below).

A feature of the life cycle is the occurrence of paratenic hosts (carrier hosts). These are hosts, such as snakes, small mammals, pigs and sometimes humans, that may ingest the amphibian host. The plerocercoid does not develop in the paratenic host, but will be found in the body cavity, often just beneath the skin. The plerocercoid in these hosts are also known as 'spargana'.

Clinical significance

Usually none; many vets believe heavy infections can produce ill-thrift or enteritis, especially in cats.

People can act as intermediate hosts (ingestion of copepod when drinking water from streams, etc) or paratenic hosts (ingestion of inadequately cooked meat containing plerocercoids or spargana, e.g. feral pig). Spargana remain alive in people and may produce pruritic sub-cutaneous nodules.

Identification

- Identification of cestode eggs
- Identification of cestodes of veterinary significance

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14.

PHYLUM NEMATODA

The Roundworms

> "Consider the nematode roundworm, the most abundant of all animals. Four out of five animals on Earth are nematode worms – if all solid materials except nematode worms were to be eliminated, you could still see the ghostly outline of most of it in nematode worms."
>
> — E. O Wilson (as cited in Barr[1])

Contents

- General morphology of nematodes

Bursate Nematodes (Order Strongylida)

- Superfamily Ancylostomatoidea (Hookworms)
- Superfamily Strongyloidea (Strongyles)
- Superfamily Trichostrongyloidea
- Superfamily Metastrongyloidea

Non-Bursate Nematodes

- Superfamily Rhabditoidea
- Superfamily Ascaridoidea
- Superfamily Oxyuroidea
- Superfamily Habronematoidea
- Superfamily Filarioidea
- Superfamily Trichinelloidea

General Morphology of Nematodes

The nematodes include the vast majority of worm species of importance in animal production. Mostly they are elongate and cylindrical but with tapering at either end; a long tube under hydrostatic pressure. A mouth is found at the anterior end; it may be surrounded by lips or have associated with it other secondary structures (teeth, plates, buccal capsule). Following the mouth is a muscular pharynx or oesophagus. The structures of the mouth and the shape of the pharynx are important in the identification of worms. The gut continues as the intestine before opening into the cloaca at the anus. The part of the body beyond this is the tail.

The sexes are separate. Males are generally smaller than females and have one or two testes opening into the cloaca with the anus. Many have a pair of pigmented, hard copulatory structures called *spicules* near the tail which are inserted into the female during copulation. Sometimes the spicules are guided by another thickened muscular part, the *gubernaculum*. In females, the two uteri converge and open at the vulva – generally toward the middle of the body, well away from the anus.

The cuticle is very tough and may be modified to form a variety of expansions such as papillae, alae ("wings") and bursae. The *bursa* is a caudal extension of the cuticle which functions in copulation – it is only found in male strongylids.

Simplified classification of parasitic nematodes of veterinary importance

SUPERFAMILY	TYPICAL FEATURES
BURSATE NEMATODES	
Trichostrongyloidea *Trichostrongylus, Ostertagia, Haemonchus, Dictyocaulus* etc	Buccal capsule small, bursa well developed Life cycle direct, infection by ingestion of L3
Strongyloidea *Strongylus, Cyathostomum, Oesophagostomum Syngamus*, etc	Buccal capsule well developed Leaf crowns usually present Life cycle direct, infection by ingestion of L3
Ancylostomatoidea *Ancylostoma, Uncinaria, Bunostomum*, etc	Buccal capsule well developed; anterior end bent dorsally ("hookworm") No leaf crowns but cutting plates or teeth on ventral margin of mouth Life cycle direct, infection by per-cutaneous penetration or ingestion of L3
Metastrongyloidea *Aelurostrongylus, Muellerius, Angiostrongylus*, etc	Buccal capsule small Life cycle indirect; infection by ingestion of intermediate host containing L3
NON-BURSATE NEMATODES	
Rhabditoidea *Strongyloides, Rhabditis* etc	Very small worms, buccal capsule small. Free-living and parasitic generations Life cycle direct; infection by L3 (ingestion or per-cutaneous penetration)
Ascaridoidea *Ascaris, Toxocara, Parascaris* etc	Large white worms 3 prominent lips at anterior end Life cycle direct; ingestion of egg containing L3
Oxyuroidea *Oxyuris, Passalurus* etc	Female has long, pointed tail, anterior end is blunt Life cycle direct; ingestion of egg containing L3
Trichuroidea *Trichuris, Capillaria, Trichinella etc*	Whip-like or hair-like worms Life cycle direct or indirect; infection by L1
Filarioidea *Dirofilaria, Onchocerca* etc	Long thin worms living in circulatory system or connective tissues Life cycle indirect; infection by L3 from insect (dipteran)
Habronematoidea (or Spiruroidea) *Habronema, Draschia* etc	Spiral tail in male Life cycle indirect; infection by L3 from insect

There are ten Superfamilies that contain important nematode parasites of domestic animals. Visit the Nematode superfamily summary table for some general, descriptive information on each of these superfamilies (including morphological features, size, location within host).

Life cycle feature: Inhibited development (hypobiosis) of nematodes

Inhibited development (hypobiosis) is a common phenomenon in a wide range of nematodes. It is a temporary cessation in development of worms at a precise point in their development (often the early third larval stage to early fourth larval stage, depending on species) within the host tissues. There are many terms used to describe this inhibited development. These terms include hypobiosis, larval inhibition, inhibited larval development and arrested larval development. All these terms are synonymous.

Factors governing whether an ingested worm will undergo hypobiosis, and when it will continue development, are incompletely understood but include:

- **Environmental factors.** If the L3 is exposed to adverse environmental conditions before ingestion, the worm is more likely to undergo hypobiosis (e.g. many L3s ingested in late autumn in Canada are likely to undergo hypobiosis whereas relatively few ingested off of the pasture in a Queensland autumn would).
- **Nematode population density**. For example, the presence of adult worms in gut lumen may inhibit development of ingested larvae.
- Host immunity.

The significance of hypobiosis includes:

- allows worm to survive adverse environmental conditions (e.g. harsh winter, drought)
- complicates control programs
- not all anthelmintics are effective against hypobiotic larvae
- mass emergence of hypobiotic larvae may produce clinical disease.

Bursate Nematodes (Order Strongylida)

General Features of Order Strongylida

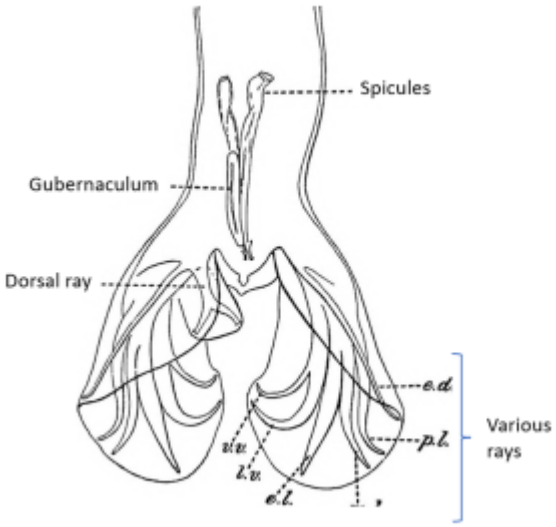
Strongylid nematodes are the most important group of nematodes in domestic animals. Strongylid nematodes can be characterised by the fact that male worms possess a **bursa** for use during copulation (strongylid nematode = bursate nematode).

Features of the group include:

- some degree of sexual dimorphism; males and females look different (males generally smaller and have a bursa)
- males have a bursa with rays. The bursa is used to grasp female worms during copulation (bursa may

be reduced in some strongylids, especially metastrongyloids)

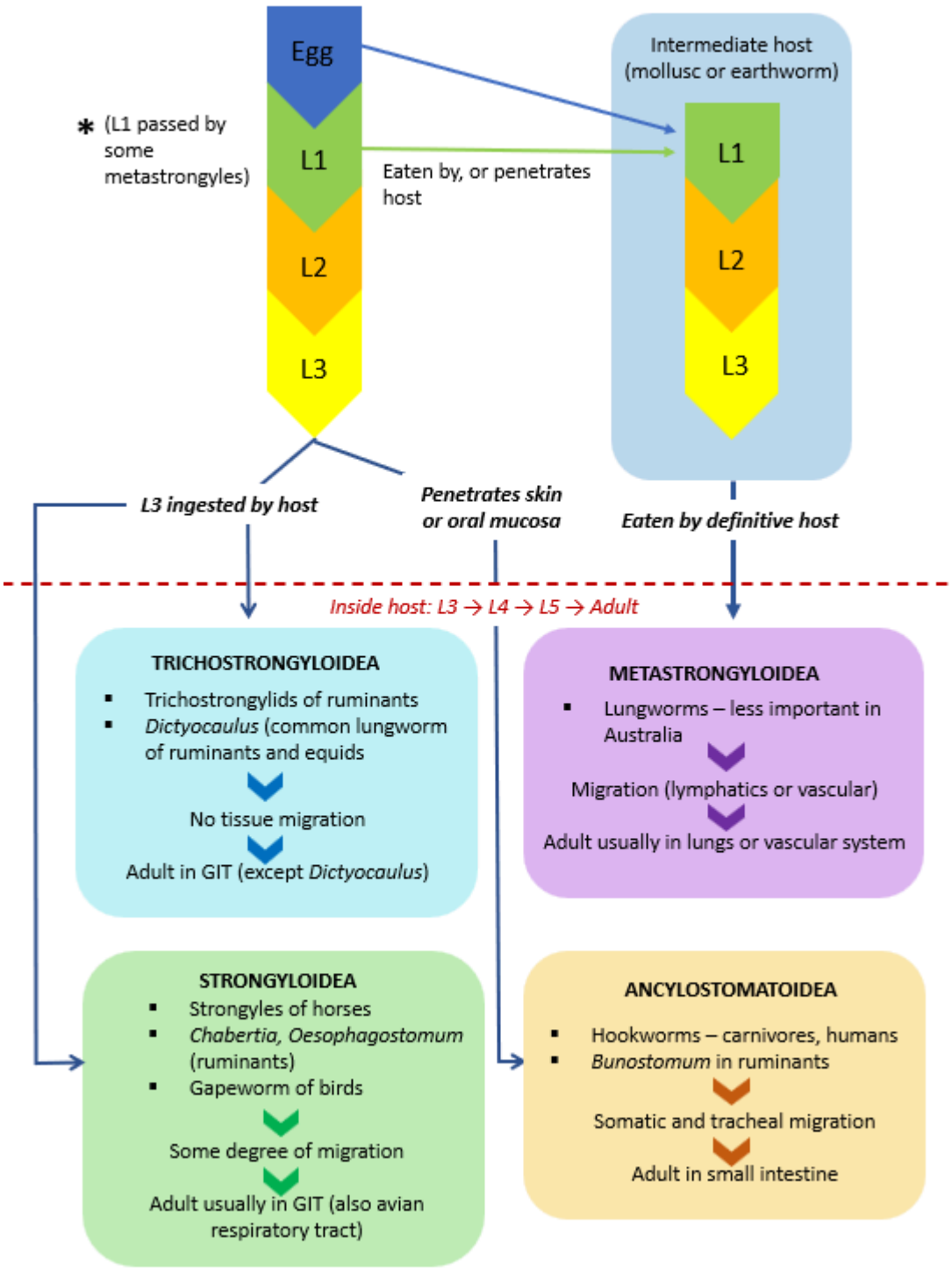
- females have a muscular ovijector at end of uteri
- all strongylid nematodes produce an unembryonated, non-operculated, thin-shelled, ovoid egg at the morula stage of development (i.e. cluster of undifferentiated cells)
- all strongylid eggs look much the same and most species cannot be easily distinguished. In most cases, faeces need to be cultured until the eggs have hatched and developed through to the L3 phase (these can often be identified to genus level)
- in most cases, the strongylid egg is passed out in the faeces but in lungworms, it has often hatched by the time it reaches the anus and an L1 is passed
- L1 and L2 have a rhabditiform pharynx and feed on bacteria (within faeces)
- when the L2 moults into the L3 phase, the L2 cuticle is retained and the pharynx assumes a filariform morphology which is more typical of parasitic worms
- **L3 is the infective stage** and is **ensheathed** (within the cuticle retained from the L2 phase) and does not feed.



Male bursa. Abbreviations: e.d. (externodorsal ray), p.l. (posterolateral ray), m.l. (mediolateral ray), a.l. (anterolateral ray), l.v. (lateroventral ray), v.v. (ventroventral ray).[2]

Note. From Underhill, B. M. (1920). *Parasites and Parasitosis of the Domestic Animals, the Zoölogy and Control of the Animal Parasites and the Pathogenesis and Treatment of Parasitic Disease* (p. 300). New York, The Macmillan company. Public Domain.

Strongylid Life Cycles



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Order Strongylida can be subdivided into 4 Superfamilies:

- Ancylostomatoidea – hookworms
- Strongyloidea – strongyles
- Trichostrongyloidea
- Metastrongyloidea

The table below summarises the main features of each of the four superfamilies within the Order Strongylida.

SUPER-FAMILY	MAIN FEATURES
Ancylostomatoidea (hookworms)	Buccal capsule well developed Buccal capsule bent dorsally Teeth or cutting plates at mouth opening Adults in small intestine
Strongyloidea	Buccal capsule well developed Buccal capsule not bent, or bent ventrally Leaf crowns usually present Adults of most occur in large intestine and/or caecum
Trichostrongyloidea	Buccal capsule vestigial Bursa well developed Leaf crowns usually absent (may be extremely reduced) Adults in upper GIT (abomasum/stomach or small intestine)
Metastrongyloidea	Buccal capsule vestigial Bursa vestigial Adults in lungs/pulmonary vasculature

Superfamily Ancylostomatoidea (Hookworms)

The Superfamily Ancylostomatoidea, commonly known as hookworms, comprises parasitic nematodes that are important in dogs, cats, ruminants and people. Adult hookworms are blood-suckers, residing in the small intestine.

Important Hookworms in Australia

The following are important in Australia, but the ruminant parasite is uncommonly encountered.

Animal	Hookworm
	Ancylostoma braziliense
	Uncinaria stenocephala
Cats	*Ancylostoma tubaeforme*
	Ancylostoma braziliense
	Ancylostoma ceylanicum
	Uncinaria stenocephala
Ruminants	*Bunostomum* spp. (uncommon)

Life cycles

L3s penetrate the buccal mucosa (ingestion) or skin (percutaneous penetration) and enter blood vessels or lymphatics -> heart -> lungs -> tracheal migration.

Tracheal migration

In the lungs, larvae break out of the blood vessels and into the alveoli. They pass up the trachea (assisted by cilia, coughing etc) and are then swallowed and enter the intestine where they complete their development to adulthood.

Routes of infection

Routes used by **all** species listed above.

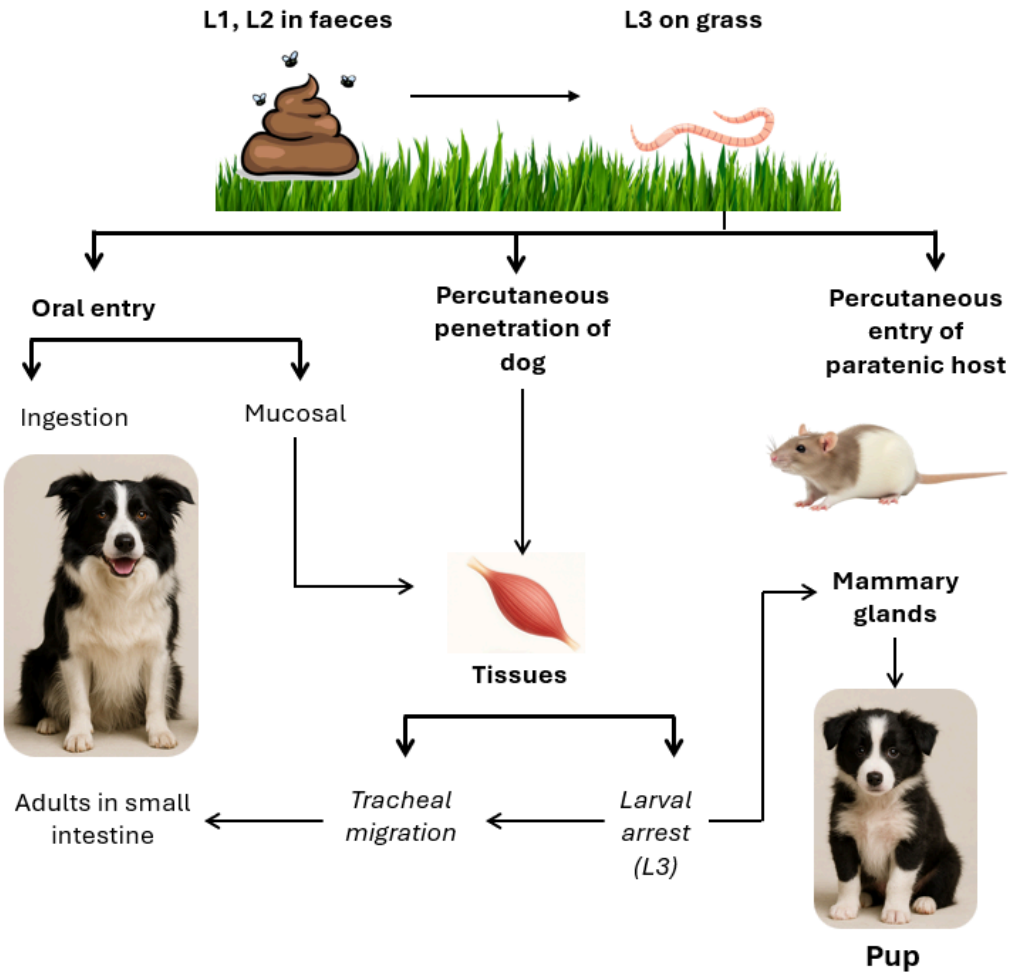
- **Per-cutaneous penetration by L3** (*Uncinaria* attempts this, but rarely successful, the other species are efficient at this route).
- **Ingestion of L3** and/or penetration by L3 of oral mucosa (whether direct development in the intestine occurs, or the parasite undergoes tracheal migration first, varies with the parasite).

Routes used by all species infecting carnivores;

- **Paratenic hosts** (L3 invades paratenic host, e.g rodents, and remains viable in tissues of this host)

Routes used by A. caninum only;

- **Transmammary** passage of larvae to puppies (larvae re-activated from somatic reservoirs late in pregnancy/early lactation)
- **Transplacental** passage of larvae (relatively unimportant)



Hookworm life cycle.

Images: Adult pup and dog – AI generated in MS Copilot; Faeces © nikiteev – stock.adobe.com; Tissues © Mostafizur – stock.adobe.com; Mouse © Agata – stock.adobe.com; Earthworm © Anna Syvak – stock.adobe.com; Grass © arturaliev – stock.adobe.com

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Uncinaria stenocephala

- Eggs are cold resistant; this is the most common hookworm of dogs and cats in temperate regions (e.g. Victoria)

Clinical signs of hookworm disease

- Anaemia
- Diarrhoea (especially carnivores) and/or ill thrift (carnivores AND ruminants)
- Different species vary in pathogenicity; *A. caninum* > *A. braziliense* >> *U. stenocephala*
- "Creeping eruption" of skin:

- in dogs, especially when *U. stenocephala* attempting percutaneous infection
- in people, **cutaneous *larva migrans***, especially from *A. braziliense* infections (but probably most can do this)
- in humans, eosinophilic enteritis can occur following infection by *A. caninum.*

Morphology and Identification

Visit Superfamily Ancylostomatoidea (Hookworms) to find information on the identification of hookworms.

Host	Species	Anterior Features
Dog	*Ancylostoma caninum*	2 x 3 teeth at mouth opening
Dog/Cat	*Ancylostoma braziliense*	2 x 2 teeth at mouth opening
Cat	*Ancylostoma tubaeforme*	2 x 3 teeth at mouth opening
Dog/Cat	*Uncinaria stenocephala*	2 x cutting plates at mouth opening
Ruminant	*Bunostomum spp.*	Well-developed dorsal cone 2 x small triangular lancets near oesophageal opening Cutting plates (hard to see)

Eggs in faeces: typical strongylid eggs will be present in faeces of infected hosts, but cannot be differentiated to species level.

Adult worms removed from the intestines can be viewed under the microscope to differentiate between possible species. The primary feature of interest is the presence and number of teeth within the buccal capsule. Males will have a copulatory bursa.

Superfamily Strongyloidea – (Strongyles)

General features of strongyles

- Adults are found in the large intestine and caecum.
- Some suck blood, others feed directly on the mucosa of the gut.
- Morphology in domestic animals includes a well-developed buccal capsule and leaf crowns around the mouth.
- Infection is **always via ingestion of L3.**
- Each species undergoes some degree of migration away from gut lumen, though in some this may simply be into the gut wall (i.e. **histotropic phase**).

Important strongyloid nematodes in Australian domestic

mammals

Animal	Strongyloid nematodes
Horses	Large strongyles: *Strongylus vulgaris, Strongylus equinus, Strongylus edentatus* and *Triodontophorus* spp. Small strongyles (cyathostomins): 50+ species, including representatives from the genera *Cyathostomum, Cylicostephanus, Cylicocyclus*
Ruminants	*Oesophagostomum* spp. and *Chabertia* spp.
Swine	*Oesophagostomum* spp., mostly *O. dentatum*

Strongyloids in Horses

Horses are host to a wide range of strongyloid nematodes that are broadly grouped as 'large' or 'small'.

Large strongyles, commonly referred to as 'blood worms', measure 2 – 4.5 cm (females) and are found in the caecum and colon. They are blood-sucking nematodes and so appear red in colour. The buccal capsule of the three important species (*Strongylus vulgaris*, *Strongylus edentatus* and *Strongylus equinus*) is distinctive and aids in identification. The prevalence of large strongyles in well-managed horses has dramatically decreased over the last few decades in response to frequent anthelmintic treatment regimens. However in areas with inadequate parasite control, *S. vulgaris* remains a serious concern.

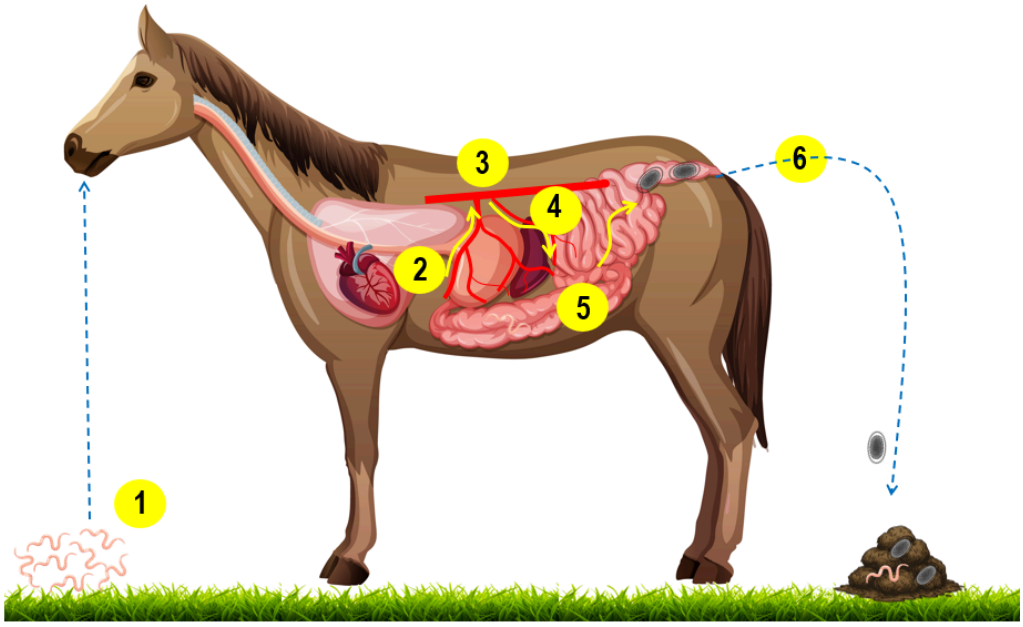
The small strongyles (cyathostomins) are also found in the caecum and colon, but are smaller in size (0.5 – 1.5 cm). They are more slender in appearance compared to the large strongyles and require closer inspection for identification. Cyathostomins are the most common gastrointestinal nematodes in horses, and there are approximately 50 species known to infect horses worldwide. While these species share similar life cycles and general morphology, they can vary in specific characteristics, such as their buccal capsule structure, which is often used for species identification. Mixed infections with multiple cyathostomin species are common in horses, making precise identification challenging.

Life Cycles and Clinical Effects

Strongylus vulgaris

S. vulgaris is the most pathogenic of the equine strongyles. The diagram below shows that after ingestion (1), L3s penetrate the intestinal wall and moult to L4 in the submucosa. These L4 larvae migrate along the surface of small intestinal arterioles (2), gradually moving toward the cranial mesenteric artery, a journey that takes around 14 days. During this time, they incite significant arteritis, thrombosis, and embolism as they penetrate the vessel wall (3). Once established at the arterial root, the L4 continue to develop, remaining *in situ* for up to four months, leading to intimal thickening and sometimes aneurysm formation. They then moult into immature adults (L5) and are carried back via the blood (4) back to the caecum and large intestine where they form cysts on the serosal surface of the gut (5). Cysts erode through the intestinal

wall, and worms are released into the lumen where they mature in approximately 6 weeks and subsequently commence egg shedding (6). The pre-patent period is approximately 6 months.



S. vulgaris life cycle.

Images: Internal anatomy of a horse © blueringmedia – stock.adobe.com; Manure and Strongyle egg – AI-generated using MS Copilot; Worms © Anna Syvak – stock.adobe.com; Grass © chiew – stock.adobe.com

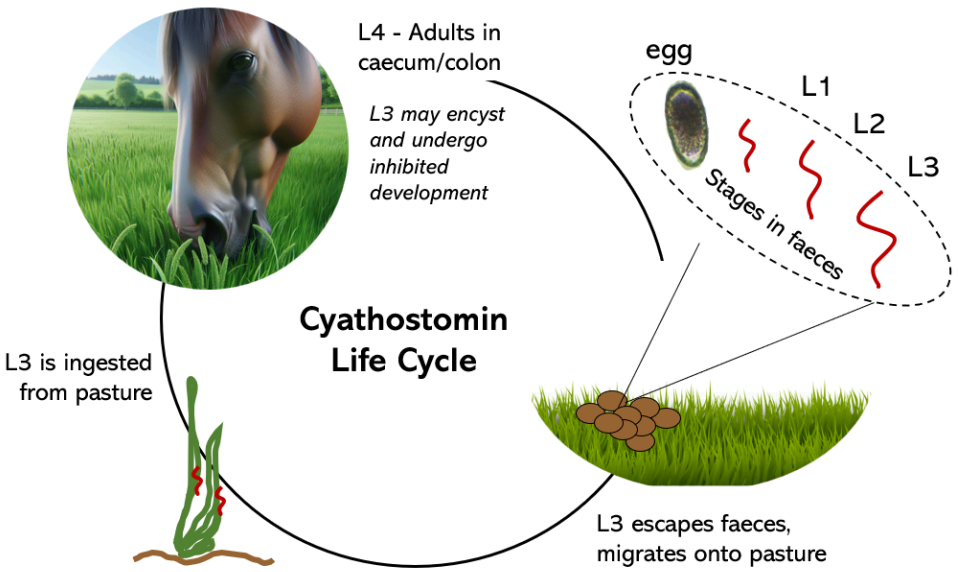
Strongylus edentatus and *Strongylus equinus* also undergo extensive abdominal migration, via the liver, but not via the vascular system and are hence less pathogenic. These species have longer pre-patent periods of 9 months (*S. equinus*) and 11 months (*S. edentatus*).

In all three *Strongylus* species, aberrant migration of larvae (e.g. to the CNS) may occur.

Cyathostomins

The life cycle of cyathostomins does not involve migration outside of the gastrointestinal tract. After ingestion, third-stage larvae (L3s) invade the mucosa of the large intestine (i.e. histotropic phase) and may then continue development or enter a stage of inhibited development, encysting as early L3s. Early L3s may remain encysted for 1-2 months, or much longer (> 2 years), before resuming development. Fourth-stage larvae (L4s) emerge from cysts and enter the lumen of the large intestine or caecum.

This emergence is associated with the destruction of mucosal cells and an inflammatory reaction. If there is *mass* emergence of larvae, dysfunction of a significant section of the colon may occur leading to **larval cyathostomosis** (weight loss +/- diarrhoea, not responsive to therapy). The pre-patent period for cyathostomins varies from 5.5 weeks to more than two years in the case of extended period of inhibited development. While larvae are encysted in the bowel wall, they are not reliably destroyed by most anthelmintics, including macrocyclic lactones, which complicates control. Further, cyathostomins are now highly resistant to the benzimidazole class of anthelmintics, and resistance is becoming more common to the macrocyclic lactone anthelmintics.



Cyathostomin life cycle

Images: Horse eating grass – AI generated with MS Copilot; Grass by Almeidah on Openclipart under CC0; Pasture and egg by Anne Beasley

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Triodontophorus spp.

Triodontophorus spp. are classified as large strongyles because of their size (2 – 2.5 cm) and feeding habits, however they do not undergo extensive migration through the body. They are not considered as pathogenic as some other large strongyles like *S. vulgaris*, but they are blood suckers and adults are frequently found in association with ulcerated mucosa.

Morphology and identification

Superfamily Strongyloidea (Strongyles) has information on the identification of Strongyloid worms of horses.

Strongyloids in ruminants and swine

There are two genera of strongyloid nematodes that are important for ruminants and/or swine. *Chabertia ovina* (the large-mouthed bowel worm) infects ruminant hosts, and species of the genus *Oesophagostomum* (nodule worms) infect both ruminants and swine.

Oesophagostomum spp. or Nodule Worms

Life Cycles and Clinical Effects

Adults are 1 – 2 cm long and reside in the large intestine and caecum.



Nodules in small intestine of sheep caused by Oesophagostomum colombianum.

Photo: © Dr Constantin Constantinoiu. Used with permission.

The life cycle is direct – L3 are ingested with the pasture and travel to the distal small intestine or proximal large intestine where they penetrate the gut wall and undergo a histotrophic phase. During this phase, the larvae moult to the L4 stage and the body mounts an inflammatory response leading to the formation of nodules (with the exception of *O. venulosum*), sometimes referred to as 'pimply gut'. The L4s can survive for extended periods of time within these nodules. After emergence from nodules, L4s migrate to the colon where they develop into adults which *do not suck blood.* Caseation and calcification of the nodules may occur, and this may interfere with normal gut motility if lesions are extensive.

Clinical signs in ruminants include weight loss, diarrhoea and decreased productivity. In pigs, infection often produces decreased growth rates rather than clinical disease.

Chabertia ovina

Life Cycle and Clinical Effects

C. ovina is common in sheep and goats, though usually in low numbers, and occasionally infects cattle.



Chabertia ovina.

Photo: © Lyn Knott

Adults reside in the colon, and have a huge buccal capsule which is bent ventrally and lacks teeth. They ingest large plugs of mucosa resulting in focal haemorrhage.

Infective larvae are ingested during grazing and subsequently shed their sheath. The L3 undergo a histotropic phase within the small intestinal wall, moulting to L4. It may take up to four weeks for the larvae to develop into mature adults in the colon. Eggs appear in the faeces approximately 49 days after infection.

C. ovina is non-pathogenic to cattle and clinical disease is seldom seen.

Morphology and identification

The strongyloids in ruminants and swine have a short cylindrical or annular buccal capsule, leaf crowns and a short dorsal gutter.

Superfamily Trichostrongyloidea

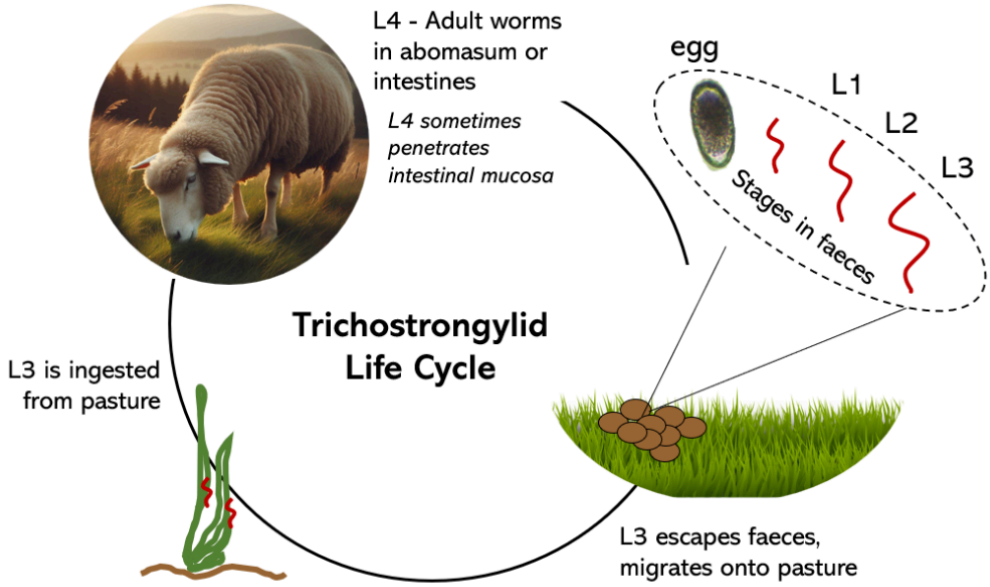
General Features of Trichostrongyloids

- **Anthelmintic resistance** is a major issue in the trichostrongyloids infecting small ruminants (sheep and especially goats); populations resistant to each anthelmintic group are common, as are multi-drug resistant populations (resistant to several anthelmintic groups and combinations). Resistance is also beginning to emerge in bovine trichostrongyloids.
- **Inhibited development (hypobiosis)** is a feature of many members of this superfamily
- Adults are small and slender ("hairworms") found in the abomasum (or stomach) or small intestine, especially of **ruminants**

Life Cycle

The typical trichostrongylid life cycle has two distinct stages – free-living stages in the environment and parasitic stages in the host. Adult female nematode eggs are shed into the environment in faeces. Under the right conditions, eggs hatch and first stage larvae (L1) emerge. Feeding on bacteria in the faeces, L1 moult twice to reach the infective L3 stage. Infective larvae migrate out onto the pasture where they are ingested by grazing hosts. Once inside the host, the L3 moult to L4 stage and can either penetrate the intestinal/abomasal mucosa or continue to mature to adult stage. Males and females reproduce sexually in the intestines and the life cycle continues. The minimum pre-patent period for most (with the exception

of *Dictyocaulus*) is ~ 21 days due to rapid pasture contamination. However, it can be as short as 18 days for *Haemonchus contortus*.



Trichostrongylid life cycle

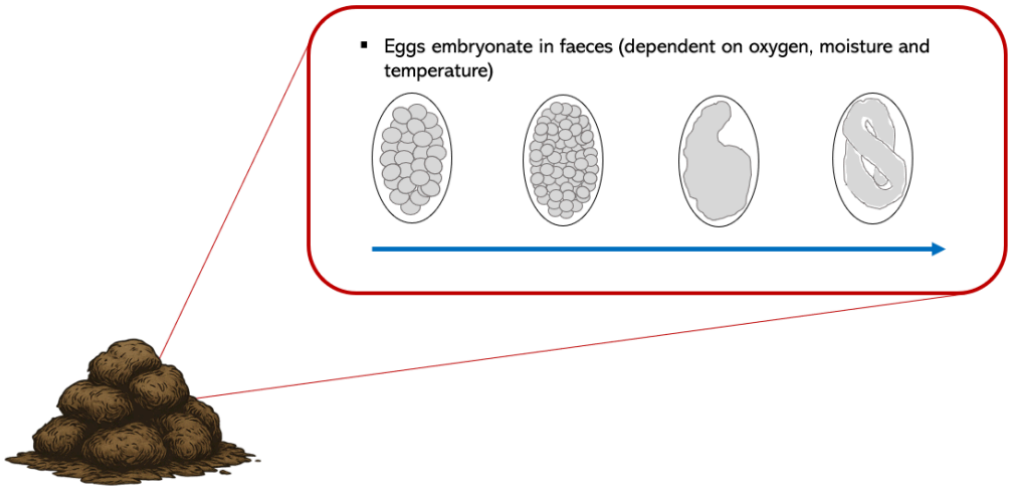
Images: Sheep – AI-generated with MS Copilot; Pasture and egg by Anne Beasley; Grass by Almeidah on Openclipart under CC0.

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Variations to this life cycle are outlined for specific species below.

Epidemiology of Trichostrongyloid Free-living Stages

The development and survival of the free-living stages of trichostrongylid parasites (including eggs and larvae) are under the influence of climatic conditions, particularly temperature and moisture.

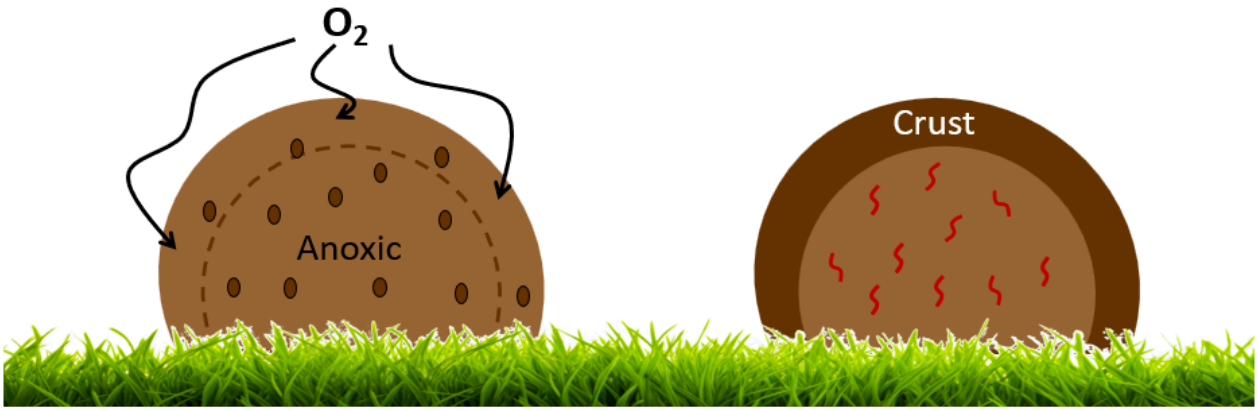


Embryonation of strongylid egg.

Images: Manure – AI-generated in MS Copilot; Eggs by Anne Beasley

Day 0

Faeces: very moist
Oxygenated at surface
Eggs scattered throughout
Only ~5% hatch while anoxic environment prevents hatching of others

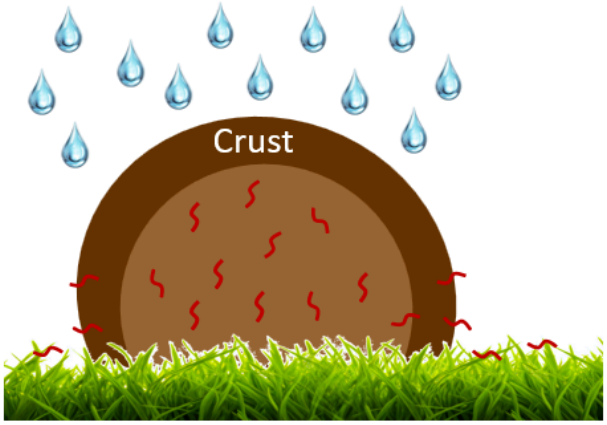


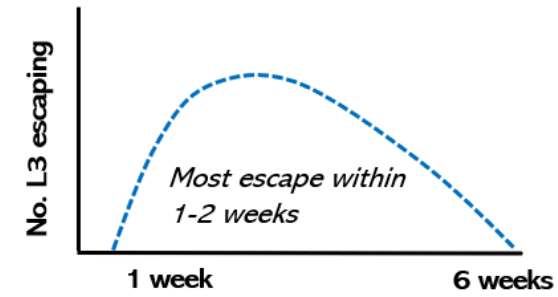
From Day 1

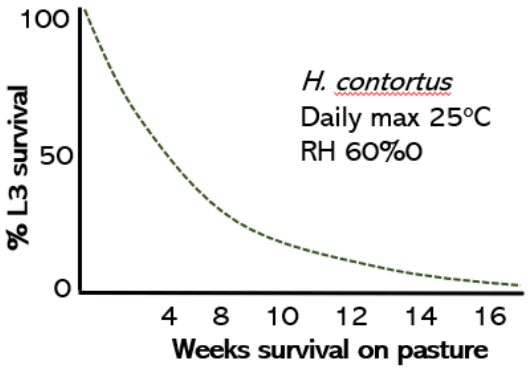
Faeces: crust forms, internal moisture retained
Eggs begin to hatch, pre-infective larvae (L1 and L2) feed on bacteria

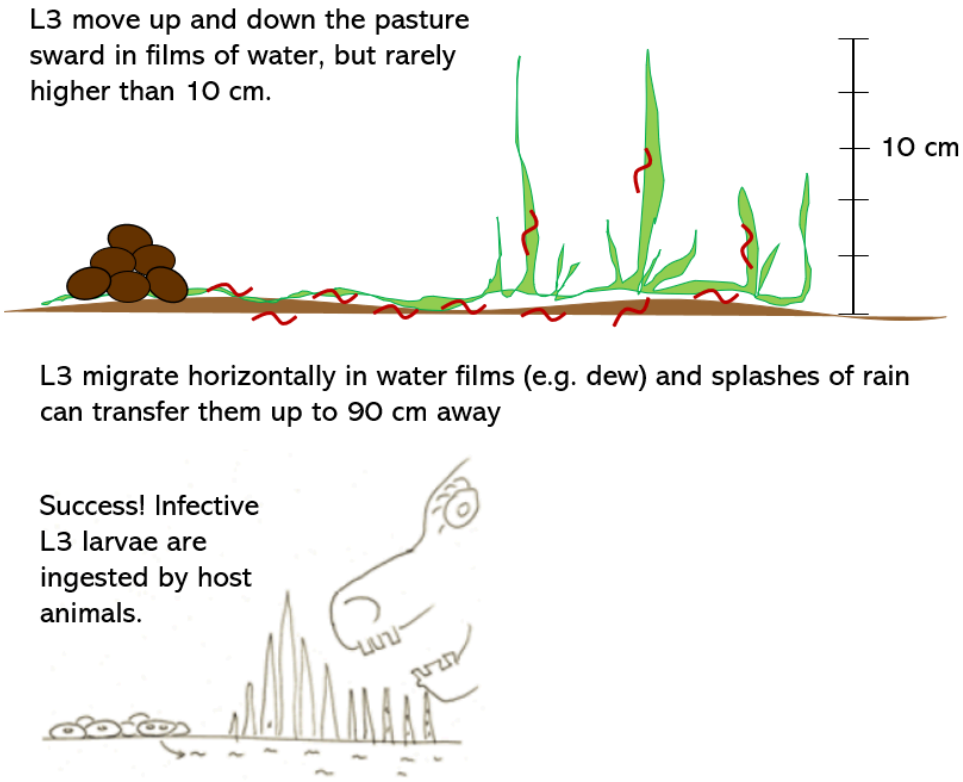
From Day 3

Faeces: maintains moisture inside
Infective larvae (L3) escape if sufficient moisture (rainfall, dew)
L3 swim in films of moisture









Artwork: Dr Tom Cribb

Host ingestion of infective larvae

Images: Grass © chiew – stock.adobe.com; "Ingestion by host animal" © Dr Tom Cribb; Other images by Anne Beasley.

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The epidemiology of the free-living stages of trichostrongyloid nematodes is heavily influenced by environmental conditions, particularly temperature and humidity. The following table summarises the development and survival of eggs and larval stages under various climatic conditions, highlighting key factors that affect transmission dynamics and parasite persistence in different regions.

Conditions	Egg development / larval survival
Cold winter	Eggs will not hatch <4oC, and will be slow to develop during winter Some L3 can survive for 4 months ('overwinter') L3 can also survive frost
Hot summer	Eggs and pre-infective larvae susceptible to hot temperatures >35oC, most L3 will die within 2 - 6 weeks
Dry	Larvae sealed inside faecal pat, but can survive in mild temperatures for months Rain that softens and breaks open pats will result in larval emergence
Favourable	Temperatures between about 20-25oC (autumn/spring) are optimum for egg development and hatching L3 survive well for ~3 months

Important Trichostrongyloids in Australia

Trichostrongylus spp.

There are a variety of species belonging to the *Trichostrongylus* genus (commonly referred to as 'scour worms') that infect small ruminants. *T. colubriformis* is more common in summer rainfall regions, *T. vitrinus* in cooler winter rainfall regions, and *T. rugatus* in arid regions.

Adults are small, hair-like worms approximately 4 – 7 mm in length, making them difficult to see with the naked eye at post mortem. They typically inhabit the first three meters of the small intestine where they cause insult to the lining of the gut when present in large numbers. This manifests in villous atrophy and nutritional disturbances (anorexia, decreased weight gain or weight loss and diarrhoea).

One species of *Trichostrongylus*, *T. axei*, is far less host-specific and can infect small ruminants, cattle, horses, and even grazing pigs. *T. axei* inhabits the **abomasum** in ruminants and the **stomach** of other hosts.

Haemonchus spp.

There are two species of *Haemonchus* infecting ruminants – *H. contortus* in sheep and *H. placei* in cattle.

They are commonly referred to as "Barber's Pole Worms" due to their characteristic appearance of the female worm, that has a red, blood-filled intestine coiled around the white reproductive organs.



Left: Adult female *Haemonchus contortus*
Right: Goat with 'bottle-jaw'

Images: Left: © Dr Constantin Constantinoiu. Used with permission. Right: © Dr Anne Beasley.

These parasites infect the abomasum and are voracious blood-suckers, making them among the most important and pathogenic worms of ruminants in summer rainfall areas. Due to their haematophagous diet, clinical signs include anaemia and hypoproteinaemia ("bottle jaw"). Animals may even succumb

to heavy infections and die before worms reach adulthood. *Haemonchus* infections alone do not cause diarrhoea, however, mixed infections (e.g. including *Trichostrongylus* spp) are the norm.

Ostertagia (cattle) and *Teladorsagia* (sheep, goats)

Ostertagia ostertagi in cattle and *Teladorsagia circumcincta* in sheep/goats are commonly referred to as "small brown stomach worm". Adults are thin, brown worms up to 1 cm in length, and infect the abomasum.

O. ostertagi are the most important parasites of cattle parasite in the temperate regions of Australia. The life cycle follows a typical direct strongylid pattern, with L3 larvae ingested while grazing. After exsheathing, parasitic L3s penetrate the mucosa, developing for about two weeks in the gastric glands. Notably, early L4s may undergo hypobiosis in the gastric glands, and subsequently resume development after one climatic season (e.g., summer). This usually occurs gradually without clinical signs, but stress can trigger mass emergence, leading to "Type-2" ostertagiosis—characterised by protein-losing gastroenteropathy, diarrhoea, and loss of condition. In contrast, "Type-1" ostertagiosis results from direct larval development without hypobiosis, and would be more typical in mobs of weaner cattle.

Penetration of the gastric glands causes "nodular" hyperplasia, initially localised around the individually affected glands. There is increased permeability of the mucosa and protein-losing gastroenteropathy. Abomasal pH increases due to a loss of parietal cells. At postmortem, the abomasum is inflamed and has a characteristic 'morocco leather' texture.

Symptoms of Type-1 ostertagiosis include scouring, reduced growth rate and loss of weight. If the larval challenge is sufficiently high, it can lead to death. Type-2 disease, however, has a different presentation. It may involve an acute onset of profuse diarrhoea, rapid loss of condition, dehydration and death if untreated. Alternatively, there may be a more chronic presentation of symptoms over several weeks. Usually in the case of Type-2 ostertagiosis, only a few animals in a herd are affected at any one time.

T. circumcincta (formerly classified as *Ostertagia circumcincta*) is a significant cause of ill-thrift and diarrhoea in sheep and goats. The aetiology of *T. circumcincta* follows the same pattern as that of *Ostertagia ostertagi*, as previously outlined.

Cooperia spp.

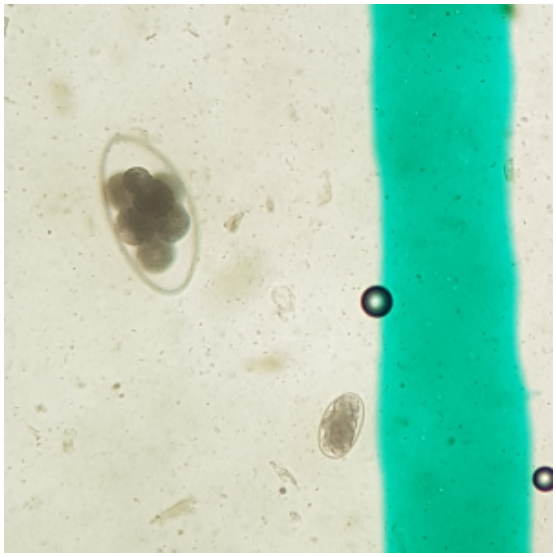
Species of this genus are found in both sheep and cattle, and reside in the small intestine. Adults are small, hair-like nematodes 9 – 12 mm long, and are commonly referred to as "wire worms" or simply "small intestinal worms".

Cooperia spp are not major parasites of sheep, and are more commonly found in sheep/goats that are co-grazing with cattle. Infections are much more common in cattle. The three main species are *C. oncophora* (in temperate climates) and *C. pectinata* and *C. punctata* (in tropical and sub-tropical regions).

Cooperia infections, much like *Trichostrongylus* infections, cause villus atrophy, hypoproteinaemia and diarrhoea. *C. oncophora* infections are only mildly pathogenic, whereas *C. pectinata* and *C. punctata* are said to be more pathogenic.

Other gastrointestinal trichostrongyloids encountered in Australia

Nematodirus is also common in ruminant small intestines and contributes to the overall syndrome of helminthosis. Adults are approximately 10-30 mm long, often with a spiral coil in the mid-body region.



Large *Nematodirus* egg in comparison to typical strongylid egg.

Photo: © Dr Anne Beasley

They are identified microscopically by a cephalic inflation, a spike on the tail of the female, very large eggs and long thin spicules in the male. Their common name is "thin-necked intestinal worm".

There are also species of trichstrongyloids present in the stomach of pigs (*Hyostrongylus* sp.) and cats (*Ollulanus tricuspis*) but these are rarely encountered in Australia. *Ollulanus* is essentially unimportant, except that it is unusual for a trichostrongyloid in that the female worm is viviparous (passes larvae rather than eggs).

Morphology and identification

The general morphology of trichostrongyloid nematodes are summarised in the table below.

GENUS	SITE	ANTERIOR	GUBERNACULUM	DORSAL LOBE BURSA	SPICULES
Trichostrongylus	Abomasum / small intestine	Featureless	Present	Symmetric	Short
Cooperia	Small intestine	Inflated	Absent	Symmetric	Short
Haemonchus	Abomasum	Stylet	Present	Present	Short
Nematodirus	Small intestine	Triangular tooth	Absent	Absent	Long, tips fused

Nematoda has more information on the features of Trichostrongyloid nematodes.

Superfamily Metastrongyloidea

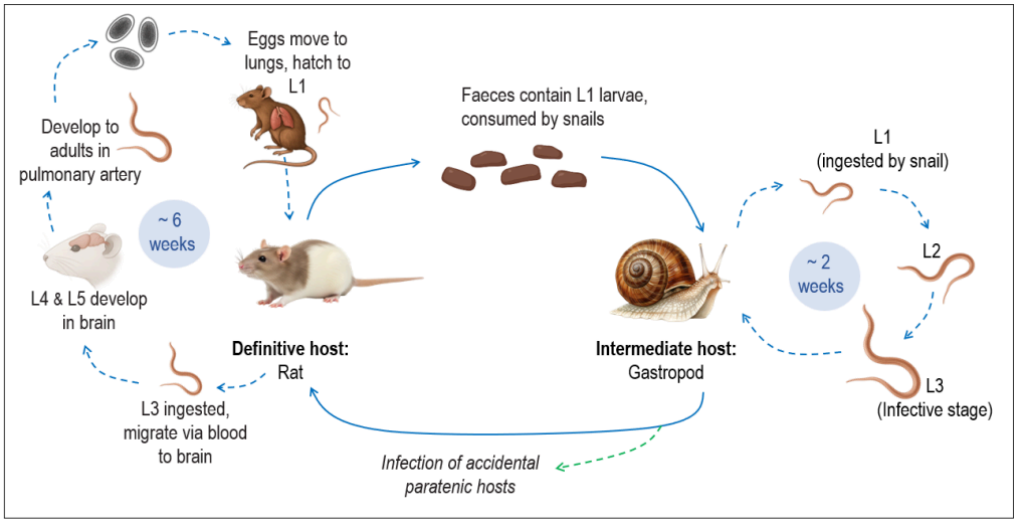
General features of metastrongyloids

The metastrongyloids mostly inhabit the lungs (or adjacent blood vessels) of their hosts and, with few exceptions, their intermediate hosts are gastropods. Some may use paratenic hosts (e.g. prawns, crabs, frogs). The parasite stage that is passed in faeces is the L1, rather that the strongylid egg, and these larvae can be identified by the characteristic kink on the tail. There are numerous examples of metastrongyloid parasites in Australian mammals, but they are rarely important in domestic animals.

Angiostrongylus cantonensis

A. cantonensis, (occasionally classified as *Parastrongylus cantonensis*) the rat lungworm, is a common parasite of South-east Asia and Pacific islands. A moderate prevalence of infection has been found in black and brown rats around public parks and residential areas of Sydney. This parasite is of importance as it is zoonotic, and can lead to fatal neural disease in 'accidental' hosts such as humans, dogs and other species. Angiostrongyliasis is an emerging disease in domestic dogs throughout the east coast of Australia, including Sydney.

As shown in the diagram below, the life cycle involves a definitive (rat) and intermediate (mollusc) host and begins when L1 larvae (in rat faeces) are ingested by snails, where they moult twice into infective L3 larvae. These L3 larvae can infect definitive or accidental hosts that consume infected intermediate or paratenic hosts. Inside the host, L3 larvae enter the bloodstream and migrate, with some reaching the brain, where they moult twice into young adults (L5). L5 larvae then move to the pulmonary artery, where they mature into adult males and females. After fertilization and oviposition, eggs reach the lungs, hatching into L1 larvae within lung tissue. The L1 larvae migrate up the trachea, are swallowed, and exit in the faeces. The full life cycle takes approximately eight weeks.



A. cantonensis life cycle.

Images: Rat with lungs, larvae, Strongyle egg and rat brain – AI-generated with MS Copilot; Rat © Agata – stock.adobe.com; Snail © Susanw – stock.adobe.com

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If a non-rat host ingests an infected intermediate host, severe neurological disease may ensue from the host reaction to the migrating larvae in the central nervous system. This occurs most commonly in dogs and people (neuroangiostrongyliasis), but has also been reported in other species.

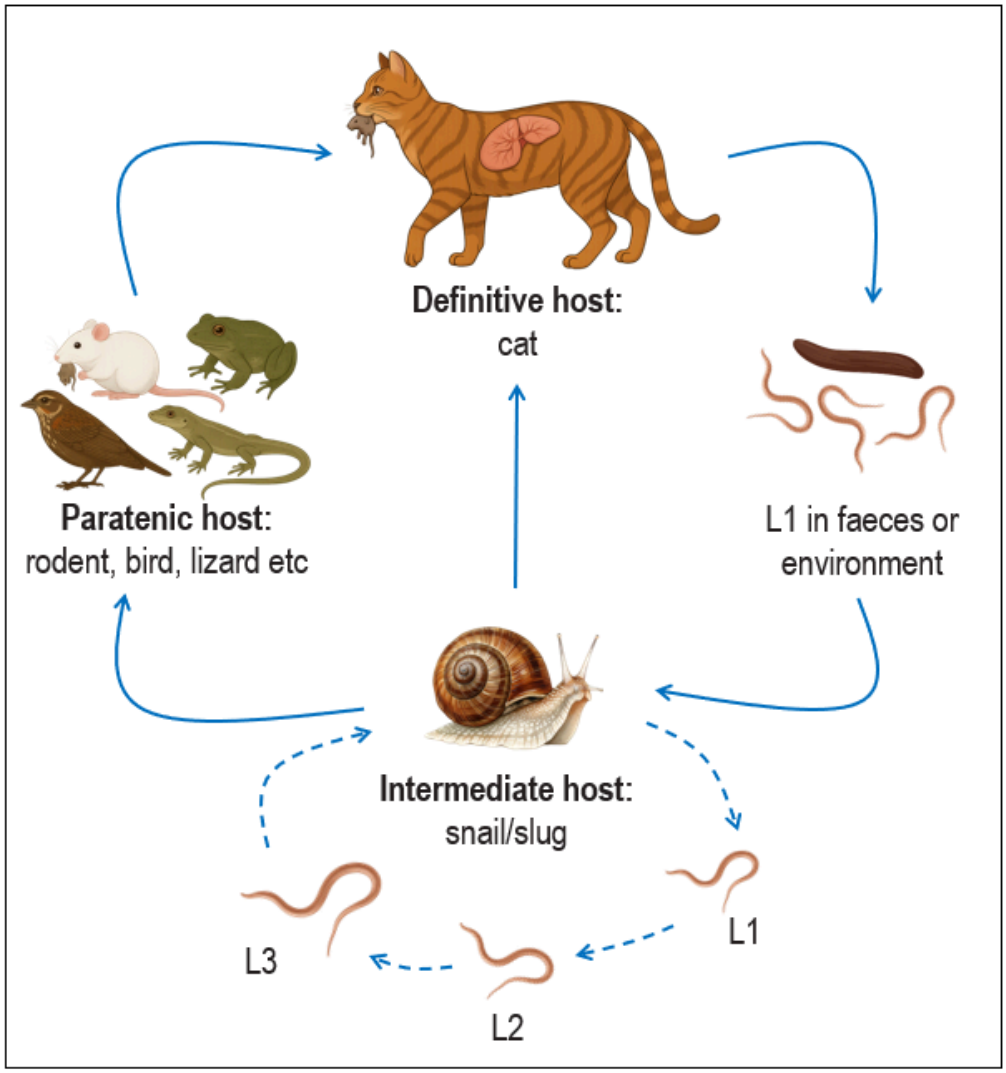
Aelurostrongylus abstrusus

The cat lungworm, *A. abstrusus*, is a small (4 – 10 mm) nematode that is found coiled in the alveoli. It is the only nematode found in the lungs of cats. They are not highly pathogenic, but can cause lower respiratory tract disease and clinical signs such as coughing, sneezing and nasal discharge. In young cats, these signs may be accompanied by weight loss.

The life cycle of *A. abstrusus* is indirect, involving snails and slugs as intermediate hosts, as well as paratenic hosts such as birds, small rodents or reptiles.

First-stage larvae (L1) are released into the environment via the respiratory mucus or faeces of an infected cat. They then penetrate or are consumed by gastropods, where they develop into infective third-stage larvae (L3). Cats subsequently become infected by consuming intermediate or paratenic hosts. **Paratenic hosts** (such as rodents, birds, amphibians, reptiles, and even small birds or lizards) ingest infected gastropods and the L3 encyst within their tissues, remaining viable until a cat preys upon them. Once mice consume infected gastropods, L3 migrate into various tissues, including liver, spleen, brain, skeletal muscle, gastrointestinal tract, and heart, where they encyst. When cats eat these infected paratenic hosts, the L3 are released in the cat's intestine and migrate via lymphatics or bloodstream to the lungs, inhaling into bronchioles, alveolar ducts, and alveoli, where they mature into adults and reproduce. Females shed eggs which migrate up the trachea, are coughed up and swallowed in order to return to the gastrointestinal tract. The prepatent period is approximately 5 weeks.

Identification of L1 in faeces is aided by the characteristic kink in the tail.



Life cycle of Aelurostrongylus abstrusus

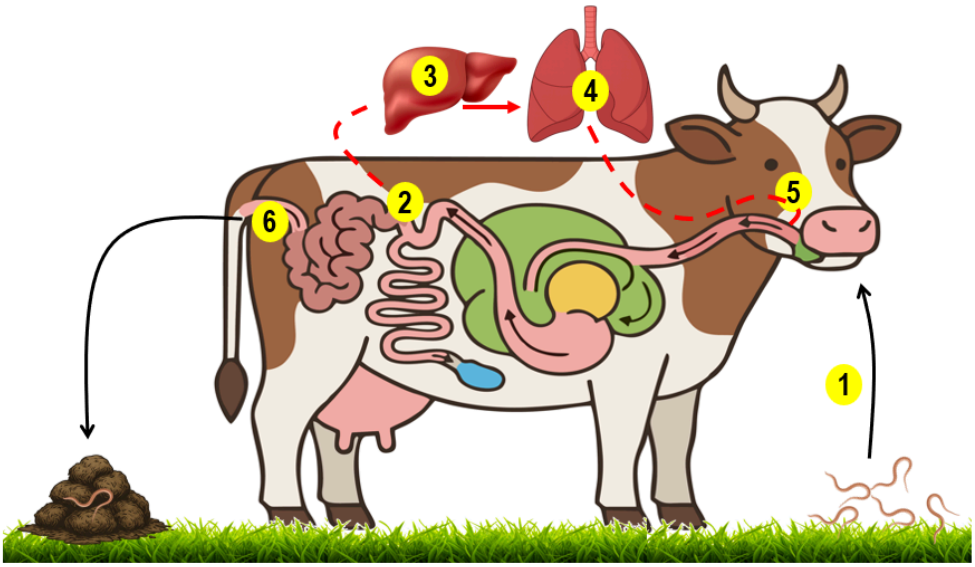
Images: Snail © Susanw – stock.adobe.com; Cat, paratenic host, worms and larvae – AI generated with MS Copilot

Dictyocaulus spp – Lungworms of ruminants and horses

The classification of these lungworms is unclear. While previously classified within the Superfamily Trichostrongyloidea, they also share characteristics with the Superfamily Metastrongyloidea. Unlike L1s of the Superfamily Metastrongyloidea, *Dictyocaulus* L1s have **no kink** in the tail.

- *D. viviparus* – cattle
- *D. arnfieldi* – equids
- *D. filaria* – sheep, goats

Infective larvae (L3) are ingested with pasture (1), then exsheath in the abomasum, penetrate the small intestinal wall (2) and migrate, via the lymphatics and blood, to the lungs (3). Larvae mature to adults in the lungs (4) and females shed eggs which are coughed up and swallowed (5) before re-entering the gastrointestinal tract. Eggs hatch to L1s as they pass through the intestines, and L1s are deposited with manure onto pasture. L1s develop to L3s in the environment so that they are ready to infect another host. The prepatent period is approximately 3 weeks.



Life cycle of Dictyocaulus viviparus

Images: Cow digestive system anatomy © Fuad – stock.adobe.com; Liver, lungs, manure and larvae – AI generated with MS Copilot; Grass © chiew – stock.adobe.com

Infections with *Dictyocaulus* spp result in respiratory signs (coughing) and ill-thrift, particularly in intensively farmed calves (e.g. dairy).

Dictyocaulus arnfieldi is virtually ubiquitous, but non-pathogenic in donkeys. Horses grazing with donkeys may become infected and develop clinical signs, but often these infections are not patent (i.e. no L1s appear in faeces). This parasite likely evolved in the donkey and horses have become an 'accidental host'.

Morphology and identification

Visit Superfamily Metastrongyloidea (Lungworms).

Non-Bursate Nematodes

Important superfamilies from various orders are covered below.

Superfamily Rhabditoidea

This is a primitive group of mostly free-living nematodes or parasites of lower vertebrates or invertebrates. Some free-living genera occasionally cause problems in animals, but there is really only one important genus from a veterinary point of view.

Strongyloides – thread worms

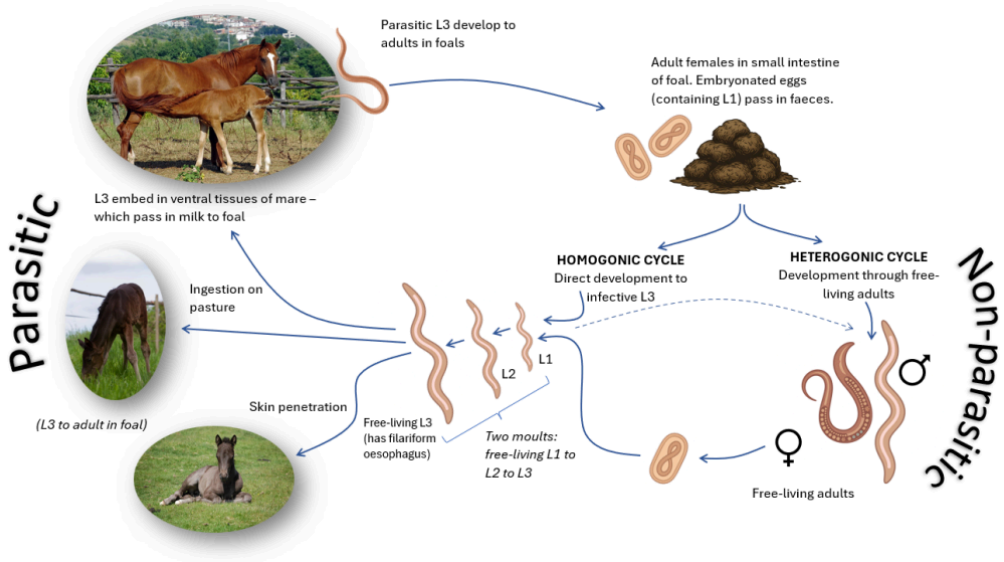
Don't be confused by the name, these are **not** strongylids.

The life cycle of *Strongyloides* is unusual among nematodes of veterinary importance because it can follow either a parasitic or a free-living generation, depending on environmental conditions. Parasitic adults are all female, very small (5-7 mm), and entwined within small intestinal villi (or caecae in the case of avian hosts). Species occur in most domestic animals and infections can be significant in very young horses, pigs, and ruminants:

- *S. westeri* – horses, donkeys
- *S. stercoralis* – dogs, cats, humans, primates
- *S. ransomi* – pigs
- *S. papillosus* – ruminants (cattle, sheep, and goats)
- *S. tumefaciens* – cats

Life Cycle

Strongyloides species are unique among parasitic nematodes due to their ability to undergo both parasitic and free-living life cycles, which allows for flexibility in transmission and adaptation to various environmental conditions. Parasitic females reproduce parthenogenetically, meaning they can produce offspring without fertilisation. This contributes to rapid increases in parasite burden within a host. Infection can occur via several routes: percutaneous penetration, oral ingestion or transmammary transmission. Adult parasitic females reside in the small intestine of the host, embedded in the mucosa. The prepatent period is 5-12 days.



Strongyloides westeri life cycle

Images: Larvae, manure, worm and larvated egg – AI generated with MS Copilot; Horse with foal and Horse laying down from Pixabay; Horse eating grass © – stock.adobe.com

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There are two main larval forms commonly referenced: **rhabditiform larvae** (L1, non-infective) and **filariform larvae** (L3, infective). However, development includes additional stages. After hatching, L1 moult to **L2**, then either:

- **Homogonic cycle (direct)**: L2 develop into infective L3.
- **Heterogonic cycle (free-living)**: L2 moult to **L3**, then to **L4** and **L5**, which become free-living adult males and females. These adults reproduce sexually, producing eggs that hatch to L1.

In the parasitic cycle, following skin penetration, L3 enter lymphatics and then the venous system, migrate to the lungs, enter alveoli, and undergo tracheal migration before being swallowed and returning to the intestine.

Auto-infection (seen in *S. stercoralis* in humans) occurs when L3 develop within the gut before leaving the host, then penetrate the lower bowel or perianal skin and repeat migration.

Significance

Infection with *Strongyloides* is often asymptomatic, even with high egg counts in faeces. The main symptoms associated with infection are diarrhoea and ill thrift in very young animals. Skin penetration may predispose lambs to foot rot.

Superfamily Ascaridoidea

The Superfamily Ascaridoidea is a group of parasitic nematodes (roundworms) that infect a wide variety of vertebrates, including mammals, birds, and reptiles. They are characterised by their large size, thick bodies, and direct life cycles, often involving oral ingestion of eggs.

Important Ascaridoids of Australian Mammals

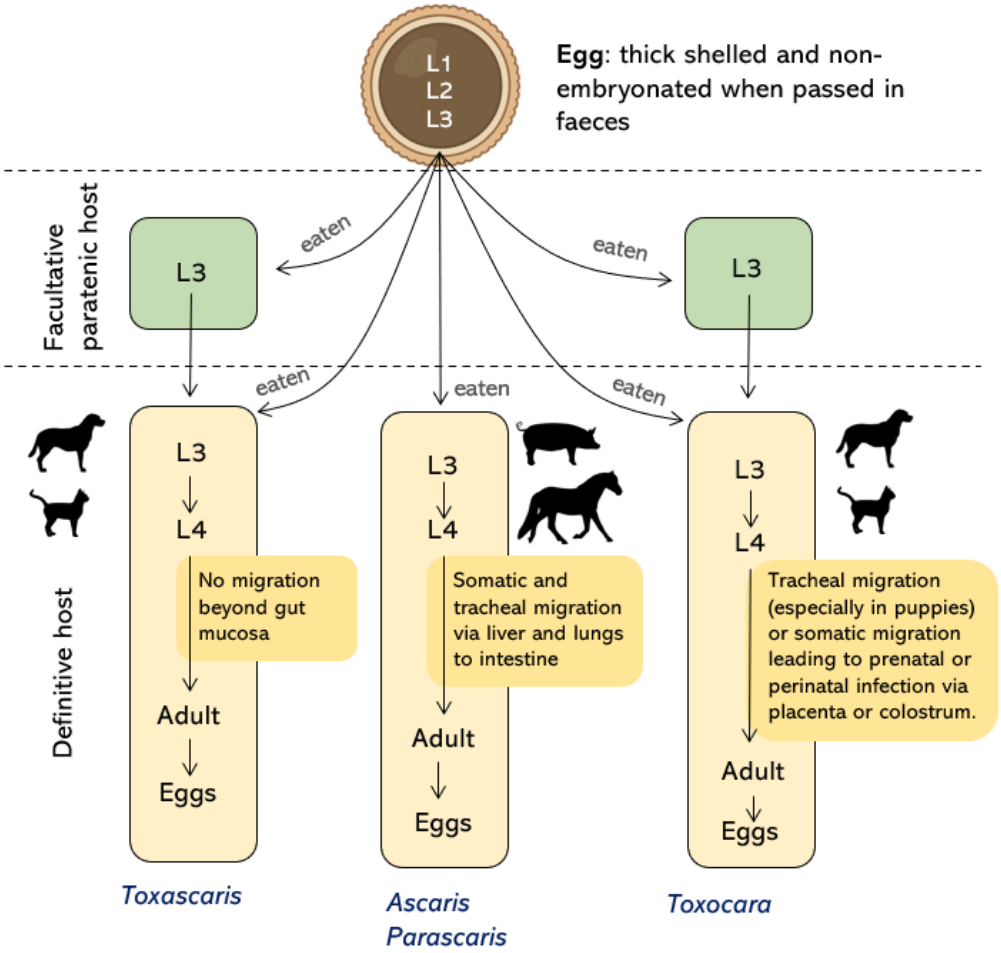
- ***Toxocara canis*** – dog (10-18 cm)
- ***Toxocara cati*** – cat (3-10 cm)
- ***Parascaris equorum*** – horse (15-50 cm)
- ***Ascaris suum*** – pigs (20-40 cm).

Other ascarids of less significance:

- *Toxascaris leonina* – dog or cat (7-10 cm)
- *Toxocara vitulorum* – cattle (25-30 cm)
- *Ascaridia galli* and *Heterakis gallinarum* are ascarids found, respectively, in the small intestine and caecae of birds. They belong to the same order (Ascaridida) but different superfamily (Heterakoidea) to the mammalian ascaridoids.

Life Cycle

Ascarid life cycles, while varying slightly between species, generally follow a similar pattern, characterised by a direct life cycle and oral infection. The egg is an important component of ascaridoid success! Adult females produce large numbers of thick-shelled, sticky eggs which pass out with the faeces. Once in the environment, the eggs require a period of development to become infective, and this phase is influenced by environmental factors such as temperature and moisture. Within the egg, the larva develops through to the L3 stage before becoming capable of infecting a new host. Note: the egg does NOT hatch in the environment, unlike the trichostrongyloids. Infection of a new host can occur through contaminated food or water, or ingestion of soil containing infective eggs. In some cases, infection takes place through ingestion of paratenic hosts (transport hosts) that have ingested the eggs. In the case of *Toxocara canis* and *Toxocara cati*, paratenic hosts are important. These might include rodents, birds, earthworms or other small mammals. After ingestion, infective larvae hatch from the eggs in the small intestine. In some species, larvae then penetrate the intestinal wall and undergo a period of migration through the host's tissues. This can involve travelling through the bloodstream to the liver and lungs, penetrating the alveoli, migrating up the respiratory tract and being swallowed back into the small intestine. Some ascarids, however, do not perform this extensive migration, and the larvae will mature within the intestinal lumen. Once larvae have reached the small intestine (either directly or after migration), they mature into adult worms a reproduce sexually to produce eggs. Some ascarids, notably *Toxocara canis*, can be transmitted from a pregnant or lactating animal to its offspring via the placenta or milk.



Ascarid life cycles

Images: Cat, cat pig and horse © Vlad Klok – stock.adobe.com; Egg – AI generated with MS Copilot

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Significance

Adult worms in the small intestine cause ill-thrift or poor growth rates. Puppies or kittens may have a 'pot bellied' appearance. Some vague gastrointestinal signs may be displayed (diarrhoea, some vomiting). Occasionally, due to the size of the adult worms, gastrointestinal obstruction may occur.

Migrating larvae may cause respiratory signs. Larval damage may predispose to other respiratory pathogens (especially in horses and swine). Migration through tissues such as the liver may cause 'milk spots' in pigs, leading to condemnation at the abattoir. Transplacental infections may cause damage leading to stillborn puppies.

Zoonotic Aspects

Some ascaridoid parasites, such as *Toxocara canis* and *Toxocara cati*, have zoonotic potential. Visceral *larva migrans* (VLM) and ocular *larva migrans* (OLM) are diseases caused by the migrating larvae of these parasites in people (accidental, dead-end hosts). Humans, particularly young children, can accidentally ingest infective eggs through pica (eating dirt), contaminated hands, food or objects (poor hygiene). Ingestion of undercooked paratenic hosts containing encysted larvae is another, though less common, route. Once ingested, larvae hatch in the small intestine and penetrate the intestinal wall. Larvae then migrate through the bloodstream to various organs and tissues. In VLM, this migration primarily affects the visceral organs, such as the liver, lungs and brain. In OLM, the larvae migrate to the eye. The larvae do not develop into adult worms in humans. They become trapped and encysted in the tissues. VLM symptoms vary depending on the organs infected, but can include fever, cough, abdominal pain, enlarged liver and eosinophilia. In severe cases, neurological complications can occur. In OLM, severe visual impairment can occur, including blindness. Other symptoms include retinal granulomas, uveitis or retinal detachment.

Superfamily Oxyuroidea

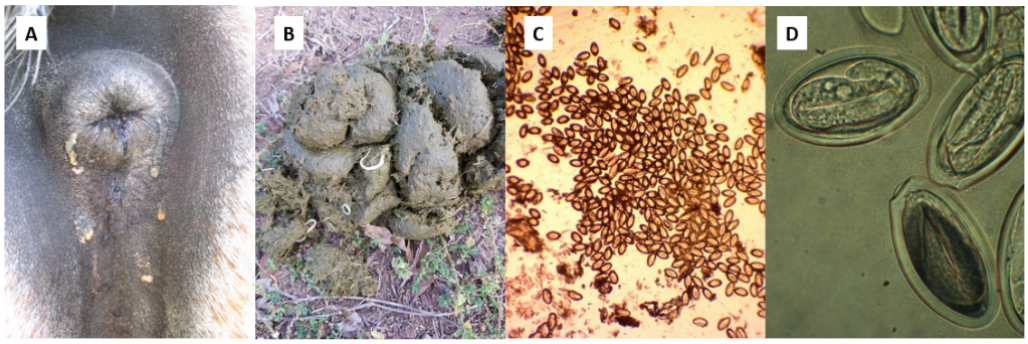
Oxyuroidea, commonly known as pinworms, are a superfamily of highly host-specific nematode parasites that primarily reside in the posterior gut of a wide range of vertebrate hosts. Characterised by their pointed tails and direct life cycle, these parasites typically transmit via the ingestion of infective eggs, often deposited in the perianal region. While exhibiting a broad host range, including many domestic animals, their veterinary significance stems from the irritation and discomfort they cause, particularly in the large intestine and perianal areas.

Important pinworms in Australia:

- ***Oxyuris equi*** – horses
- ***Enterobius vermicularis*** – human pinworm
- ***Syphacia* spp** – rodents.

Oxyuris equi – equine pin worm

Oxyuris equi, the equine pinworm, primarily affects young horses, inducing perianal pruritus. This parasite, a thick-bodied nematode ranging in size from smaller males (9-12 mm) to substantially larger females (reaching up to 10 cm), is distinguished by its elongated, tapering tail.



A: *Oxyuris equi* egg packets on perianal skin of horse; **B:** Adult *O. equi* passed in horse manure; **C:** Egg packets retrieved from perianal skin via sticky tape impression; **D:** Individual *O. equi* eggs.

Photos: © Dr Anne Beasley

Life cycle

The life cycle is direct; mature female pinworms migrate to the rectum, exiting the anus to deposit eggs on the perineal skin in a sticky substance that provokes intense irritation. These eggs, containing infective L3s, contaminate the environment and are ingested by the host. Larvae hatch in the small intestine, migrating to the large intestine where they mature into adults, feeding on intestinal contents.

A lengthy prepatent period of five months precedes the onset of clinical signs. The primary pathological effect is perianal irritation, resulting in restlessness and tail rubbing, which leads to hair loss and skin damage. Consequently, the only prominent clinical indicator of *O. equi* infection is anal pruritus.



Tail head of pony with perianal pruritis caused by pinworm infection.

Photo: © Dr Anne Beasley

Enterobius vermicularis – Human pinworm

Pinworm infections are extremely common in humans, with virtually everyone likely experiencing an infection at some point in their lives. Sometimes pharmacists and doctors recommend deworming family pets when children are diagnosed with pinworms, BUT, remember that oxyurid parasites exhibit high host specificity. Consequently, dogs and cats are NOT reservoirs for human pinworm infections, and treating them serves no purpose in preventing reinfection within the human family.

Superfamily Habronematoidea

Habronematoidea are a superfamily within the spirurid order of nematodes, characterised by its reliance on indirect life cycles involving arthropod intermediate hosts. A distinguishing feature of this group is the morphology of the male, which possesses a tightly spirally-coiled tail.

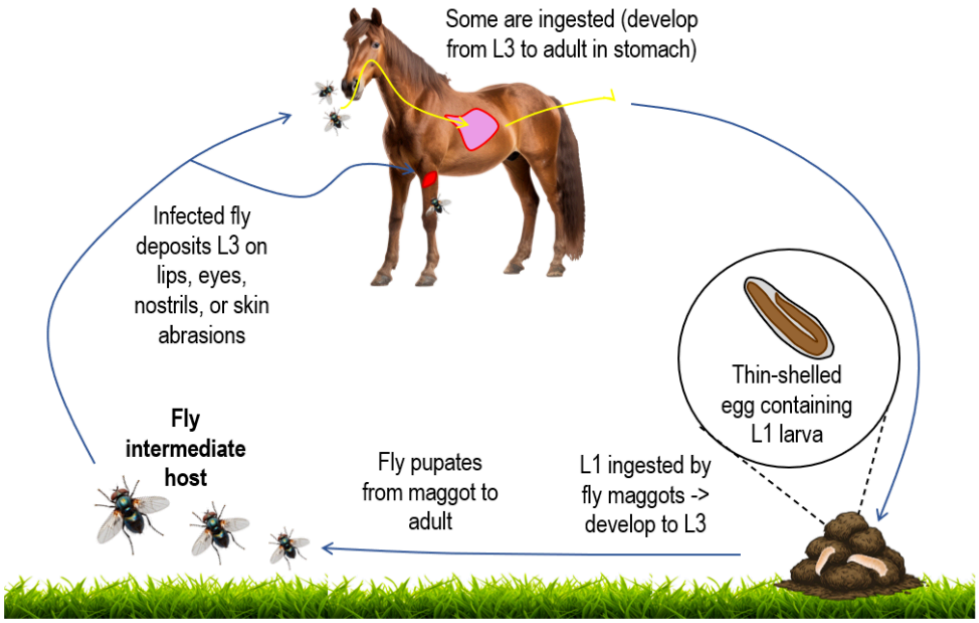
Two closely related nematode genera, *Habronema* and *Draschia*, inhabit the equine stomach. These relatively small worms, typically measuring 1-2 cm, reside either on the gastric mucosa's surface, as seen with *Habronema* species, or within stomach wall nodules, characteristic of *Draschia megastoma*.

Three species found in equids:

- ***Habronema muscae*** – reside on gastric mucosa, intermediate host is *Musca* spp.
- ***Habronema*** *majus* (= *microstoma*) – reside on gastric mucosa, intermediate hosts are *Stomoxys calcitrans* or *Musca* spp
- ***Draschia megastoma*** – reside in gastric nodules in stomach, intermediate host is *Musca* spp.

Life cycle

Thin-shelled, embryonated eggs are shed in faeces, hatching into L1. These larvae are then ingested by developing fly larvae, specifically house flies (*Musca domestica*) or stable flies (*Stomoxys calcitrans*). Inside the fly's hemocoel, the larvae develop to the infective L3. Upon fly metamorphosis and accidental ingestion by a horse, the L3 larvae mature in the stomach. Larvae can also be transmitted when infected flies feed around the horse's mouth. While *Habronema* remains on the mucosal surface, *Draschia megastoma* creates large nodules by burrowing into the stomach wall. L3 larvae deposited by flies on skin lesions can migrate within the wound, exacerbating it and resulting in cutaneous habronemiasis, although they do not reach adulthood in these locations.



Life cycle of Habronema/ Draschia

Images: Horse © Flowal93 – stock.adobe.com; Flies © RTUN – stock.adobe.com; Maggot © Nikolay N. Antonov – stock.adobe.com; Grass © chiew – stock.adobe.com; Manure – AI generated with MS Copilot; Thin shelled egg by Anne Beasley

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Significance

Although adult *Habronema* worms are generally not highly pathogenic, they can induce gastritis. *Draschia*, however, is more detrimental, causing tumour-like lesions in the stomach. Larval deposition in existing skin wounds can worsen the lesions, leading to the clinical condition known as 'cutaneous habronemiasis' or 'ocular habronemiasis' – more commonly known as 'summer sores'.

Superfamily Filarioidea

Filarioid nematodes live as adults in the circulatory system or connective tissues of their hosts. They don't release eggs or larvae directly; instead, they release microfilariae into the blood or tissue fluids. These microfilariae are then picked up by biting insects, which act as intermediate hosts. Adult males have a loose spiral to their tail.

Important filarioid parasites:

- *Dirofilaria immitis* – canine heartworm
- *Dipetalonema reconditum* – subcutaneous filarial worm

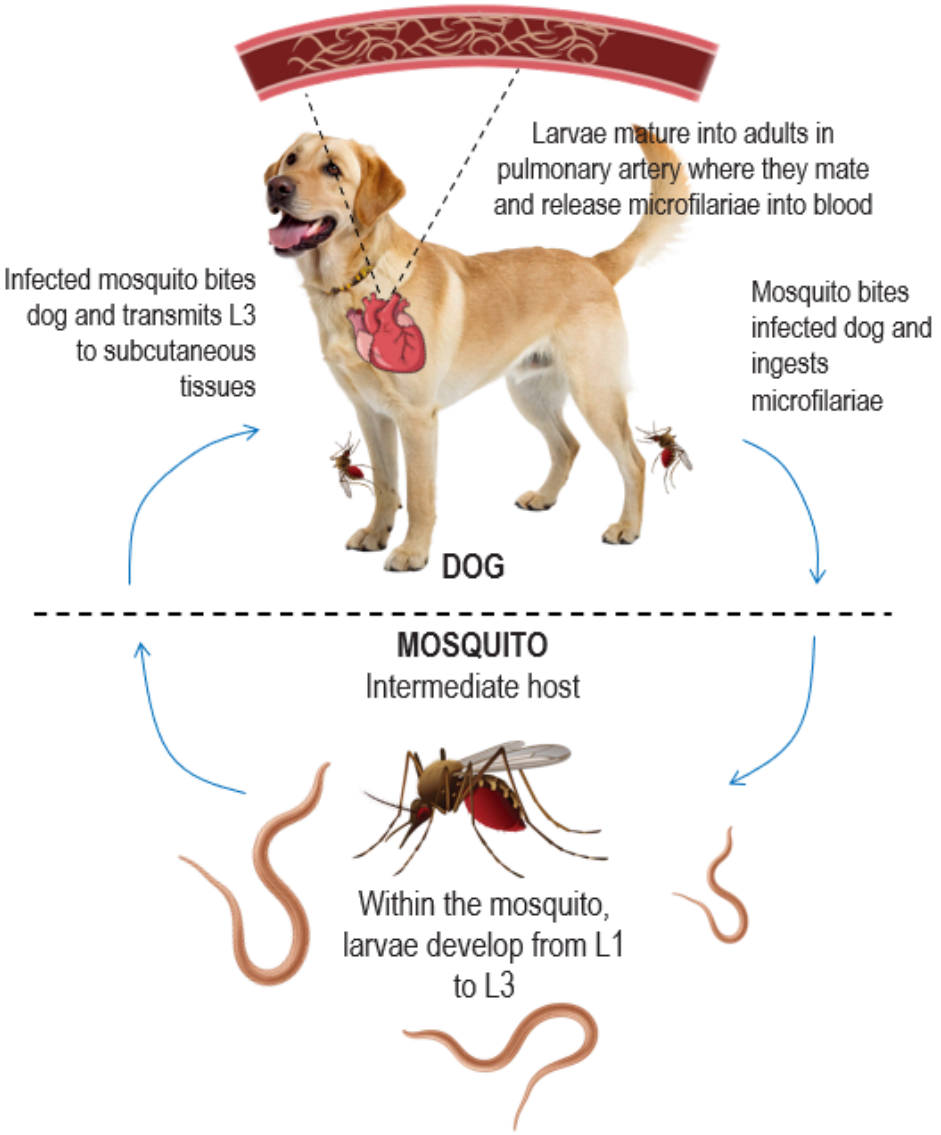
- *Onchocerca spp.*

Dirofilaria immitis – canine heartworm

Canine heartworm, caused by *Dirofilaria immitis*, is a significant parasitic threat to dogs, particularly in warm climates globally. These large, white nematodes, ranging from 12 to 30 cm in length, reside primarily in the pulmonary arteries and right ventricle of infected dogs, and less frequently in cats, ferrets, and other animals like sea lions. These are the only worms of that size found in that location. While another nematode, *Angiostrongylus vasorum*, can inhabit similar sites, it is a much smaller metastrongylid, less than 3 cm long, and is extremely rare in Australia. *Dirofilaria immitis*, the single species responsible for canine heartworm, is a major concern for canine health.

Life cycle

Canine heartworm disease commences with adult female worms releasing microfilariae, roughly 300 mm long, into the dog's bloodstream. These microfilariae are then ingested by feeding mosquitoes, primarily of the *Culex* or *Aedes* genera. Within the mosquito's hemocoel, the microfilariae develop into infective third-stage larvae (L3) over 2-3 weeks, subsequently migrating to the mosquito's mouthparts. When the infected mosquito bites another dog, these L3 larvae penetrate the bite wound. The L3 and L4 larval stages then develop within the connective tissues of the host. After moulting into L5 larvae, approximately three months post infection, they enter the large veins and are carried to the distal pulmonary arteries. As they mature, they migrate to more proximal regions of these arteries. The pre-patent period, the time from infection to the presence of detectable microfilariae, is approximately six months.



Dirofilaria immitis life cycle.

Images: Dog © Anatoli – stock.adobe.com; Heart © Dzianis – stock.adobe.com; Mosquito © MDSHAHIN – stock.adobe.com; Worms – AI generated with MS Copilot

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Diagnosis can be complicated by occult infections, where animals are infected but lack circulating microfilariae. This can occur due to low worm burdens (either a single worm or all worms of the same sex), which is particularly prevalent in cats and areas with low heartworm prevalence. Additionally, drug-induced elimination of microfilariae or sterilisation of adult females, as seen with monthly macrocyclic lactones used for heartworm prevention, can result in occult infections. Pre-patent, geriatric, or ectopic infections can also contribute to the absence of circulating microfilariae, making accurate diagnosis challenging.

Significance

Heartworm disease poses a serious threat to canine health, with chronic infections leading to significant cardiopulmonary problems and potentially fatal outcomes in heavy infestations. The presence of adult heartworms causes damage to the lungs, resulting in pneumonitis, and can progress to congestive heart failure. The disease can trigger renal complications, such as immune complex glomerulopathy, associated with the presence of microfilariae in the bloodstream.

Dipetalonema reconditum

Dipetalonema reconditum is a small, whitish nematode, ranging from 10 to 30 mm in length, that resides in the subcutaneous tissues, body cavity, connective tissues, or kidneys of dogs. Adult worms release microfilariae into the bloodstream, which can lead to diagnostic confusion with the more pathogenic *Dirofilaria immitis* (heartworm). However, aside from this potential for misdiagnosis, *Dipetalonema reconditum* is generally considered to have no significant clinical impact on dogs. Unlike heartworm, where mosquitoes are the vectors, *Dipetalonema reconditum* microfilariae circulate in the blood but are spread through flea and lice bites.

Onchocerca spp.

Onchocerca spp. are long, thread-like filarial nematodes that primarily inhabit the connective tissues of cattle and horses, often encapsulated within nodules. Specifically, *O. cervicalis* and *O. reticulata* are found in the ligamentum nuchae and flexor tendons/suspensory ligaments of horses, respectively. *O. gutterosa* typically infects cattle, but has been occasionally observed in horses in specific regions like South East Queensland. These species are not found in New Zealand.

Microfilariae, released into the skin via lymphatics, are transmitted by biting midges (Ceratopogonidae). *Onchocerca* microfilariae tend to concentrate within the skin, particularly around the horse's belly and navel, though they can also be found in smaller numbers on the withers, rump, and face. Biting midges of the *Culicoides* genus act as intermediate hosts, consuming these larvae during blood meals. Inside the midge, the larvae mature into the infective L3. Transmission to horses occurs when these L3 larvae are deposited into the skin during subsequent midge bites.

Significance

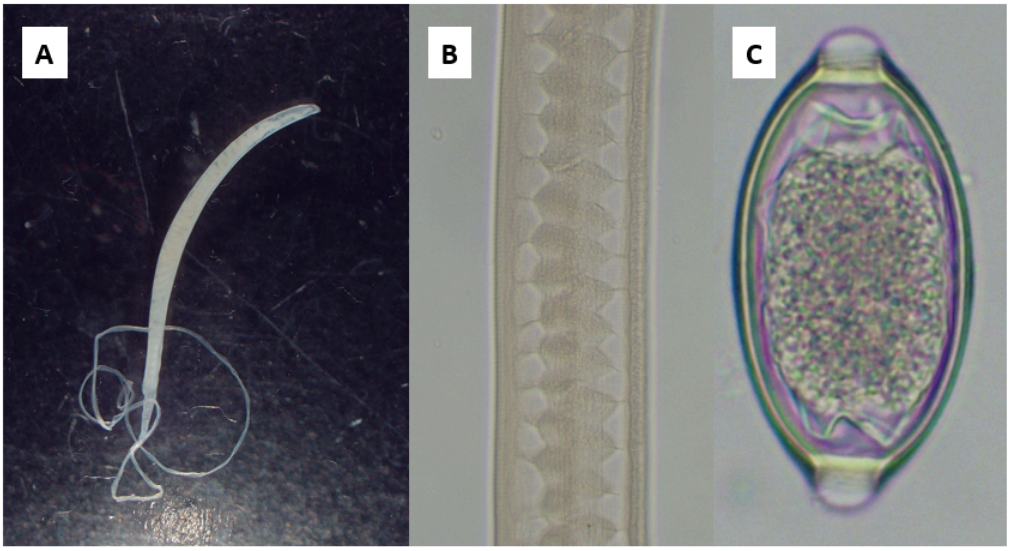
While often considered clinically insignificant, *Onchocerca* infections can lead to dermatological issues in horses. Cutaneous onchocerciasis, a skin condition associated with microfilarial presence, manifests as hair loss, scaling, and itching, primarily along the underside of the abdomen. These lesions can spread to the areas between the legs and the thighs. This skin reaction is attributed to a combination of hypersensitivity to the midge bites and a direct inflammatory response to the microfilariae within the skin. Additionally, affected carcass components may be condemned during meat inspection.

Superfamily Trichinelloidea

Trichinelloidea represents a distinct group of nematodes, differing from previously discussed superfamilies by belonging to a separate class and by having the L1 as the infective stage. These nematodes are characterised by a **stichosome** or **trichuroid oesophagus** (B), a capillary-like tube encircled by a single column of cells. With the exception of *Trichinella* species, members of this superfamily produce eggs with characteristic bipolar plugs (C).

Trichuris spp (whip worms)

Trichuris species, commonly known as **whipworms (A)**, are nematodes that reside in the large intestine and a cecum of various hosts, including dogs, pigs, ruminants, and humans, with each host typically having its own species-specific parasite.



A: Adult *Trichuris* illustrating 'whip-like' shape; **B:** stichosome oesophagus; **C:** Egg

Images: © Lyn Knott

Their name derives from their distinctive morphology: a long, thin anterior end, resembling a whip (A), which is embedded in the mucosal lining, and a shorter, thicker posterior end, resembling a whip handle, which protrudes into the intestinal lumen.

Life cycle

Trichuris females produce distinctive, barrel-shaped eggs (C) containing the L1 larva, which are then shed in the host's faeces. These eggs are remarkably resilient, capable of surviving in the environment for multiple years. The life cycle is straightforward, requiring no intermediate hosts. When a susceptible host ingests these mature eggs, the L1 larva hatches and completes its development entirely within the gastrointestinal system, culminating in adult worms. The prepatent period is approximately 40 days.

Significance

While *Trichuris* infections in ruminants and cats are generally of low pathogenicity, and most infections across species are light and asymptomatic, heavier burdens can lead to significant health issues. In dogs and pigs, particularly, large worm burdens can cause severe typhlitis, resulting in large intestinal diarrhoea characterised by frequent passage of small amounts of mucoid or gelatinous faeces. *Trichuris suis* infections in pigs can increase susceptibility to bacterial infections that contribute to swine dysentery, exacerbating the overall disease impact.

Capillarid worms (*Capillaria* spp.).

Capillaria spp., commonly known as **hairworms**, are a diverse group of slender nematodes found in various animal hosts. While avian parasites remain classified within the *Capillaria* genus, many mammalian parasites previously grouped under this name have been reclassified into several distinct genera. However, due to the prevalence of the older nomenclature in existing literature, both the traditional and revised classifications are often used. These nematodes are exceptionally thin and hair-like, despite reaching lengths of up to 25 mm. They are frequently found embedded within host tissues. Male worms possess a single spicule, and females produce characteristically shaped eggs, which, while resembling *Trichuris* eggs, are slightly asymmetrical and have a non-smooth surface. Although some *Capillaria* species inhabit the gastrointestinal tract, others can be found in a variety of organs, including the liver, bladder, and lungs.

Life cycle

Capillaria species typically exhibit a direct life cycle, with eggs containing the L1 larva being shed in the host's faeces. Infection occurs when a new host ingests these eggs. However, some *Capillaria* species employ an indirect life cycle involving earthworms. In these cases, earthworms may act as simple transport hosts, or they may be a necessary intermediate host. The eggs are ingested by the earthworm, and then the earthworm is eaten by the definitive host.

Significance

Capillaria species exhibit varying degrees of pathogenicity depending on the host. Notably, they are significant pathogens in the intestinal tract of birds, where heavy infections can induce severe enteritis and mortality. In mammals, however, *Capillaria* infections are generally considered to have low pathogenicity. For instance, *Capillaria feliscati* is frequently found in cats in regions like Brisbane, but it rarely causes clinical disease. Similarly, species that inhabit the bladder of cats and dogs are typically only mildly pathogenic, if at all, although their eggs may be encountered during urine analysis and require identification. Conversely, *Capillaria aerophila* can cause severe bronchitis, especially in young animals. *Capillaria hepatica* is a potentially zoonotic species.

Trichinella spp

Trichinella species are zoonotic nematodes that infect a wide range of mammals. While *Trichinella spiralis* is absent in Australia, ***Trichinella pseudospiralis*** is present. Adult worms, measuring 1.5-3 mm, reside in the small intestine, where females produce L1s, 70-100 μm in length. These larvae penetrate the intestinal wall and are transported via the bloodstream to muscle tissues throughout the body.

- *T. spiralis* (encapsulated): The most common and pathogenic species in humans globally, associated primarily with the domestic cycle (swine). When the L1 larva embeds in the host muscle cell, it induces the formation of a collagen-based capsule (or cyst) around itself.
- *T. pseudospiralis* (non-encapsulated): This species does not induce the formation of a capsule around the larvae in the host muscle cell. The L1 larvae remain freely coiled within the modified muscle cell. Found in sylvatic cycles, with a unique ability to infect both mammals and birds, posing a risk through the consumption of various wild animal meats. Highly infective for humans; infections can be unusually prolonged and pose a significant public health risk, though severity depends on the infectious dose.

Identification

- How to identify nematode eggs
- Identification of nematode species

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PART IV

SINGLE CELLED PARASITES - THE PROTOZOANS

15.

PROTOZOA

Single-celled parasites

'*.....among these streaks there were besides very many little animalcules ... And the motion of most of these animalcules in the water was so swift, and so various upwards, downwards and round about that 'twas wonderful to see.....'* – Anton van Leeuwenhoek, 1674, cited from Lane[1].

Introduction

The protozoans are single-celled eukaryotes. The term Protozoa is a term of convenience and has been used historically to describe single-celled eukaryotes that typically lack plant-like organelles (that lack chloroplasts) and are actively motile. The organisms we classify as protozoans are now recognised to belong to highly diverse clades. Some 'protozoans', like the flagellates or amoebae are animal-like; while others share with plants the possession of chloroplasts. Others are just bizarre and do not resemble other organisms.

Herein we will use the term "Protozoa" to describe these single celled eukaryotes that are parasitic in animals of veterinary significance. Some characteristics of these single-celled organisms are listed below.

Most single-celled eukaryotes are free-living organisms, and only a small proportion of those that are parasitic produce disease. As the word **eukaryote** implies, the organisms have a true nucleus (that is, the nuclear material, DNA and its regulatory molecules, is enclosed within a membrane, the nuclear envelope). In most species, the cells possess a single nucleus. Ciliates, however, have two types of nucleus in the cell, a vegetative macronucleus and a reproductive micronucleus. Further, among all parasitic forms, some species may be multinucleate for some or all of their life cycle. The cytoplasm contains membrane-bound organelles. Mitochondria are present in many species, but may have been lost and secondarily replaced by analogous structures, such as the hydrogenosomes of some flagellates.

Protozoa are **unicellular.** Some species may form colonies of genetically identical individual cells. The cells of many species can be complex. Apicomplexans, for example have an array of structures at the anterior

pole of the cell, the apical complex, that is used for the purpose of invading host cells. Ciliates may have distinctive organisation of their cytoplasm that incorporates distinct regions for ingestion and 'defaecation' of food particles, thus developing the appearance of having a gut, all within a single cell.

Locomotion

Flagella are whiplike structures composed of a central axoneme and an outer sheath that is a continuation of the cell membrane. The axoneme arises from a kinetosome (similar to the centrioles of eukaryotic cells). Kinetosomes are fixed in position so that flagella may be directed anteriorly, laterally or posteriorly. Most flagellates have more than one flagellum. In some organisms, a flagellum may be bent back along, and loosely attached, to the body to form a finlike **undulating membrane**.

Cilia are small "hair-like" extensions of the cell membrane, structurally similar to flagella. They include a kinetosome and an axoneme but ciliate pellicular structure ("root system") is very complex and different to that of flagella. The structure of these complexes is important in the classification of ciliated protozoa.

Pseudopodia are temporary extensions of the cell membrane. Movement by pseudopods is a complex form of protoplasmic streaming, probably involving the interaction of microfilaments of myosin and actin.

A **glideosome** is characteristic of members of the Apicomplexa, a group that includes the malaria parasite, *Babesia,* and the coccidians. This consists of adhesive molecules that are present in the apex of the cell that adhere to a substrate, often a cell or tissues of the host. The adhesive molecules are moved posteriorly by cytoskeletal components that lie beneath the membrane. This backwards movement of the molecules propels the cells forward and this strategy is used to orient the parasite cell on a host cell for subsequent invasion.

Undulating ridges are formed by tiny undulating waves in cell membranes imparting a forward gliding motion to the organism. The mechanism for this is unknown but it may involve microtubules beneath the external plasma membrane.

Reproduction

Generally, all protozoans have huge reproductive potential. Protozoa may reproduce by asexual or sexual means.

Asexual reproduction

This form of reproduction involves various mitotic divisions and may result in the production of genetically and morphologically offspring cells, of through a form of budding that produces cells of unequal size and shape.

A common form of asexual division is termed **binary fission.** In this, a cell with divide through mitotic division to form two offspring that part and exist independently of each other. In members of the Apicomplexa, a clade of protozoan characterised by prodigious reproductive potential, asexual reproduction can occur through a form of **multiple fission**. In this, the parent cell will generate multiple offspring.

In apicomplexans, the various occurrences of multiple fission are named according to the life cycle stage in which multiple fission occurs. The process of **schizogony or merogony**, results in the formation of **merozoites.** These are cells that are formed during asexual reproduction within the host. By contrast, the process of **sporogony** results in the formation of **sporozoites**.

Merogony is used by apicomplexan (see figure: Life cycle of an enteric coccidian below) and some amoeboid organisms. The nucleus and other essential organelles divide repeatedly before the cell separates; a large number of daughter cells are produced almost simultaneously. Cells undergoing merogony are called **meronts** or **schizonts**. The daughter cells are called **merozoites** and finally break away from a small residual mass of protoplasm which is all that remains of the mother cell. They then undergo another phase of merogony or enter gamogony.

Sporogony or sporulation is the multiple fission after the union of gametes and is seen in some of the Apicomplexa. Many protozoans must undergo sporulation outside the host before they become infectious. Sporogony occurs in life cycle stages that occur in the environment orin the vector host, and results typically in elongate **sporozoites** that have roles in establishing new infections in the vertebrate host. For example, the malaria mosquito injects malaria sporozoites into the human host.

Sexual reproduction

This is seen commonly in the Apicomplexa and involves the formation of gametes followed by union to form a zygotic cell. As apicomplexans are intracellular parasites, the formation of gametes occurs within host cells. The cell that divides to form the gametes is called the **gametocyte**. Meiosis occurs in the first division of the zygote following fertilisation. That is, all life cycle stages from sporozoites through to gametocytes are all haploid, only the fertilised zygote and unsporulated oocyst is diploid.

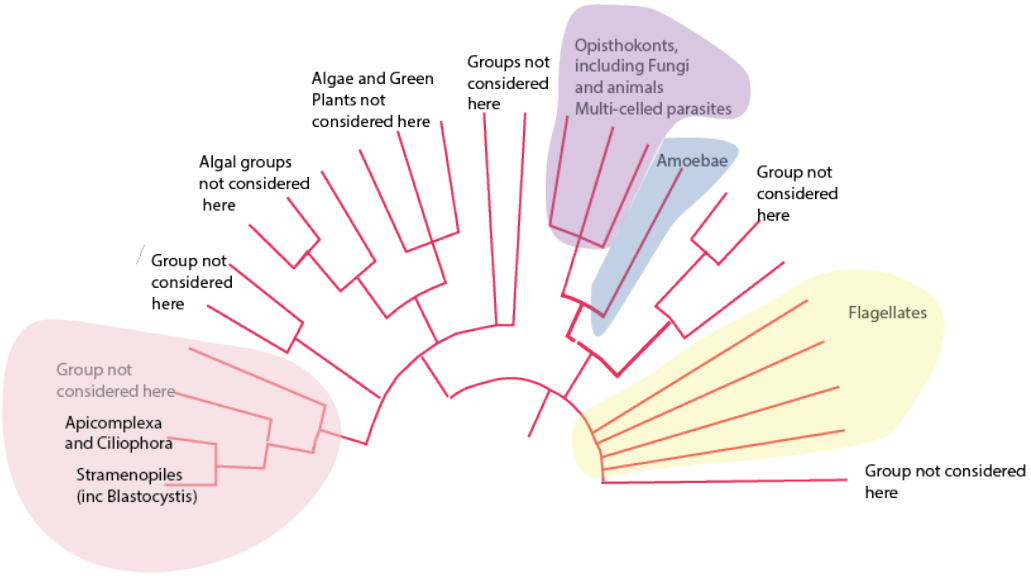
The reproductive process of **gamogony** is the formation of haploid gamete-like cells from gametocytes in a process of sexual reproduction.

In the Ciliates a form of sexual reproduction occurs, called **conjugation**, occurs. This involves the exchange of haploid nuclei between two cells that have fused.

Overview of the Parasitic Protozoa

The taxonomy of the eukaryotes is exceedingly complex. In the figure below, the interrelationships of the various clades of eukaryotes is presented as a phylogenetic tree[2]. The groups we consider as parasites, as

well as the pathogenic fungi, are all eukaryotes. Note that the apicomplexans are more closely related to the ciliates and to the bizarre intestinal parasite (*Blastocystis)* (pink-shaded branches at left of figure). The flagellates (yellow shading- far right of tree) belong to a distinct clade of organisms, which to a large extent are characterised by possession of more than one flagellum per cell. The amoebae and opisthokonts form sister groups (purple shades). The Opisthokonta is a large and diverse clade of organisms that includes many unicellular and multicellular species. Prominent members of this clades are the animals and fungi. All multicellular parasites (that is the worms and arthropods) belong in the Opisthokonta group.



The relationships of the eukaryotes of veterinary significance. Note: Taxonomic groups not of veterinary relevance have not been named in this image.[2]

Adapted from Burki, F. Roger, A.J. Brown, M.W. Simpson, A. G.B., The New Tree of Eukaryotes. *Trends in Ecology & Evolution.* 2020; 35, 1, 43 – 55. doi: 10.1016/j.tree.2019.08.008. Creative Commons Attribution 4.0 licence.

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Phylum Apicomplexa

Phylum Apicomplexa contain members that are characterised by possession of an apical complex in the cell. The **apical complex** is an aggregation of vesicles and bodies (conoid, polar ring, micronemes, rhoptries, subpellicular microtubules and micropore) that is used for invasion of host cells. All apicomplexan species are parasitic and are obligate **intracellular** parasites. Apicomplexans show high host specificity, and are highly restricted in the cells that they can invade. In the section below on coccidians, we

show the distribution of different species of *Eimeria* in the gastrointestinal tract of chickens. Each *Eimeria* species invades distinctive region of the tract, and this site specificity is governed by species-specific arrays of molecules expressed by the apical complex.

As stated above, the apicomplexans use a glideosome to move. The apicomplexans can only really glide across the surface of host cells. These parasites are not capable of independent movement in the external environment and must rely on tissue fluids (blood lymph or gut contents) to move within a host.

Haemoparasitic apicomplexans are parasites of blood and are carried with the blood stream. **Haemozoans** rely on vector species, such as mosquitoes or ticks, to transfer them between definitive hosts. The **coccidians** are parasites of the gastrointestinal tract, and a carried with fluid flow through the tract. Coccidians exist in the external environment as **oocysts**. These immotile stages are typically ingested with food or water. As the oocyst passes through the tract, the wall is digested by host enzymes and liberate multiple infectious cells, the sporozoites. Sporozoites will pass through the gastrointestinal tract with peristalsis. Some will be pushed against the lining of the gut and if they encounter a susceptible cell, will invade that cell through action of the apical complex. After multiple reproductive stages, zygotes of the coccidians will encyst to form the oocyst. The immobile oocyst is entirely dependent on environmental factors and host eating and drinking behaviours to further the life cycle.

Coccidians

Coccidians are highly host-specific parasites of the gastrointestinal tract of animals. All animals of veterinary importance are infected with coccidians and these parasites are highly pathogenic. Most coccidians have a one-host life cycle. Here, we shall call these parasites the **enteric coccidians**.

There are also three genera of coccidian-like organisms that can use multiple hosts to complete their life cycle. These, which we call here the **tissue coccidians**, will have a definitive host in which the parasites undergo sexual reproduction, and an intermediate host in which the parasite undergoes asexual reproduction only. The tissue coccidians can occur in a range of tissues in the intermediate hosts.

Lifecycle of Coccidians

Terminology: The coccidians typically include three reproductive phases in their life cycles. Two are asexual forms of reproduction involving forms of binary fission or multiple fission. The reproductive activity is described in the table below.

Reproductive Stage	Form	Location	Progenitor Cells	Progeny	Activity of Progeny
Merogony	Asexual reproduction by schizogony	Within cells of the gastrointestinal tract	Sporozoites or Merozoites	Approximately 12-24 Merozoites are formed from each schizont within a host cell.	Offspring of merogony are called merozoites. These can: 1. Invade new cells to undergo merogony, or, 2. Invade new cells, transform to gamonts and commence gamogony.
Gamogony	Sexual Reproduction	Haploid gamonts develop within cells of the gastrointestinal tract.	Merozoites invade cells and transform. These can become: 1. Microgametocytes, producing microgametes 2. Macrogametocytes, producing macrogametes.	Microgametocytes: many microgametes are formed. These escape the host cells Macrogametocytes: These form macrogametes that remain inside the host cell until fertilised by a single microgamete.	Fertilised cells (zygotes) will escape the host cell while forming a cyst wall. The mature oocyst passes with faeces from the host.
Sporogony	Asexual reproduction	The zygote within an oocyst will rupture a host cell and pass with faeces.	Zygote	Sporozoites. There are typically 8 sporozoites within an oocyst.	Sporozoites remain dormant in the oocyst and will emerge when the oocyst is ingested by a suitable host.

The coccidians form a very diverse group of intracellular parasites. Most parasites of veterinary importance belong to the Order Eucoccidiorida. Identification of genera and species can be difficult and relies on the observation of **oocysts** within faeces. In a faecal preparation, identification of the coccidian species is based on size of the oocyst, the number of **sporozoites** in the mature oocyst generally. In some genera, sporozoites are arranged within smaller cysts within the oocysts. These sub-cysts are called **sporocysts** and the number of sporocysts within an oocyst and the number of sporozoites within a sporocyst can be used to distinguish major genera of coccidians.

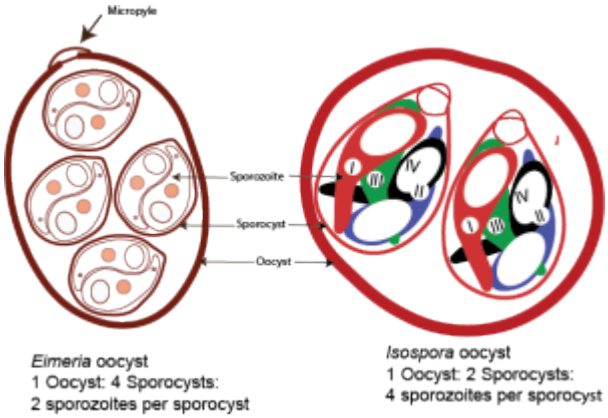
Enteric Coccidia

General features

The enteric coccidians have a direct life cycle (i.e. no intermediate hosts), and gamogony and merogony occur in the digestive tract of single host. There are many genera, but the two primary genera are ***Eimeria*** and ***Isospora.***

Genera of Important Coccidians

The genera *Eimeria* or *Isospora* may be distinguished by the structure of the mature oocyst in faeces. It is important to remember that the oocysts may be unsporulated (immature) when observed in fresh faeces, and this may complicate diagnosis.



Oocysts of *Eimeria* and *Isospora*

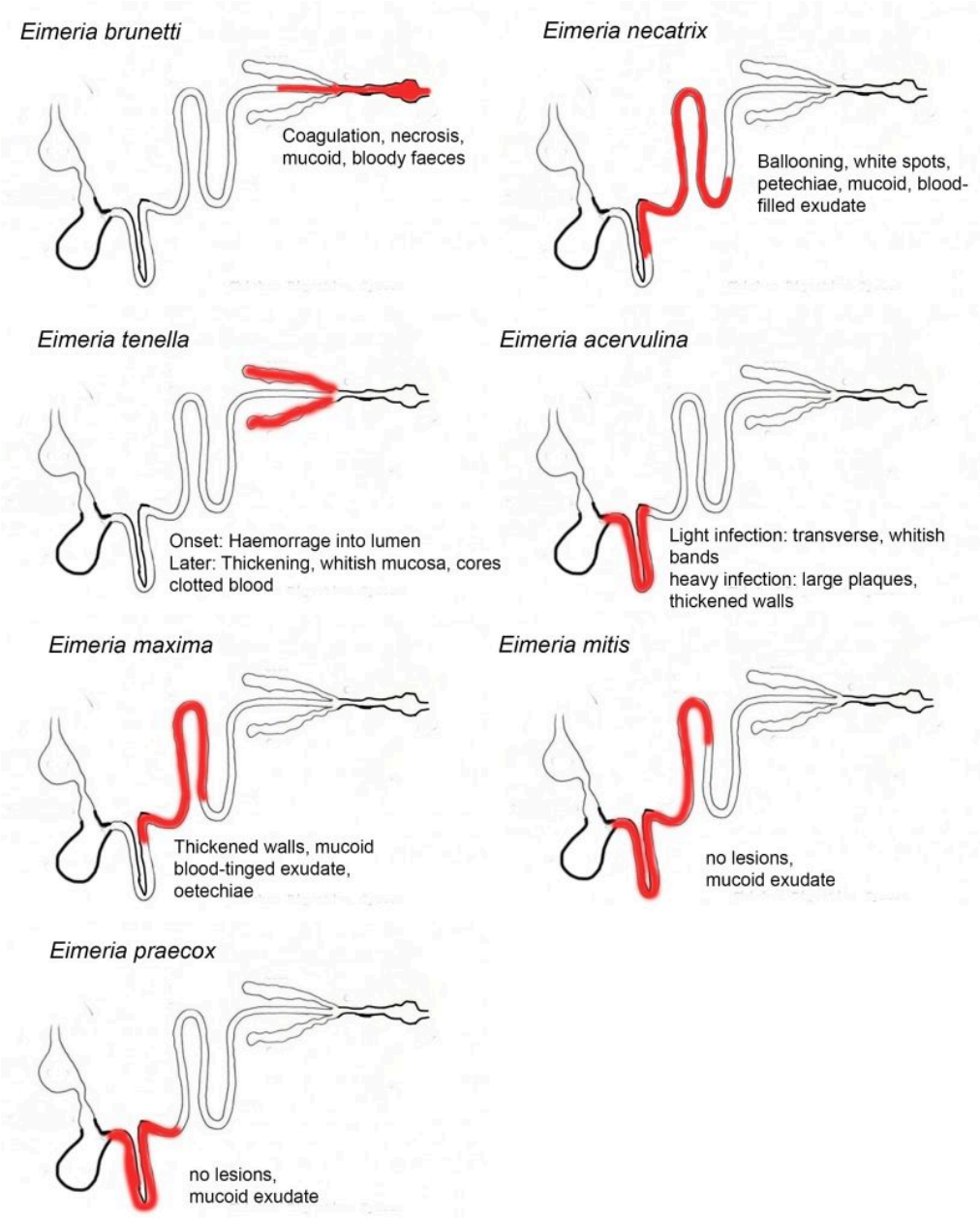
For species of *Eimeria*, the oocyst has a **1:4:2** configuration. That is, the **1 oocyst**, contains **4 sporocysts** (sub-cysts in the oocyst), with **2 sporozoites** in each sporocyst (see figure). The 8 sporozoites are the infectious organisms that will establish new infection when an oocyst is ingested by a new host. Members of the genus *Eimeria* are common in birds, especially poultry, but are also found in ruminants and marsupials. Non-pathogenic species of this genus occur in pigs.

Members of the genus *Isospora* has the reverse configuration. The **1 oocyst** contains **2 sporocysts**, each with **4 sporozoites**. (Note that oocysts of both genera always have 8 sporozoites in total). Mildly pathogenic species in **carnivores, people** and **pigs.**

Some species, originally described as belonging to the genus *Isospora* were recently transferred to the genus *Cystoisospora*. Such species include those infecting humans, pigs and some carnivores. Some *Cystoisospora* species are able to form tissue cysts in tissues other than those of the gastrointestinal tract.

Life cycle of enteric coccidians

Members of the genera *Isospora* and *Eimeria* are highly host specific. Domestic hosts can be infected with multiple species of either *Eimeria* or *Isospora*. Pigs, however, carry species of both genera. Different species can occupy different regions of the gastrointestinal tract (See figure on distribution of *Eimeria* species in the gastrointestinal tract of poultry, below). While most species infect lining cells of the tract, some coccidians can infect the kidneys (*Eimeria* in geese), the gall bladder (in rabbits) or liver (marsupials). Different species are variable in pathogenicity, and the effects of the coccidians on hosts is dependent on the age of the host and initial infectious dose.

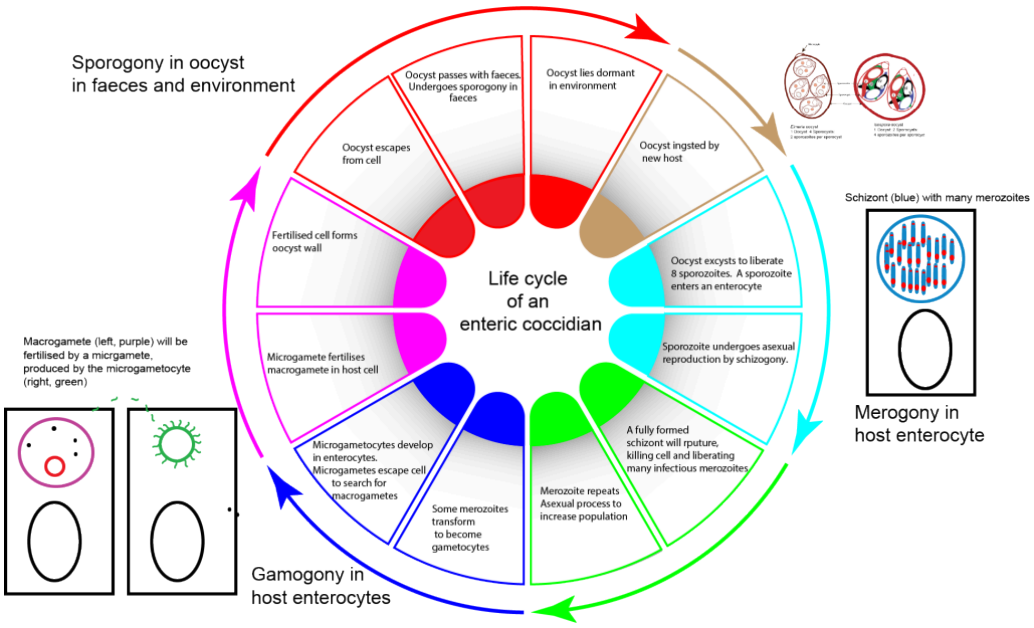


Sites of infection of different species of *Eimeria* in the chicken gastrointestinal tract. The red shade shows the distribution of each species. Pathogenic effects of each species is also indicated.

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Terminology of life cycle stages is provided in the section on Reproduction. Details of the life cycle is provided in the graphic below.

Life cycle of an enteric coccidian



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An ingested **oocyst** will pass into the gastrointestinal tract. The oocyst wall and sporocyst wall will be digested by proteolytic enzymes in the stomach and duodenum. In *Eimeria* and *Isospora*, 8 sporozoites will be liberated.

The sporozoites will pass with passage of food and peristalsis through the GIT. Some will brush against lining cells of the GIT. These will invade the enterocytes using components of the apical complex of the parasite cell.

Once inside a cell the sporozoite will grow, using nutrients from the cell. This parasite develops into a larger cell, which divides by multiple instances of mitotic replication to form progeny cells (approximately 24 in some species). This dividing cell is called a **schizont**; the progeny produced by asexual reproduction are **merozoites**.

When fully mature, the schizont will rupture from the host cell, killing it. Merozoites invade new enterocytes, forming the next generation of schizonts. This process can be repeated many times until the host dies, or develops an effective immune response. Generally, it takes from 4-7 days for a chicken to display signs of infection.

Some merozoites will invade host cells and will switch their developmental biology to become **gametocytes**. This life cycle process is called **gamogony**. The gametocytes are dimorphic.

Microgametocytes form spermatozoon-like microgametes; macrogametocytes form ovum-like cells. Microgametes fertilise macrogametes within the host cell. The resultant diploid zygote secretes an oocyst wall and ruptures the host cell. The oocyst is thus liberated into the lumen of the tract, and will eventually pass from the host with faeces. Coccidiosis can be diagnosed by faecal flotation microscopy when these oocytes appear in faeces.

Within the faeces, the zygote reproduces by asexual divisions to form sporozoites. This form of asexual reproduction is complex, in that the sporozoites are enclosed within sub-cysts, the sporocysts.

Coccidiosis is a disease of **intensive husbandry**, and can be exacerbated by conditions of stress and the presence of young or immunologically-naive animals. Poultry are particularly at risk of severe disease, with chickens especially at risk from infection with *Eimeria tenella*. Other animals at risk include dairy calves or early weaned beef calves that crowd around food supplement, or kittens or puppies in refuges, piglets (only *Isospora*, not *Eimeria*). Macropodids trapped on "islands" during floods, as well as rescued joeys, can be at risk of serious disease and death.

An intense infection can result in profuse watery to bloody diarrhoea, generally with high morbidity. Mortality varies with parasite species and host factors (age, breeding etc). Thus, it is important to identify the coccidians to species level.

Enteric coccidiosis is generally a **self-limiting infection**. That is to say, after a life cycle of a species has run its course in a host individual, the parasite will be entirely 'gone' from that host. Recovered hosts have a strong immunity to that **species of parasite**, but can still be susceptible to other species of coccidians.

This concept of self-limiting infection is important, as it can be used for parasite control by live attenuated vaccines. With this strategy, the parasites are artificially weakened through a variety of methods and oocysts from these weakened parasites are fed to chickens. The vaccine is either administered in water or by spraying with water onto the chickens. Chickens then ingest these weakened parasites. Because the development of attenuated parasites is slower than that of wild-type parasites the host is able to mount an acquired immune response to the parasite before the parasites reach population levels than are pathogenic.

Watch Benefits of coccivac vaccines in coccidiosis management (YouTube, 9m 58s).

Cryptosporidiosis (*Cryptosporidium* spp.)

The following information is based on the review of the genus *Cryptosporidium*[3]. Species of this genus belong to a family of small coccidian-like parasites. *Cryptosporidium* species occur in mammals, birds, and sometimes reptiles, and are almost always enteric.

Latest taxonomic studies suggest that there is likely to be approximately 120 distinct species (or genotypes) in the genus[3]. Three species, *Cryptosporidium parvum, C. hominis, and C. meleagridis* are responsible for most clinical cases in humans. The last species, primarily a parasite of birds, is the third-most common

cause of zoonotic infection, indicating that many species have a wide host range, that can span different classes of vertebrates. At least 12 species of the genus infect cattle, while 13 species infect sheep and goats. Rodents are common hosts of members of the genus.

Some 30 species of *Cryptosporidium* infect birds, with most infections occurring in digestive tract, respiratory system or renal system. Fifty-seven species of reptiles have been recorded as hosts of different species, and even fish, but less commonly amphibians can become infected.

Cryptosporidiosis can be transmitted to humans through contaminated water or at any stage of food production involving animals. Water-borne infections of humans are more likely to be caused by *C. hominis*, while food-linked outbreaks are more commonly caused by *C. parvum*. While predominantly associated with humans, *C. hominis* is able to infect a wide range of hosts. Interestingly, while dogs and cats are both hosts to *Cryptosporidium* species, these parasites do not easily infect humans, so household transmission between pets and humans is not common. *Cryptosporidium* (PDF, 341KB) is found in Australian wildlife, with macropodids and rodents being common hosts.

A survey of outbreaks has revealed that person to person or animal to animal transmission is the most common form of outbreak. Humans are most commonly at risk of *Cryptosporidium* carried by other humans or bovines. Animals and humans are often infected through water bodies contaminated by faeces. Other fomites that may carry oocysts include unpasteurised milk, uncooked meats, some vegetable sources, sewage-based contamination, agricultural effluents, and manure from infected animals. Cryptosporidiosis in production system accompanies stress and crowding.

Animals and humans are infected through the faecal-oral route (i.e. ingestion of oocysts). *Cryptosporidium* differs from the other coccidians described above in that there are only 4 sporozoites and these are not enclosed within sporocysts. Sporogony occurs prior to passage from the host, so oocysts in faeces are mature (the term is sporulated- that is, the oocysts always have developed sporozoites internally).

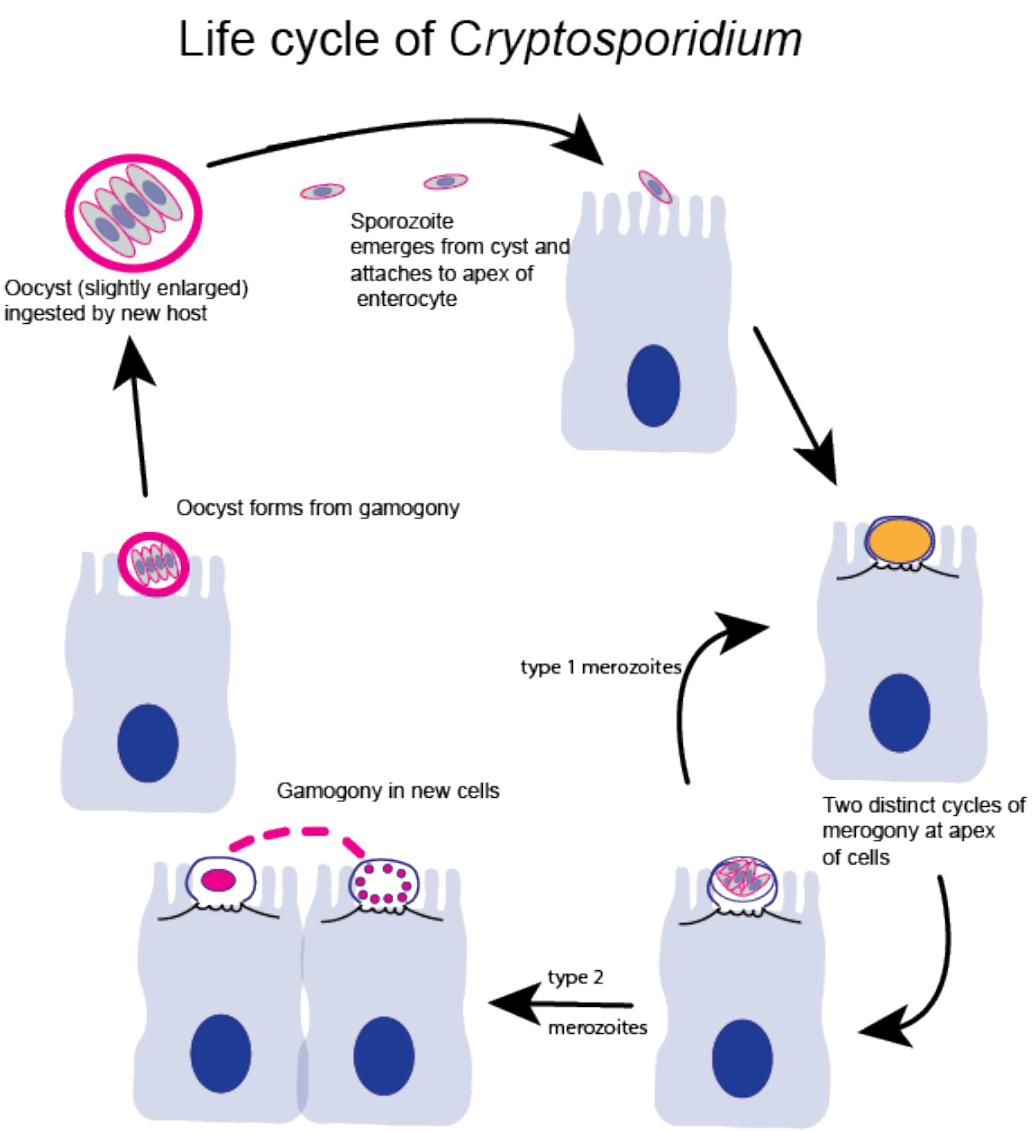
The oocysts are minuscule (6 microns in diameter) and are visible usually after staining with acid dyes.

Sites of Infection and Life Cycle

Cryptosporidium species infect mucosal epithelia, especially of the ileum (*C. parvum* in mammals), but also respiratory tract (birds) or stomach (reptiles, some mammalian species). One species of avian parasites infects the eyes of its hosts.

A host becomes infected after ingesting oocysts, which each contain **4 sporozoites**. The sporozoites form parasitophorous vacuoles (membrane bound spaces in which the parasites develop) around themselves. These structures are attached to the membranes of microvilli at the apex of the mucosal cells. The parasites occupy a peculiar location of the cell in that they are connected directly with the cytoplasm but their vacuole is outside of the cell- a hybrid between intracellular and extracellular parasitism. The parasites undergo rapid asexual reproduction, which is typified by the production of 'type 1' meronts. These

are asexual reproducing stages that form 8 merozoites. The type 1 meronts can undergo rapid asexual reproduction and can cycle indefinitely until immunity controls their population and eliminates them. Some will transform into type 2 meronts. These produce only 4 merozoites, that go on to form the sexual stages. An oocyst is formed by gamogony. Oocysts, can have either thick or thin walls. Thck-walled oocysts pass out of the host with faeces, while thin walled oocysts can auto-infect the host. Up to 20% of oocysts may excyst within the host. Thick-walled oocysts are very resilient in the environment and can be resistant to chlorine treatments of drinking water[3].



Life cycle of *Cryptosporidium*

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Disease

In most species, cryptosporidioisis is characterised by transient watery diarrhoea. Neonates are more likely to show clinical signs. Clinical signs may appear between 1-12 days after exposure and may last for days or weeks. Cyrptosporidiosis is generally self-limiting in immunocompetent hosts. In immunocompromised hosts, chronic and severe infections may occur. *Cryptosporidium* can cause serious secondary infections in people with advanced AIDS or who are on immunosuppressive therapies.

Tissue Cyst-Forming Coccidia

These coccidian parasites belong to the Family Sarcocystidae. There are three clades of primary importance in Australia, namely *Toxoplasma gondii, Sarcocystis* species, and *Neospora caninum*.

General features

The tissue cyst-forming coccidians are coccidian parasites, and thus possess many of the life cycle features described above. A major difference between these and enteric coccidians is that the tissue cyst-forming species display an **indirect life cycle** with a minimum of 2 hosts required – a definitive host and an intermediate host. The **definitive host** is a carnivore. Sexual reproduction (gamogony) occurs in this host. The **intermediate host** is most often a herbivore or omnivore, and merogony and cyst formation occurs in this host, usually in specific tissues or a range of tissues.

Toxoplasma gondii

This species was first discovered in 1908 as cysts is a variety of host species. The importance of *T. gondii* in congenital infection was discovered in the 1920s and 1930s, when the infection was recognised to be associated with cases of children born with hydrocephalus, retinochoroiditis and encephalitis. The species is also known to cause ocular disease, often in newborn children.

During the AIDS/HIV epidemic of the 1980s, many people with acquired immunodeficiency died of infection with *Toxoplasma gondii.* In the 1950s, the parasite was found to be the causative agent of **abortions in sheep** in New Zealand and an association with abortions in humans was also established.

Although *Toxoplasma gondii* was recognised as a coccidian-like parasite, for many decades the species was only known as a cyst-forming tissue parasite. The full life cycle was elucidated in the 1960s after felines were established as the definitive host, in which sexual reproduction of the parasite occurs.

A wide range of warm-blooded vertebrates can be intermediate hosts, especially mammals and occasionally birds. The parasite can also cause tissue cysts in cats.

Site of Infection and Life Cycle – Cats

In the cat, *T. gondii* is an **enteric parasite,** with oocysts being released in faeces. The **enteroepithelial** cycle of merogony, followed by gamogony culminates in the production of oocysts that are passed in the faeces. The life cycle in cats is thus similar to that of enteric coccidians described above. The oocysts are **unsporulated** in fresh faeces, and take 3-4 days to undergo sporogony and become infectious. The mature or sporulated oocysts appear as **small** oocysts (1:2:4 configuration), 10-13 x 10 microns. The oocysts can remain in the environment for up to 18 months.

Extraintestinal Cycle – Cats and Non-Feline Hosts

In many hosts (including cats), parasites migrate beyond the gut and proliferate asexually in **extraintestinal** tissues. There are two phases:

1. An **acute phase** in which there is rapid division of parasites to produce 8-32 **tachyzoites** in a cell. The tachyzoite ruptures the host cell and new cysts are formed.
2. In the **chronic phase**, division of the parasite division slows and parasites form tissue cysts, containing large accumulations of parasites, termed **bradyzoites** because of their slow development.

Tissue cysts are most commonly found in the brain, and in cardiac and skeletal muscles, and may persist for years. The formation of bradyzoites coincides with development of immunity to parasites and this immune status is maintained by the ongoing presence of the parasites. The immune state is called **premunition.**

Transmission

Toxoplasma gondii is transmitted to hosts through:

- ingestion of **sporulated oocysts** excreted by cats (in soil, litter trays, on inadequately washed vegetables, in sand-pits)
- ingestion of tissue cysts, especially in fresh or undercooked meat (freezing or cooking destroys these cysts)
- transplacentally.

Disease and Zoonotic Aspects

In most cases, infection produces few clinical signs and is followed by strong immunity.

There are two situations in which infection can be life threatening. The first situation is the infection of non-immune females during pregnancy. This is problematic in people, sheep and goats as the parasite can transit the placenta and cause lesions in the developing foetus.

Transplacental transfer is less common in the first trimester than the third trimester, but effects in earlier stages can be more severe. Infections early in gestation can result in severe disseminated lesions often leading to death of the foetus. In later stages, particularly the third trimester of pregnancy, effects may be less severe but can give rise to abnormalities in the foetus. Tachyzoites cause necrosis in the placenta and foetus, especially the central nervous system and eye. These lesions may give rise to abortions, still births, congenital abnormalities or ocular abnormalities which, in humans, may not become clinically apparent until 2nd or 3rd decade of life.

The second situation occurs when a host is immunocompromised. In such situations, new infections, or reactivation of bradyzoites that were previously contained by the immune system, can result in severe infections leading to severe pathology or death. This situation was observed frequently in people with AIDS during the epidemic of the 1980's.

Some useful tips on how to minimise risks of toxoplasmosis for people contemplating or entering child-bearing can be found in the CDC site of the USA. People at risk of toxoplasmosis should consult their health and veterinary professionals.

Neospora caninum

Neospora caninum was first described from dogs in 1984. Two species are currently known for the genus, *N. caninum* which uses cattle (and many other species, including chickens and other birds) as intermediate host, and *N. hughesi* from horses. *N. hughesi* only occurs in North America and causes conditions similar to a species *Sarcocystis neuroni.* Neither species appears to be a zoonotic risk.

Life Cycle and Transmission

Gamogony and oocyst formation has only been reported in canids, including domestic and wild dogs, dingoes, coyotes and wolves. Cattle are infected through ingestion of oocysts of *Neospora caninum* from pasture. The sporozoites will invade the host and form tachyzoites in various tissues. Cysts develop predominantly in the central nervous system and skeletal muscle of cattle. The species can also infect a wide range of domestic and wild hosts. Birds, including sparrows and domestic poultry can also be infected and it has been suggested that infection of cattle is enhanced when these birds are present.

The parasite does not pass horizontally from production animal (that is, the disease is not contagious between post-birth ruminants. However, in dogs and cattle, the parasite can be passed between generations, through the placenta, and in dogs via milk. In cattle, this vertical transmission is seen as an adaptation to sustain the population of the parasite in an environment where there are no dogs to sustain the full life cycle. This might be seen particularly in instances of intensive production.

Dogs can be infected by eating tissues of affected cattle or barnyard chickens.

Disease

Neospora caninum causes abortions in cattle because of invasion of the placenta during mid-to-late term pregnancy in cattle. Neosporosis can be a common cause of abortion in cattle. Calves that survive congenital infection may be weak at birth.

Canids are also able to harbour tissues phases. The parasite can pass from mother to pups via the placenta and possibly milk, resulting in **paresis** in affected pups.

Sarcocystis

Some 250 species have been described for this genus of tissue coccidians, but the taxonomy is far from settled. In Australia, *Sarcocystis* is common in sheep and cattle. Estimates suggest that probably 90% of sheep and 60% of cattle in Australia have cysts. Tissue cysts are common in skeletal and cardiac muscle and these can vary in size from microscopic to macroscopic. The parasite will undergo several cycles of merogony in endothelial cells before tissue cyst formation.

Numerous life cycles have been elucidated, including those of sheep-dog, cattle-dog, cattle-cat, sheep-cat, cattle-human and pigeon-hawk. Gamogeny and sporogony occurs in the small intestines of the definitive (omnivorous or carnivorous) hosts, but merogony does not occur. Fully mature (sporulated) oocysts produced within the cells of gut lumen. The oocyst wall breaks down during faecal formation, so that only sporocysts may be observed in faeces.

Transmission is by ingestion of uncooked tissue cysts for definitive hosts, and by ingestion of sporocysts for intermediate hosts.

There is no clinical sign of disease in definitive hosts as the asexual, proliferative, stage is not present. Most infections in intermediate hosts are also asymptomatic. Macroscopic cysts may cause condemnation of animal carcasses at abattoirs. In the intermediate host, different parasites may vary in pathogenicity. Rarely, tachyzoites in endothelial cells may produce anaemia and fever and Sarcocystis neurona can be a cause of abortions in horses. Tissue cysts may occasionally produce clinical disease; muscular or neurological usually.

Other tissue coccidians

Besnoitea species can cause debilitating skin lesions in cattle, but not in Australia. *Besnoitea*-like species are present in kangaroos and other wild animals, but these species do not seem to transfer to cattle.

Class Haematozoa

The formal name for this clade is the **Class Aconoidasida**, but we will use Haematozoa because its prefix (haema-) assists to signify where in the hosts these species occur. There are two orders, the Order Haemosporia and the Order Piroplasmida. The haemosporidians includes human parasites like malaria and avian parasites, such as *Leucocytozoon*. The piroplasms contain many species of veterinary significance, including *Babesia* and *Theileria*.

Haematozoans infect **blood cells** in the definitive host. Because of this infectious site, the parasites must be transmitted between definitive hosts, through the activity of blood-feeding arthropods or other invertebrates.

Order Piroplasmida – the tick fevers

The term 'piroplasm' comes from the Latin word *'pirum'* which translates to the English word 'pear'. The parasites are seen as small single-celled pear-shaped organisms in erythrocytes of mammals. Species in this group are transmitted between hosts **by ticks**.

The piroplasms are now known to undergo a form of sexual reproduction involving fusion of morphologically similar gametes. This fusion occurs in the gut lumen of ticks (this would make the ticks the true definitive host, but let's not go there!). The cells that form the presumptive gametes develop in the blood-stream of the mammal host and are transferred into the gut of a naive tick through a blood meal.

Reproduction in the mammal cells is by binary fission within the cell. In the tick hosts, the parasites undergo merogony and thus produce multiple offspring from a single cell.

Babesia spp.

Members of the genus *Babesia* are important blood parasites of mammals and birds and are responsible for severe haemolytic disease. In mammals, at least, *Babesia* is transmitted by ticks of the family Ixodidae (the hard ticks). Two species of *Babesia* from north America and Europe can infect humans, and there have been cases in the USA of one of these species being accidentally transmitted with blood transfusions.

In Australia, there are four species of primary concern.

Babesia bovis and *Babesia bigemina*

These species are parasites of cattle, and together with the bacterium ***Anaplasma marginale***, are agents of the **tick fevers** of cattle in northern Australia. All three tick fever organisms are transmitted by ***Rhipicephalus australis*** (the Australian cattle tick). ***Babesia bovis*** is an extremely virulent parasite. This species causes a haemolytic anaemia with fever and "toxic shock"-like syndrome. Blood in urine (haemoglobinuria) can occur. Infection may give rise to neurological signs (e.g. aggression, paralysis) due

to sludging of red blood cells in the capillaries of the brain. **Peracute** and acute cases may simply be found dead. ***Babesia bigemina*** is generally less pathogenic than *B. bovis,* although still of concern.

Babesia canis and *Babesia gibsoni*

These are parasites of canids. ***Babesia canis*** is transmitted by ***Rhipicephalus linnaei.*** Although the vector is widespread, infection with ***Babesia canis*** seems to be overwhelmingly confined to tropical regions in Australia. The vector of *Babesia gibsoni* in Australia is unknown, although it may be transmitted by *Rhipicephalus linnaei* or *R. sanguineus* and *Haemaphysalis longicornis* in Europe and *Haemaphysalis longicornis* in New Zealand. In Europe, dog breeds used for illegal dog-fighting are especially prone to infection and one explanation may be that blood is transferred between two individuals during a fight. ***Babesia canis*** in Australia, generally produces haemolytic anaemia in puppies or no clinical signs at all. The strain of this species in Australia is less virulent than exotic strains, some of which produce syndromes similar to *B. bovis* infection in cattle (including neurological signs). There is evidence from Europe to suggest that *B. gibsoni* may be more pathogenic than *B. canis*.

Life Cycle

The following account will describe the life cycles of the bovine species. There are slight variations in life cycle biology between the two species of cattle.

Infection occurs when an infected ***Rhipicephalus australis*** tick feeds on a bovine host and injects saliva with parasites into the host. Larval ticks can transmit ***Babesia bovis,*** while nymphal ticks transmit ***Babesia bigemina.*** The parasites initially invade circulating lymphocytes and then continue in red blood cells. Parasites infecting host RBCs divide by binary division to produce two (sometimes four) parasites within the red blood cells. Host red cells rupture and liberated merozoites penetrate new RBCs. The rupture of millions of blood cells can overwhelm the animal, resulting in toxic shock, breakdown of organs, and excretion of blood in urine (hence the name redwater fever as a description for babesiosis). The parasites have a prepatent period of 3 weeks (that is, the. time from infection of a bovine until parasites can be seen in blood smears).

Babesia bovis appears to modify the membrane of red blood cells it affects, causing infected cells to stick together in capillaries. The aggregation of 'sticky' cells can block capillaries, causing anoxia in downstream tissues.

Some parasites in red blood cells will transform into gametes in the blood stream. Once ingested by a tick, these will transform in the gut lumen to become ray bodies. Two ray bodies fuse, and the resultant zygote will enter a gut-lining cell of the tick. Within that cell, the zygote will undergo meiotic division to form haploid merozoites. These then continue to invade a range of cells in the tick body.

Two sorts of cell invasions are of special importance for the life cycle of the parasites. The first involves **invasion of ova** in female ticks. This choice of cell is of critical importance for maintaining the life cycle of

the parasites, for *R. australis* only infects one host individual in their life. Parasites that invade ova may go on to become incorporated into the egg of the tick and then into hatched larvae. This process of **vertical transmission** is called **transovarial transmission.**

The second invasion is of the cells of the salivary gland. Parasites in the gland cells will rupture in the salivary gland lumen and will be transmitted with saliva. This is the means by which ticks infect animals. Salivary gland infection can also be important for **trans-stadial** (between stages) infection in cases where a cattle tick is accidentally transferred between hosts through close contact.

Theileria spp.

Theileriosis is a major disease of ruminants in other regions of the world. *Theileria parva* is an important agent of disease in cattle and buffalo in East Africa, while *T. annulata* is important for cattle and buffalo in North Africa, southern Europe, India and China.

Until recently, Theileriosis was not considered to be important for cattle in Australia. Historically, the parasite in Australia, ***Theileria orientalis buffeli*** was common in cattle, but was thought to be only associated with mild forms of anaemia. More recently, more serious disease has been observed and attributed to a new strain (isolate) called *Theileria orientalis* 'ikeda'. The disease is referred to as Bovine Anaemia caused by *Theileria orientalis* group (BATOG).

BATOG affects calves, late pregnant or recently calved cows. BATOG can cause anaemia, fevers and red urine, jaundice, breathing difficulties and gasping after running, abortions or still births, dystocia and lower milk yields.

Theileria orientalis in Australia appears to use species of *Haemaphysalis* as vectors, notably *Haemaphysalis longicornis,* but also possibly *H. humerosa* and *H. bancrofti*. *Theileria* uses **transstadial transmission** (i.e. across moults of the tick host) between nymphs and adults, but **not transovarial transmission.**

Overseas, clinical disease with Theileriosis is much more important and characterised by initial fever and swollen lymph nodes. Subsequent symptoms vary with *Theileria* species and include rapid loss of condition, respiratory distress, diarrhoea and heavy mortalities (*T. parva*, the agent of East Coast Fever), haemolytic anaemia and icterus with protracted recovery in survivors (*T. annulata*, agent of Mediterranean coast fever).

Cytauxzoon felis

Visit Feline Cytauxzoonosis (PDF, 23KB).

This organism is related to members of the genus *Theileria* and is transmitted by the bite of a tick.

Cytauxzoon felis primarily occurs in North America, where it is transmitted by the Lone star tick, *Amblyomma americanum.* The species is normally a parasite of the American bobcat (*Lynx rufus*).

In the feline host, the parasites will firstly invade mononuclear phagocytic cells. These cells can enlarge and at times, may occlude capillaries. After the tissue phase, the parasite enters an erythrocytic phase, in which red blood cells are infected.

Although first described for North America, there is evidence that the parasite is also found in South America and parts of Europe.

Order Haemosporia

This group contains **malaria and malaria-like parasites** that are primarily parasites of red cells, and sometimes white blood cells. Members of this group use parasitic arthropods as vectors. While many of the hundreds of species known for this group are generally of little harm to the host, some, notably the agents of human malaria, are highly pathogenic.

Plasmodium spp.

This genus contains parasites generally referred to as the malaria parasites. *Plasmodium falciparum*, the agent of malignant malaria of humans, is responsible for the deaths of 400,000 people per year, primarily children in Africa. Other species of malaria cause significant human disease. In some tropical areas of South America and Asia, zoonotic malarias are responsible for human disease. In humans, malaria is characterised by periodic fevers and chills. As with *Babesia bovis,* the agent of malignant malaria, *P. falciparum,* causes aggregation of red cells in capillaries of the brain and other organs. Severe cases may lead to cerebral malaria, resulting from decreased blood flow and de-oxygenation of the brain.

In Australia, species of *Plasmodium* are recorded for birds and reptiles (snakes and lizards), but these are neither zoonotic nor transmitted to domestic animals. These wild (sylvatic) malarias of Australia are usually not considered pathogenic, though illness ("sick bird syndrome") and deaths have been reported. Evidence of malaria infection in birds is most likely to been seen in blood smears from asymptomatic carrier birds. In these the obvious sign will be the presence of *haemozoin* – characteristic brown pigment produced from digestion of host haemoglobin by the intra-erythrocytic parasite.

Plasmodium species are transmitted by species of mosquitoes. For human malaria, the vectors are from the mosquito genus *Anopheles.*

Haemoproteus spp.

Members of this genus infect a wide number of species, including birds, lizards and turtles. Members of *Haemaproteus* are transmitted by biting midges, tabanid and hippoboscid flies. Mostly species are considered non-pathogenic; parasitaemias (infection of host blood cells) of up to 50% have been associated

with no clinical signs of disease. If disease is evident in an infected host, then one should look for underlying stressors.

Haemoproteus has been recorded in over 50 species of Australian birds and commonly infect pigeons, ducks, turkeys. The life cycles are poorly known. The first development stage appears to be an asexual meront that forms in various tissues including kidneys and muscle, depending on the species. This asexual reproduction gives rise to erythrocytic gametocytes that are taken up by the vector during a blood meal. The tissue phase can be pathogenic, especially in accidentally infected hosts but sometimes also in the normal hosts of the species. For example, a species of *Haemoproteus* can give rise to a seasonal disease in pied currawongs in the Sydney district. In this, it has been reported that birds fall out of the sky with extensive death of tissues in skeletal, cardiac and gizzard muscles.

Leucocytozoon spp.

This is an understudied genus of haemosporidians, with some 50 species known, although some 1400 distinct lineages have been identified (Valkiūnas and Iezhova, 2023). Infections occur world wide in domestic and wild birds. Disease, due to the development of large asexual stages in fixed tissues, can occur in domestic and wild birds. Asexual and sexual stages are found in a range of blood cells. Parasites of this genus are transmitted by simuliid blackflies and midges. Some species are highly pathogenic, especially in young birds but the significance of these parasites in wild Australian birds is not known. A species of *Leucocytozoon* can give rise to a seasonal disease in pied currawongs in the Sydney district (PDF, 5.1MB). It has been reported that birds fall out of the sky with extensive death of tissues in skeletal, cardiac and gizzard muscles.

There have been reports of mass deaths of the Nankeen kestrel to a *Leucocytozoon*-like organism that affected the optic nerve and CNS.

Phylum Ciliophora (Ciliata)

Members of the Ciliophora possess cilia in at least one stage of their life cycles. Most species are free-living, although the group includes many important symbionts of animals and humans. The ciliates have highly organised cells and these may be motile or sessile. Ciliates possess two forms of nucleus- the **macronucleus** and **micronucleus**. The macronucleus appears to be involved in day-to-day transcriptional activity of the cell, while the micronucleus is a genetic 'repository' or master-copy and is used in sexual reproduction.

Symbiotic Ciliates

Symbiotic ciliates inhabit the reticulo-ruminal systems of ruminants and the large intestines of horses. Many other herbivorous mammals and birds also harbour ciliates in their gastrointestinal tracts. The ciliates act as apex 'predators' in the systems, both by taking up plant materials (starch grains and plant

fibres) or ingesting members of the microbial components that inhabit the fermentation systems. Many prokaryotic microbes also lives as symbionts within the ciliate cell.

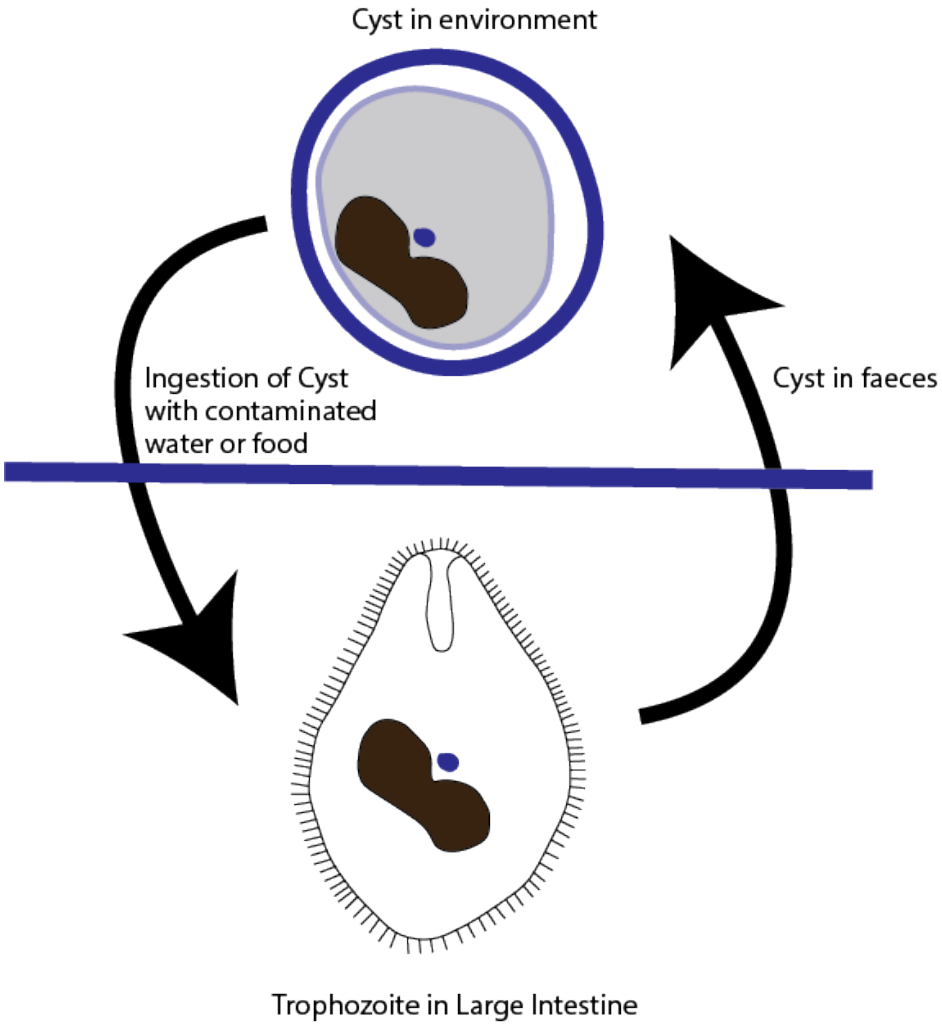
The ciliates may be recovered from the faeces, or may be found in ruminant lungs at necropsy due to agonal inspiration of ruminal contents. This is of no clinical significance!

Balantidium coli

This is a gastrointestinal parasite that lives in the large intestine of a range of hosts, especially people and pigs. This is the only ciliate known to infect humans. Other hosts include rodents, camels equiids and non-human primates.

This species normally gives rise to subclinical infections in the large intestines. In some cases, it may be associated with ulceration of the colon, diarrhoea and dysentery, especially in humans. Pigs are asymptomatic hosts, but are common sources of zoonotic infections.

Cysts (40-60 microns) are passed in faeces and contaminate the environment; following ingestion of cyst by the porcine host, the cyst wall is digested by enzymes and **trophozoites** (active, feeding stages) are released into the lumen of the intestines.



Life cycle of *Balantidium coli*

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=570#h5p-55

White-spot disease of fish

Ichthyophthirius multifiliis is the agent of white spot disease in fish. Active stages, visible as white spots, are seen on the epidermis, cornea and gill filaments of aquaria fish.

Blastocystis hominis

This strange parasite is related to the ciliates and apicomplexans, being a member of the stramenopiles. *Blastocystis* inhabits the large intestine of humans and a wide range of animals. It is uncertain if the organism causes disease.

The Flagellates

The flagellates are a diverse assemblage of single-celled eukaryotes that bear flagella at some point in their life-cycle. The species typically have multiple flagella arising from the cell. The flagellates reproduce usually by **binary fission**, an asexual form of reproduction, resulting in two identical offspring cells.

In the sections below, we will consider the flagellates in two groups: those that **parasitise mucosal surfaces** of the gastro-intestinal tract and the reproductive organs, and those that parasitise **blood** primarily.

Flagellates that Parasitise Mucosal Surfaces

Some important flagellates inhabit mucosal surface, either of the gastrointestinal tract or reproductive tissues. These mucosal parasites are transmitted from host to host in faeces or genital secretions.

Giardia spp.

Giardia doudenalis (also known as *G. lamblia* or *G. intestinalis*) is a parasite of domestic animals, humans and many wild animals. The full scientific name (*Giardia doudenalis)* is possibly a term of convenience, as the taxonomy of the genus is complex and confused. This complexity[4] arises because different forms encountered in different hosts cannot be distinguished by morphological means, and molecular studies suggest that there are many different genetic lineages infecting animals. Three species groups of *Giardia* are currently recognised, one group from rodents, a second from frogs and a third from birds and a wide range of mammals. The species of veterinary and medical importance, traditionally called *Giardia duodenalis,* belongs to that third group of species.

Giardia duodenalis itself, is a complex of at least 8 genetic lineages, with more likely to be discovered. Two groups, termed assemblages A and B, infect many mammals including humans, dogs, cats non-human primates, cetaceans and seals, and some birds.

Australian wildlife are commonly infected with *Giardia,* although reports of disease in these animals are rare. Reports of spillovers (transmission of *Giardia* assemblages from animals to humans) and spillbacks (transmission of *Giardia* adapted to humans infecting animals that are not normally infected by that assemblage) have been made.

What can we take from the complexity of the taxonomy of *Giardia*? The best message is that much more research needs to be done on the genetic lineages of *Giardia* that infect humans and domestic animals. From a **clinical perspective**, these scientific questions may not matter and it may be sufficient to identify an infection as giardiasis, without elucidating

the genetic identity of the isolate. However, variation in pathogenicity, epidemiology and resistance to drugs in particular cases may be explained by the genetic background of the parasite, so continued scientific investigations will be needed.

Giardia is an anaerobic, flagellated parasite, with cells characterised with two nuclei and 8 flagella. The flagella arise from the anterior end of the cell and are arranged into 4 pairs.

The ventral surface is modified into a concave cavity or sucking disc. Prominent cytoskeletal bodies, and medial bodies are present in the cell. The trophozoite of *Giardia* from mammals is 10-15 microns in length.

Giardia parasites attach to the microvillar surface of cells of the duodenum. Their feeding activity disrupts absorption and enzyme production by the cells. The parasites also secrete substances that are toxic to cells. The combined effects of heavy infections lead to malabsorption and poor extracellular digestion of food by the host. Animals with giardiasis will present with diarrhoea, often with excess fat and mucous appearing in faeces.

The life cycle of *Giardia* is simple and involves an active feeding stage, the **trophozoite**, in the intestine and a **cyst** in the external environment. With peristalsis, trophozoites become displaced in the intestine. As they move posteriorly, the environmental conditions will induce cyst formation to protect the trophozoite as it passes inevitably into the external environment. In normal faeces, the cysts are usually fully mature. The organism within the cyst wall will undergo nuclear division, so that the encysted form has four nuclei. Upon ingestion by a new host, the cyst wall will disintegrate, and the liberated cell with 4 nuclei will complete cell division to form 4 trophozoites. The pre-patent period in 3-10 days.

If a host has diarrhoea, *Giardia* may not have time to form cysts and parasite appears in faeces as a trophozoite. These trophozoites will not survive in the environment, and, if through any circumstances, these trophozoites are ingested by an animal, they will be killed in the stomach. Only encysted stages are able to establish new infections as the cyst wall protects the parasites from digestion.

Animals and humans are infected by cysts on foods by the faecal-oral route. Water-borne transmission is an important source of the parasites. Untreated tank water may be a source of infection. *Giardia* cysts can contaminate water supplies for humans and animals. *Giardia* cysts can survive freezing for some period of time.

Clinical signs

Giardiasis causes diarrhoea, especially in young or immunocompromised hosts. Giardiasis is most commonly seen in cats, dogs and caged birds. The diarrhoea can range from soft stool to watery

consistency, with a greenish tinge. Steatorrhea (fatty stools) may be observed. Many animals can carry *Giardia,* but are asymptomatic.

Trichomonads

The trichomonads are another group of anaerobic flagellates. These parasites inhabit the gastrointestinal and reproductive tracts of many animals. The organisms are pear-shaped flagellates with a rod-like axostyle (a cytoskeletal structure) protruding beyond their posterior margin. The cells have 3-5 flagella that emerge from the anterior margin of the cell. One flagellum runs the length of the cell and is attached to the cell by an undulating membrane.

The trichomonad species are difficult to distinguish from each other morphologically, and not surprisingly, there remains much uncertainty about the numbers of species there are in the clade, and about their interrelationships. Typically we rely on host and site specificity to distinguish species. Counts of the number of anterior and trailing flagella may assist, although molecular taxonomic methods will be more informative.

Tritrichomonas foetus

This species is responsible for early abortions in cattle, especially in maiden heifers. The parasite is transmitted by sexual activity. Infection is generally asymptomatic in bulls, but is pathogenic in females. In bulls, the parasite occurs in the preputial cavity and is transferred to females during coitus. In females, the parasite attaches to the lining of the vagina and migrates to the cervix and uterus. As the parasite is transmitted between individual hosts by direct contact during reproduction, there is no evidence of cystic forms in the life cycle of the parasite.

Infection with *T. foetus* causes loss of foetuses and such loss is one sign that the parasite is established in a herd. Bulls are asymptomatic carriers and screening of preputial washings, as well as of cervical mucous in females is one way of confirming the presence of the parasite in a herd.

There have been reports of *T. foetus* infections in other animals, including cats, horses and roe deer. In cats, the parasite is occurs in the gastrointestinal tract and, evidently, is transmitted through the faecal-oral route. This parasite can cause chronic diarrhoea in cats. In pigs, the parasite occurs in the nasal passages, stomach, cecum and colon.

Trichomonas spp.

This second genus of trichomonads are oral, intestinal and genital parasites of various hosts.

Important species include *Trichomonas gallinae,* which causes produces necrotic ulcerations in upper GIT

of birds, and *Trichomonas vaginalis*, which is spread sexually in people, and may produce vaginitis in women.

In addition to *Trichomonas vaginalis,* humans can be infected with *Trichomonas tenax,* a parasite of the oral cavity and *Pentatrichomonas hominis*, which occurs in the gastrointestinal tract. Originally described as a human parasite, *T. tenex* has now been shown to occur as an an oral parasite of dogs, cats and horses, and in the urogenital system of humans and monkeys and in the cloacas of some birds. The parasite is associated with periodontal disease, although whether the species is pathogenic is far from certain.

Histomonas meleagridis

This parasite infects galliform birds (turkeys, chickens, peafowl, quail and pheasants). Although an flagellate in birds, the species can occur either as a flagellated cell or as an ameboid cell devoid of flagella! The flagellated form occurs in the caeca of its hosts, while the amoeboid form occur in the liver. The parasite causes hepatic disease in affected birds. The parasites invade the walls of the caeca, migrating to other organs but especially the liver. Affected livers may have a bulls-eye (target) appearance when viewed macroscopically.

As with other species of this group, the parasite does not have a cystic form. Rather, transmission between hosts is often through direct beak-cloaca contact. Interestingly, the trophozoites of this species are able to enter the eggs of an ascaridoid nematode (*Heterakis gallinarum*). When a bird ingests the egg of the ascaridoid nematode, it may thus become infected with the nematode and this protozoan.

Flagellates of Blood and Solid Tissues (The Kinetoplastids)

These flagellates are parasites of the blood, lymph and/or tissue spaces for much of their life. The species must be transmitted by a vector, which is typically a **haematophagous** insect. Ticks and leeches can also act as vectors for some blood-dwelling flagellates.

The scientific name for the group, '**kinetoplastid**', derives from the presence in the cell of a large mitochondrion that is closely associated with the basal body of the flagellum. Typically, the kinetoplastids have one flagellum in the cell. The cells of kinetoplastids can vary considerably throughout the parasitic life cycle of the organisms. Some stages lack flagella, while in other stages, the flagella can emerge from either the anterior pole or the posterior pole of the cell.

The kinetoplastids contain some important parasites, including the African trypanosomes, the South American trypanosome and the members of the genus *Leishmania.*

Trypanosoma species

Trypanosomes are typically seen in the blood of their hosts. The blood-resident stage are elongate cells,

bearing a single flagellum that emerges from the anterior end of the cell. Other life-cycle stages of the trypanosomes, such as those in an arthropod digestive tract or salivary glands will have different morphologies, which we will not consider here. One species (*Trypanosoma cruzi*, from the American continents) can invade host cells, and its intracellular form lacks a flagellum.

Trypanosomes infect a wide range of hosts from all vertebrate groups. The trypanosomes are relatively host specific although there are important zoonotic species. Australia is largely free from pathogenic or zoonotic trypanosomes. Five exotic species have been introduced to Australia[6]. Of these, *Trypanosoma lewisi,* a parasite or rodents, was introduced to Christmas Island and may have led to the extinction of two species of native rats[6]. The pathogenic agent of surra in horses, *Trypanosoma evansi*, was fortunately eradicated soon after its introduction to Australia[6].

As parasites of blood or internal tissues, trypanosomes require a blood-feeding vector to sustain the life cycle. Mammals can be infected with trypanosomes by:

- **Salivarian Transmission:** Trypanosomes with salivarian life cycles are transmitted by the bite of an infected arthropod (or sometimes a leech). The parasite is introduced into the blood stream with arthropod saliva.
- **Stercorarian Transmission**: Trypanosomes with stercorarian life cycles infect mammals through contamination of the host's mucous membranes, or of abraded skin, with faeces of the infected arthropod.

Salivarian trypanosomes

The most notorious forms of the parasites are found in the *Trypanosoma brucei* complex of species, the agents of African trypanosomiasis. These species are transmitted by the tsetse flies (*Glossina* spp.) and are thus confined to tropical Africa. The parasite follows a complex development within the tsetse fly, with individual parasites migrating from the digestive tract through the body cavity to the salivary glands.

In other species, the parasites do not always undergo development within the vector, and are transmitted mechanically by biting flies or vampire bats.

Clinical signs of trypanosomiasis vary with parasite species, and the susceptibility of host species. The agents of African trypanosomiasis (also called sleeping sickness or Nagana) are blood parasites. Animals and humans infected with the trypanosomes will undergo periodic fevers associated with fluxes in the populations of the parasites in host blood and lymph. For reasons unknown, the parasites may invade the cerebrospinal fluid, resulting in early stages in fever, with increasingly adverse neurological signs. The long-term result of this neurological invasion is a disease called sleeping sickness in humans, a progressive neuropsychiatric disorder. Sleeping sickness will almost certainly result in death of the human if the disease is not treated. Horses and dogs are also highly susceptible to blood infection and the subsequent neurological disorders. Nagana**disease** is produced in ruminants. Nagana is only mildly pathogenic in indigenous wild ruminants of Africa, while it is highly pathogenic in introduced ruminants. African

trypanosomes are thus major One Health pathogens, affecting both humans and their livestock. Trypanosomiasis is a disease that reinforces poverty in endemic areas. The disease affects animal fertility, yields of milk and meat, and reduced herd size. The wildlife hosts act as reservoir hosts.

Trypanosoma evansi produces the disease **surra** in all species of domestic animals. Its clinical presentation and effects on different host species is similar to that described above for *T. brucei*. It is transmitted mechanically by biting flies, rather than requiring the fly for development. The agent of surra is widespread, occurring in Africa, Asia, some parts of Europe and South America. The parasite is present in Indonesia and East Timor, and thus remains a biosecurity threat for Australia (PDF, 275KB), not only for its threat to animal production, but also for wildlife

Stercorarian trypanosomes

The most well-known stercorarian trypanosome is *Trypanosoma cruzi*, the agent of Chagas disease. This zoonotic parasite is present in South America, particularly Brazil, but it has spread to North America. The intermediate hosts are species of reduviid bugs (Order Hemiptera). Hemipterans are usually sap-sucking insects, but the reduviids are among some bug groups that have become blood feeders. Members of the hemipteran genus *Triotoma* are the vectors- these bugs are sometimes called kissing bugs, cone-nose bugs or vampire bugs. The bugs live usually in proximity to vertebrates and they can be found in sheds or poor-quality housing with gaps in the walls etc in which the bugs can hide. In the USA, the reduviid bugs typically do not inhabit human housing. Some of the vector bugs can be found in sugar cane farms. People have become infected by drinking juice from the sugar cane. In such instances, infected bugs are crushed with the cane and people imbibe the contaminated juice.

In the mammal host, *T. cruzi* invades host cells, typically cardiac and smooth muscle cells and cells of the reticuloendothelial system. The infected cells form into cyst-like colonies (pseudocysts in muscle cells). The parasites within host cells lack flagella and are termed **amastigotes**. When an infected host cell ruptures, it liberates the amastigotes, which transform into flagellated **trypomastigotes.** These circulate in blood and may enter another host cell. Some circulating trypomastigotes may be ingested by the biological vector with a blood meal.

The clinical signs of Chagas' disease due to *T. cruzi* infection include **lympadenopathy**, **splenomegaly**, **hepatomegaly**, acute **myocarditis** and, in people at least, dilation of tubular organs (especially oesophagus and colon). These chronic conditions may not appear for years or decades after infection.

Trypanosoma theileri is a nonpathogenic stercorarian trypanosome found in cattle world-wide, including Australia, and is transmitted by tabanid flies.

Leishmania spp.

Members of this genus of kinetoplastids infect animals and humans from around the world. All 30 species

of *Leishmania* infect mammals, especially humans, dogs and rodents. One species occurs in Australia but this only infects kangaroos in northern Australia.

Worldwide, species of *Leishmania* are transmitted by sandflies (Diptera: Nematocera) of the family Psychodidae (subfamily Phlebotominae). Phlebotomines are obligatory intermediate hosts, transmitting the flagellates with saliva during blood feeding. Although the sandflies are required for the life-cycle under natural circumstances, the parasites can be transferred from host to host mechanically. Such mechanical transfer has been used as a means to deleterious outcomes in cases of **cutaneous leishmaniasis** in humans.

The parasite in the sandflies have flagella that emerge anteriorly in the cell (the stage is called a promastigote). After the bite of the sandfly, the parasite will invade host cells, typically macrophages. Within the host cells, the parasite loses its external flagella. The stage is known as an amastigote form.

Clinical signs

Different species of *Leishmania* are associated with the different syndromes:

Cutaneous leishmaniasis: In this form, the parasite cases ulceration of the skin. The ulcers may persist for 12 years.

Visceral leishmaniasis (or kala-azar): This form of the disease occurs when the parasites invade internal organs, most commonly the liver, but also the spleen. Clinical signs include hepatosplenomegaly, oedema, haemolytic anaemia. Dogs with visceral leishmaniasis often also become **alopecic** (initially commencing around eyes, the appear like spectacles). This is the **most common form in dogs**.

- Recovered animals have immunity, but long periods of remission followed by reappearance of clinical signs are also common.
- Some species are adapted to humans (via sandfly transmission) BUT the dog is a natural host for some strains which can also infect people (i.e. **zoonotic**).

The life cycle of *Leishmania* parasites.

During blood feeding by female sandflies, the parasites are regurgitated into the host by the sandfly. These parasites are then phagocytosed by cells at the site of the bite. Once inside the host cells, subvert the cell digestion pathways. They lose their flagellum, transforming into amastigotes and then develop and reproduce inside **phagolysosomes**, part of the cell digestive pathway. Amastigote replication may lead to host cell rupture, liberating parasites that go on to infect new phagocytic host cells.

When infected phagocytes are taken up by another sandfly during the blood meal, amastigotes transform into flagellated cells in the sandfly midgut. The parasites, developing through 2 more stages will fasten themselves to the lining of the anterior regions of the gut. When an infected sandfly feeds again, the

parasites are vomited back into the host. Thus, *Leishmania* does **not** invade sandfly tissues, but remains an intestinal parasite of the insect.

The Amoebae

The amoebae are species that move by means of **pseudopodia**. Parasitic amoebae reproduce asexually. Different forms are present including those infecting the gastro-intestinal tract, and those that invade the central nervous system. Amoebae are phagocytic, internalising microbes and minuscule detritus using their pseudopodia. In pathogenic amoebae, the parasites may phagocytose host cells.

In its simplest form, the life cycle alternates between active, feeding stages (the trophozoites) in the host and cystic forms in the environment. The trophozoites display amoeboid motion The amoebic cysts are resistant to environmental degradation and thus protect the metabolically inactive on the inside.

Most amoebae of the host gastrointestinal tract feed on bacteria in the intestine. As the feeding trophozoites pass down the gut, they form multinucleated cysts which are very resistant to environmental conditions. Transmission is by ingestion of cysts in contaminated food or water.

Differentiation between species is a job for a specialist; a number of non-pathogenic species occur in both people and animals.

Entamoeba histolytica

The most significant parasitic amoeba is *Entamoeba histolytica*. This species is the agent of **amoebic dysentery** in people, a serious disease of predominantly tropical regions that may have amoebic abscess of the liver or brain as a potentially fatal sequela.

Entamoeba histolytica is occasionally recovered from animal faeces, especially nonhuman primates and occasionally infects dogs and cats. There are rare cases of pathogenic infections of dogs caused by this species.

Facultative Amoebae of the Central Nervous System.

Some amoebae of water free-living amoebae that occasionally invade an animal host where they may produce serious disease. These amoebae are encountered in freshwater. The disease is best described in people e.g. amoebic meningoencephalitis due to *Naegleria fowleri* – especially following dipping of head into spa water/geothermal springs etc.

There are only sporadic reports of disease in animals. One case report from the USA describes infection of Holstein cattle with *Naegleria fowleri* resulting in meningoencephalitis[6]. The source of infection was most likely warm surface water used by the cattle.

Identification

- Information on various Protozoa

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PART V
PARASITOLOGY SKILLS

16.

PARASITE MICROSCOPY AND SYSTEMATIC PARASITE IDENTIFICATION

Learning Objectives

- Learn how to systematically identify an unknown parasite using relevant information and morphological keys.
- Familiarise yourself with the functional components of both the light microscope and the dissecting microscope.
- Examine slides and specimens provided and use appropriate techniques to make an identification.
- Become familiar with the microscopy skills appropriate for examining Gram stains (microbiology).

Parasite Microscopy

To identify a parasite easily and effectively, you must:

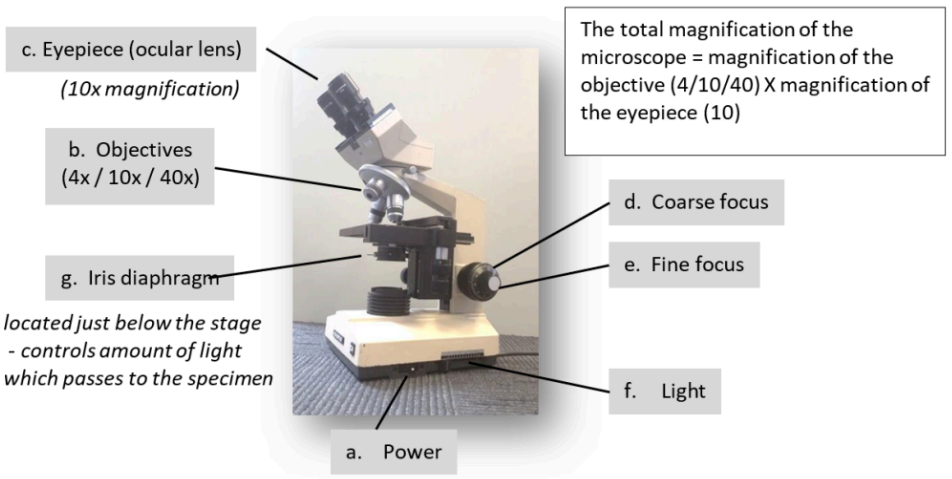
1. Obtain some information about the parasite host – i.e. the host it was found on/collected from, where about on/in the host it was collected?
2. Have access to some useful resources to help you make the ID – in addition to the knowledge you have about the parasites of various hosts, you might need to use dichotomous keys, host-parasite lists, information tables/charts. These resources should direct you to look at defining features of the parasite.
3. Be able to use both the light microscope and the dissecting microscope effectively!

Examining a small specimen using the light microscope

The types of specimens examined under the light microscope are those that are too small to see in any detail either with the naked eye or with the dissecting microscope (things like helminth eggs, protozoan oocysts or cysts, nematode larvae, small helminths, small ectoparasites like lice, mites and fleas).

The main components of the light microscope that you will need to be familiar with and adjust whilst examining parasite specimens are:

a. power
b. objectives
c. eyepiece
d. coarse focus
e. fine focus
f. light
g. Iris diaphragm.



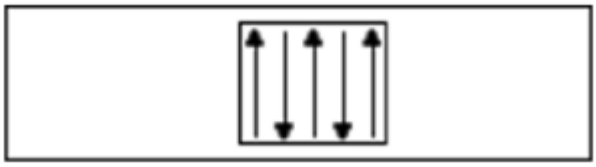
Components of a light microscope.

Image: © Lyn Knott

Procedure

1. Turn on the power (a).
2. Switch to the 4x objective lens (b).
3. Clip the specimen slide on the stage in the proper position.
4. Look at the ocular lenses of your scope (c). One lens is fixed and the other has a focusing ring (like a pair of binoculars). Use the coarse focus (d) to bring the lens as close to the slide as possible, then, looking only through the fixed ocular lens, back off until the specimen (or an air bubble or other artefact) just comes into focus. Adjust fine focus (e).
5. Now, looking only through the adjustable ocular, adjust its focus using the focus ring around the lens. Look with both eyes (adjust for distance between eyes until you see a single round lighted field) and make any minor adjustments to focus.

6. If you can locate the specimen on the slide easily – centre the image and adjust the light (f). If you can't locate the specimen easily, move to the corner of the coverslip and systematically scan up, across and down until you locate it (easier to do this on a lower power like 4x or x10).

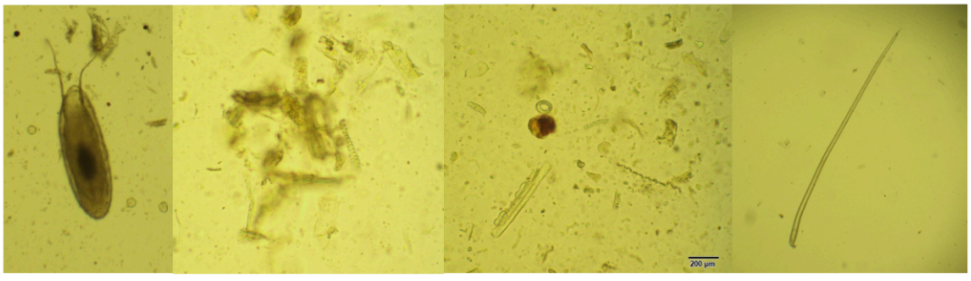


7. Once you have located the specimen and chosen the desired objective for magnification, adjust the light and use the fine focus to get the image as clear as possible.
8. Check the iris diaphragm (g) is positioned adequately – as you move the lever to the right you'll notice there is more contrast and as you move the lever to the left the contrast will decrease. The optimal position of the iris diaphragm for looking at most parasite structures is centre to right.
9. Change objectives as needed – for most parasite eggs, 10x objective is adequate. For smaller structures e.g. protozoan oocysts/cysts, 40x will be required. You may need to readjust the fine focus and iris diaphragm slightly after changing objectives.

Non-parasite material, artefacts or "junk"

As you scan around a slide, especially one prepared from a faecal sample, you will see lots of artefacts or "junk", as well as air bubbles and it's important to be able to differentiate between these structures and parasite stages. Things that may be seen include:

- food residue
- products of digestion
- plant cells
- epithelial cells
- mucous
- microorganisms such as yeast and bacteria.



Artefacts and 'junk' visible in faecal float.

Images: © Lyn Knott

First – be mindful of the parasite structures which you **expect** to find in a particular sample. For example, when examining a faecal float from a sheep you could expect to find strongyle eggs, tapeworm eggs, *Trichuris* eggs, or *Eimeria* oocysts. You would *not* expect to find *Toxocara* eggs (from dogs!) or *Parascaris* eggs (from horses!). Have your reference chart handy and refresh your memory

on what the eggs look like. If the structure you are examining under the microscope does **not** resemble one of these, there is a good chance it is an artefact.

Ask yourself:

- Is the structure a regular/symmetrical shape (i.e. round/oval)? Most parasite structures are symmetrically shaped (with some exceptions like certain tapeworm eggs). Plant material and other artefacts can be irregular shapes and sizes.
- Can you see any organised internal structures? When viewing an egg or oocyst, you can usually see an outer shell and some internal cell division or structure, or even perhaps developed larvae.

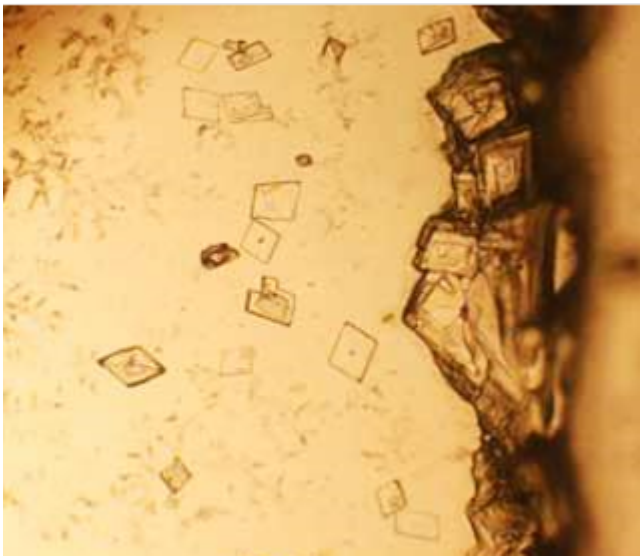
Don't be confused by air bubbles! Air bubbles are circular and appear at very high contrast (i.e. dark black outline and empty, with no internal structure) as opposed to other matter which appears more "grey scale" or "sepia" in colour.



Air bubbles above an egg

Image: © Lyn Knott

If a slide prepared from a faecal float is left to sit on a bench or microscope for a period of time, crystalline salts of the float solution (e.g. saturated NaCl) will start to precipitate out and become visible. These crystals usually start forming at the edges of the coverslip, before working their way inward.



Crystalline salts of the float solution

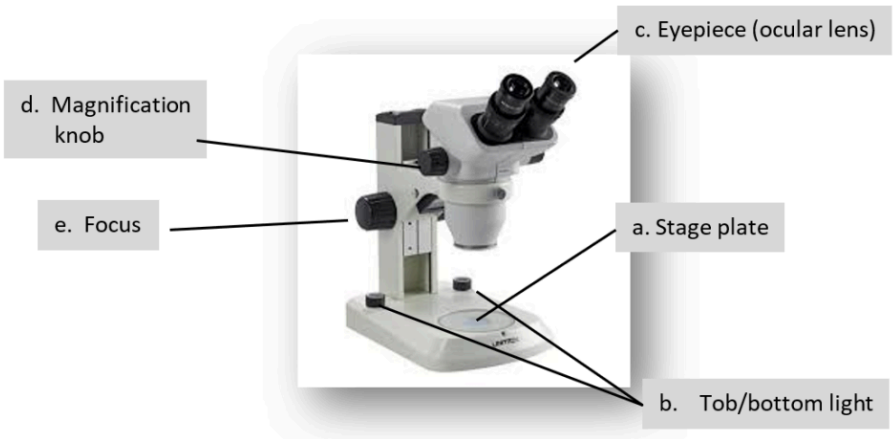
Image: © Lyn Knott

Examining a larger specimen using the dissecting microscope

The types of specimens examined under the dissecting microscope are those that may be too small to see in any detail with the naked eye and are too big to examine under the light microscope (things like ticks, flies, maggots, large helminths).

The main components of the dissecting microscope that you will need to be familiar with and adjust whilst examining parasite specimens are:

a. stage plate
b. top/bottom light
c. eyepiece (ocular lens)
d. magnification knob
e. focus.



Dissecting microscope

Procedure

1. Turn on the power, and place the petri dish containing a specimen over the stage plate (a).
2. Adjust the light source (b). If you will be looking at a transparent specimen, bottom lighting

will work best. If the specimen you are viewing is opaque or solid (light cannot pass through it from below), use top lighting so that the light can reflect off the specimen's surface.

3. Adjust the eyepiece(s) (c) so that you can look through the microscope comfortably without straining your eyes.
4. Bring the specimen to the desired magnification level using the magnification knob (d).
5. Focus on the specimen using the focus knob (e). Note: you will often be viewing three-dimensional specimens that have many different levels under the dissecting microscope. You will not be able to focus on every feature clearly at the same time.

Systemic Approach to Parasite ID

Each time you are presented with a parasite specimen to identify, follow this basic approach. By process of elimination it will help you to focus on a much shorter list of possibilities.

1. **Firstly ask yourself:** *What host species was the specimen collected from?* This will narrow down the possibilities substantially! Use the host-parasite lists included at the end of this guide.
2. **Secondly ask yourself:** *From where was the specimen recovered? i.e. faeces, blood, urine, skin scrape, GIT at necropsy?* This will shorten the list of possibilities even further *and* tell you what life cycle stage you will be looking for, or even the type of parasite. For example:

    - Faeces – eggs or oocysts, occasionally L1 larvae or whole tapeworm proglottids/ nematodes
    - Skin – ectoparasites, usually mites, lice, fleas, flies, maggots or ticks
    - Urine – eggs
    - Blood – protozoan parasite stages, nematode microfilaria
    - Necropsy (gastrointestinal tract) – adult or immature helminths.

3. **Now look at the specimen!** If the specimen is large enough for you to examine with the naked eye (e.g. whole adult helminths), you may be able to identify it without the use of a microscope. If you need a microscope, choose the appropriate one:

    - Small specimen mounted on slide (not able to see detail with naked eye or with dissecting microscope) – use the **light microscope**.
    - Larger specimen (not able to see detail with naked eye) -> use the **dissecting microscope**.

4. Use **appropriate resources** to help ID the parasite. These resources will indicate the diagnostic features of the specimen that will assist you with the ID.

    - Host parasite lists (Section VI – Chapters 21 to 26).
    - Keys and Identification Aids (Section VII – Chapters 27 to 37).

Microscopy Skill

If properly focused using the 4X and 10X, the fine focus shouldn't need too much adjustment on 40X.

17.

USE A DICHOTOMOUS KEY

Using Dichotomous Keys (YouTube, 2m37s) includes a clear description on using dichotomous keys.



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18.

PERFORM A BLOOD SMEAR

How to make a thin smear

Gloves **must** be worn for this procedure.

Sometimes we need to prepare cells or items into a monolayer. The most common form of smear is a blood smear. These are used to investigate haematological disorders (problems in the blood). The problems might have their origin in the animal itself (e.g. white cell cancers, anaemia), or may arise because of some infectious agent. A small drop of blood is placed on a slide. Using a second slide, the drop is smeared across the surface of the slide so that a thin film of blood cells is formed. Cells are best examined in the thinnest part of the smear – at the trailing edge of the smear. After brief fixation in methanol, the smear is stained.

In mammals, the red cells (erythrocytes) lack a nucleus. These are the most abundant cell type. Other cells are present in a smear:

- neutrophils
- eosinophils
- basophils
- lymphocytes.

These cells can be distinguished on their staining characteristics and nuclear morphology.

Procedure

Watch How to make a Blood Film in 3 steps (YouTube, 30s) and then read the instructions below.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uq.pressbooks.pub/principles-disease-parasitology/?p=197#oembed-1

1. Label a very clean slide with indelible ink or water resistant label.
2. Place a small drop of blood on the same side of the slide as the label.
3. Lower a second slide (the spreader slide) onto the first slide, holding the spreader slide at an angle of 30 degrees.
4. Holding the first slide, draw the spreader slide back until it touches the drop of blood. The drop will spread by capillarity along the edge of the spreader slide.
5. Maintain firm pressure and push the second slide along the first in one movement. The cells will smear and form a monolayer at the far edge.
6. Air-dry the slide.

Stain the smear

- Ensure the slide is completely dry before staining.
- Stain the slide using Diff-Quick, or other differential stain.

Diff Quick Staining

1. Dip in fixative 5 times.
2. Dip in red solution 5 times.
3. Dip in blue solution 5 times.
4. Rinse in running water.

19.

PERFORM A FAECAL FLOAT

Purpose of the Procedure

The faecal float procedure is used to identify the presence of helminth eggs and some protozoa in faeces.

The method is quick and inexpensive, but is qualitative only. Flotation solutions have a higher specific gravity (SG) (usually between 1.2 and 1.25) than water. As most helminth eggs have a SG between 1.1 and 1.2, they will float to the top when mixed with these solutions.

Faecal floats are used commonly with domestic animals such as dogs and cats to assess the need for anthelmintic therapy.

Cestode eggs will often float in these solutions, but the results are not always reliable.

The most common flotation solutions are listed below.

Flotation Solution	Specific Gravity	Eggs & Oocysts Floated	Other Protozoa Floated	Disadvantages
Sodium nitrate	1.2	Yes	No	Distorts eggs over time Oxidizing agent Special waste procedures required
Zinc sulphate	1.2	Yes	Giardia Cryptosporidium	Not as efficient as sodium nitrate Special waste procedures required Centrifugation recommended
Sheather's sugar solution	1.25	Yes	No	Not as efficient as sodium nitrate Sticky to deal with Centrifugation best butnot essential
Saturated salt	1.18	Yes	No	Distorts eggs over time Corrosive to microscopes

Procedure using the Fecalyzer® apparatus

FAECAL FLOAT

using the Fecalyzer® technique



Flotation solution

Saturated sodium chloride (SG 1.18) will recover most eggs

PROCEDURE

1. Scoop pea-sized amount of faeces into base of container, and then replace the green basket insert
2. Half fill the chamber with flotation solution and twist basket back and forth to thoroughly mix sample.
3. Push down firmly to secure the basket inside the chamber.
4. Add more flotation solution until a positive meniscus is formed.
5. Place coverslip gently on top and allow to sit for 5 minutes.
6. Carefully lift coverslip and place onto microscope slide.
7. Scan whole slide for parasite stages under 10X and 40X magnification.

CLEAN UP

Rinse out Fecalyzer apparatus well and place in wash up tubs in sink.
Discard slides / coverslips into sharps container.

Note: Saturated salt solutions are highly corrosive – please WIPE any spillage on the microscope with a damp paper towel.

Faecal float procedure

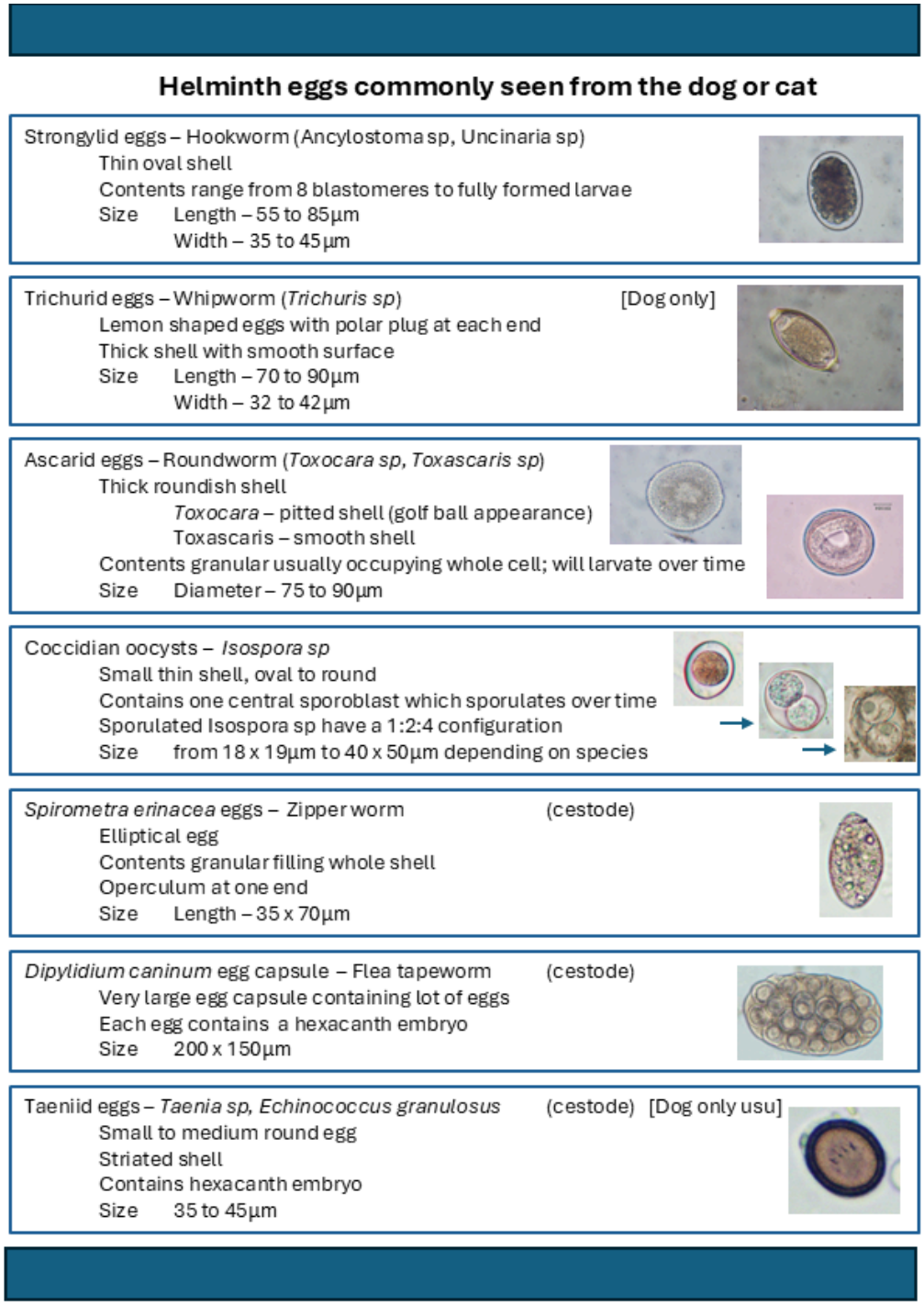
Photo: © Lyn Knott

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https://uq.pressbooks.pub/principles-disease-parasitology/?p=195#h5p-10

Visit Faecal float – Fecalyzer technique to view a video of this procedure. Other parasitological procedures are also available.

Results of the Faecal Float



Images: © Lyn Knott

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online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=195#h5p-11

20.

PRESERVE AND LABEL A PARASITE FOR IDENTIFICATION

It is often important to preserve and store multicellular parasites for subsequent identification by morphological examination or molecular biology. Although the manner of fixation (preservation) of parasites varies with the group of parasites, a common preservative used is ethanol at a concentration of 70-80%. The parasites are stored in plastic or glass containers.

It is important that the parasites are labelled correctly. The labels can be prepared from quality paper, on which pertinent information is written in pencil, laser ink or India ink. Don't use pens or biros as many of their inks from are soluble in ethanol. The **label** is placed **inside the container** with the parasite.

Each label should contain:

Label Information

Information Required	**Details**
Correct identification of the parasite	The parasite should be identified as far as possible, and where possible, the information should include the formal scientific name of the parasite
Name of host	This should also be the formal **scientific** name of the host
Location of parasite	This could be the location on or in the host (for example, liver), or location in the environment of the host (for example, stable door)
Geographic location of the host	For example, Gatton, Qld
Date collected	
Your name	

Preserving Parasite Material

Some parasites can be difficult to fix. Helminths may contract severely when placed in fixative. Maggots are able to contract all openings in fixatives until they die due to lack of oxygen. Even after death, the fixative won't penetrate the maggots and they will rot from the insides, turning black in the process.

Typically, we fix specimens in 80% ethanol, although for some purposes, fixation in 4% formalin is preferable for preservation (but much more toxic).

For difficult to fix parasites, such as helminths or maggots, heat fixing can be used. **Care! Hot Liquids!** Very carefully boil water and add the parasites to the boiling water. Immediately remove heat and when cooled, transfer parasites to fixative. **Care! Hot Liquids!**

PART VI
HOST PARASITE LISTS

21.

SOME PARASITES OF AUSTRALIAN DOGS

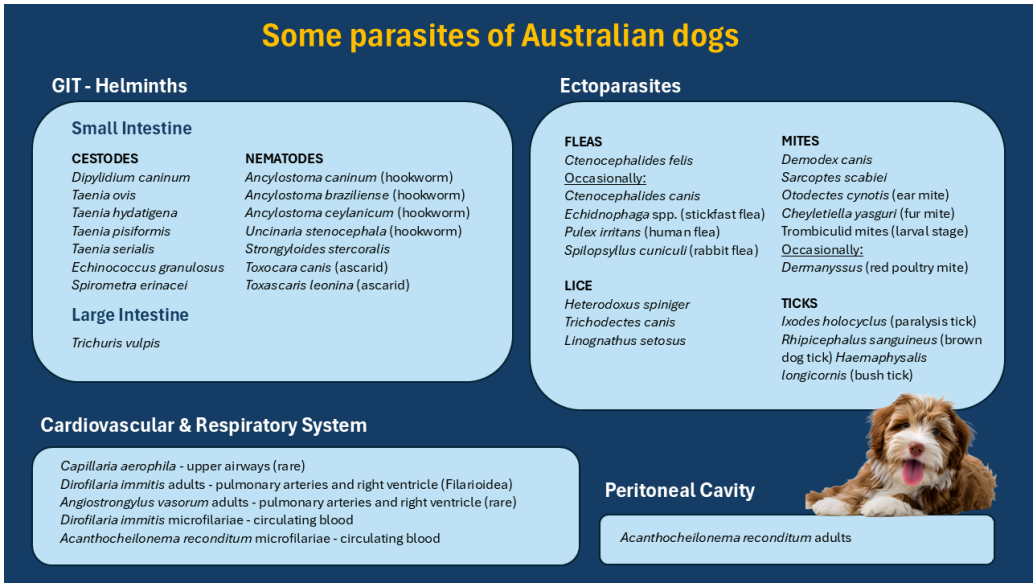


Image: Fluffy brown and white puppy lying down © Daniel – stock.adobe.com

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22.

SOME PARASITES OF AUSTRALIAN CATS

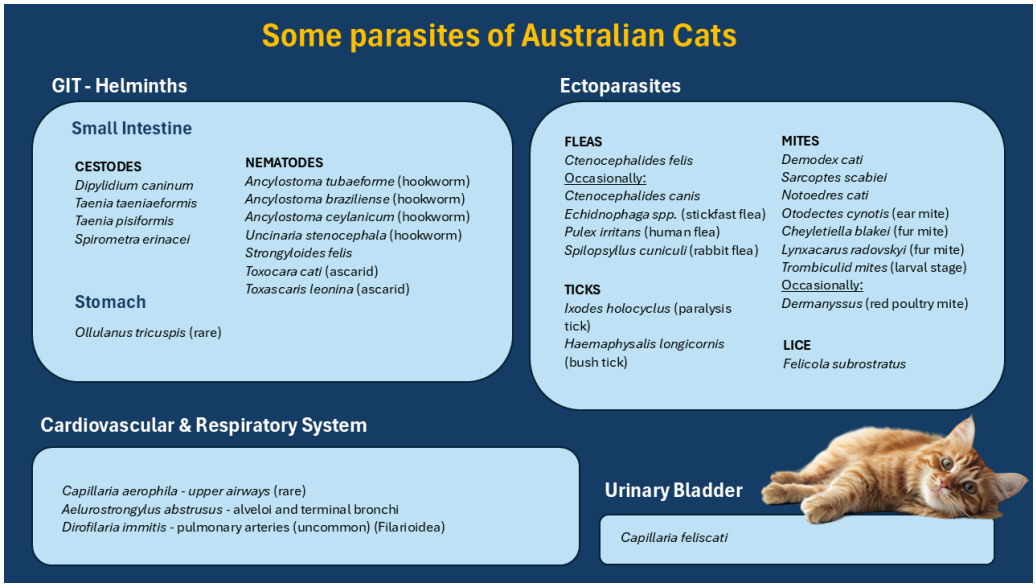


Image: Playful orange tabby cat lying on side © Asier – stock.adobe.com

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23.

SOME PARASITES OF AUSTRALIAN HORSES

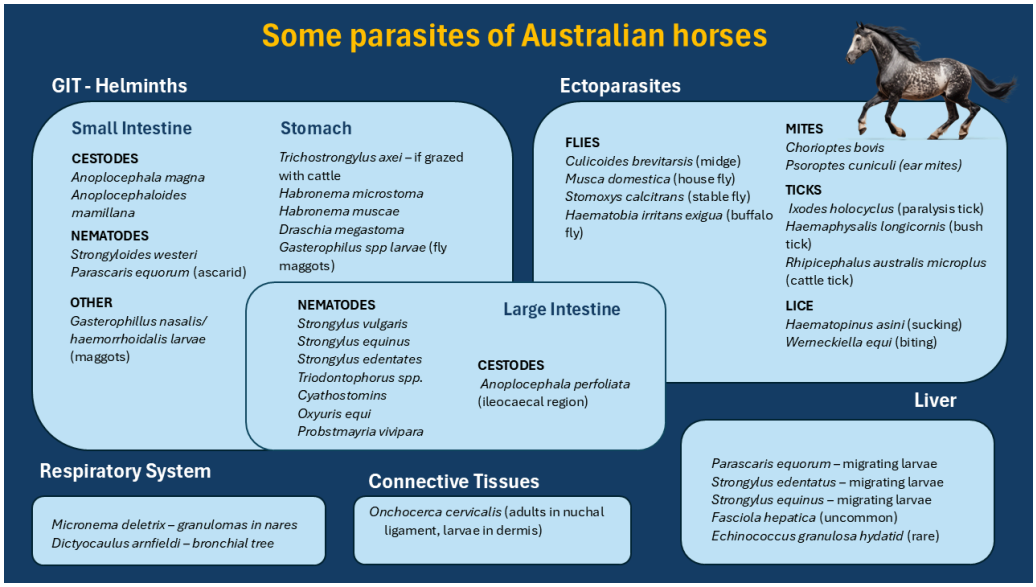


Image: Black appaloosa horse running © FP Creative Stock – stock.adobe.com

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24.

SOME PARASITES OF AUSTRALIAN CATTLE

Internal parasites

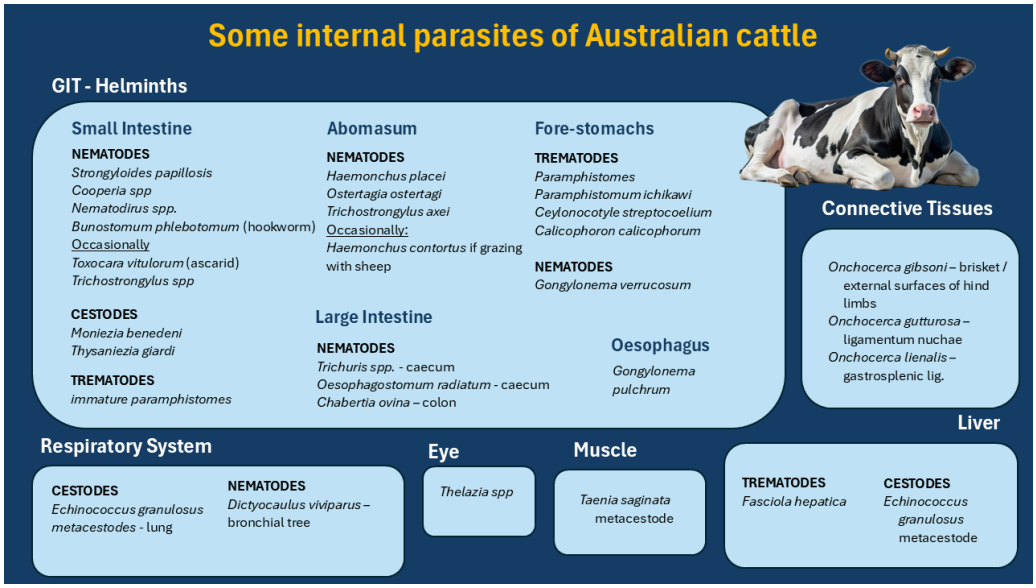


Image: Black and white cow lying down relaxed pose © Faiqdesigner – stock.adobe.com

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External parasites

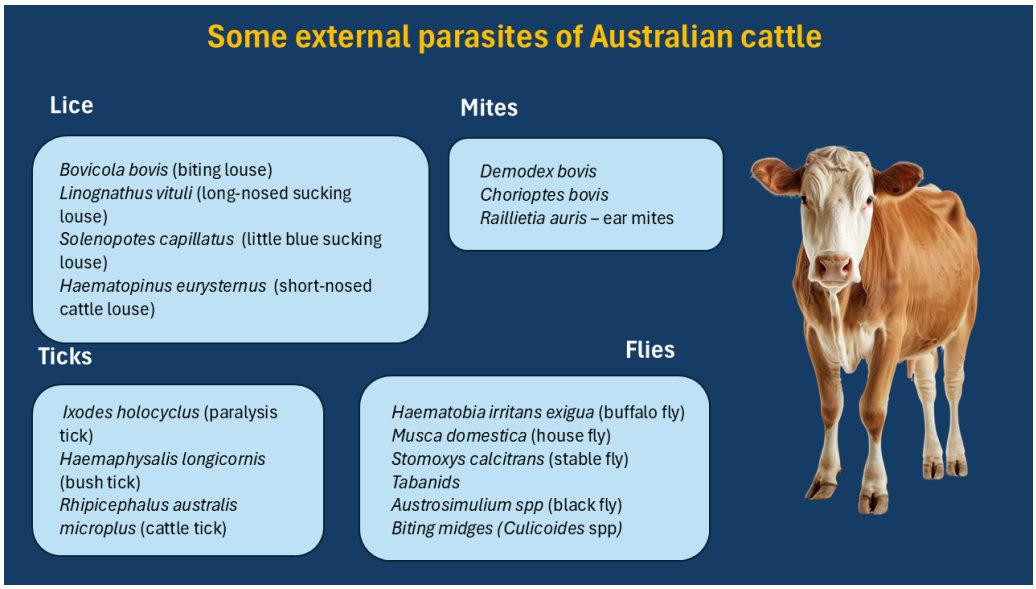


Image: Set of different coloured cow © Arup Debnath – stock.adobe.com

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25.

SOME PARASITES OF AUSTRALIAN SHEEP

Internal parasites of Australian sheep

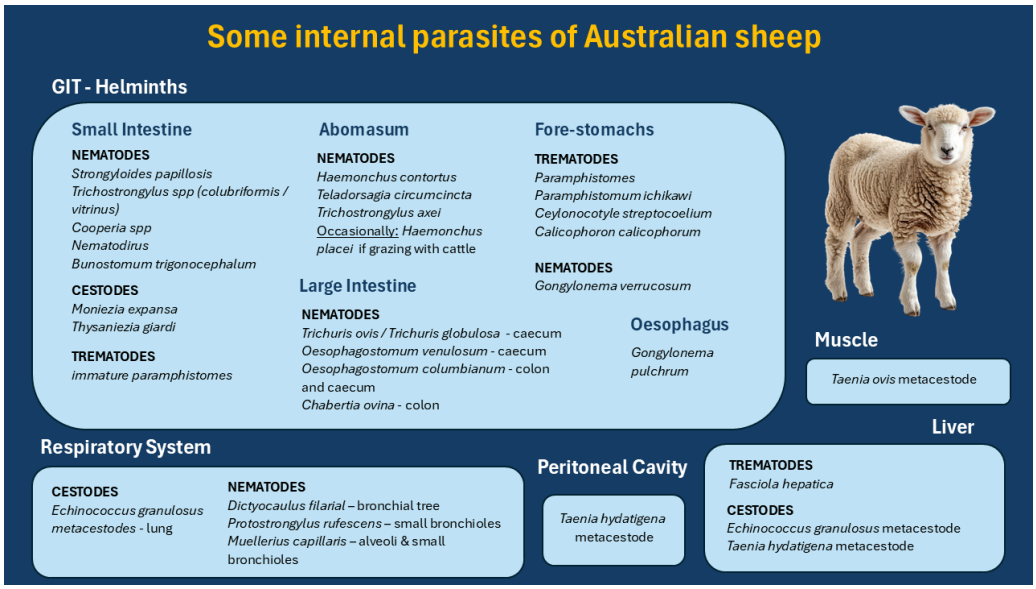


Image: White lamb standing © Netroder – stock.adobe.com

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External parasites of Australian sheep

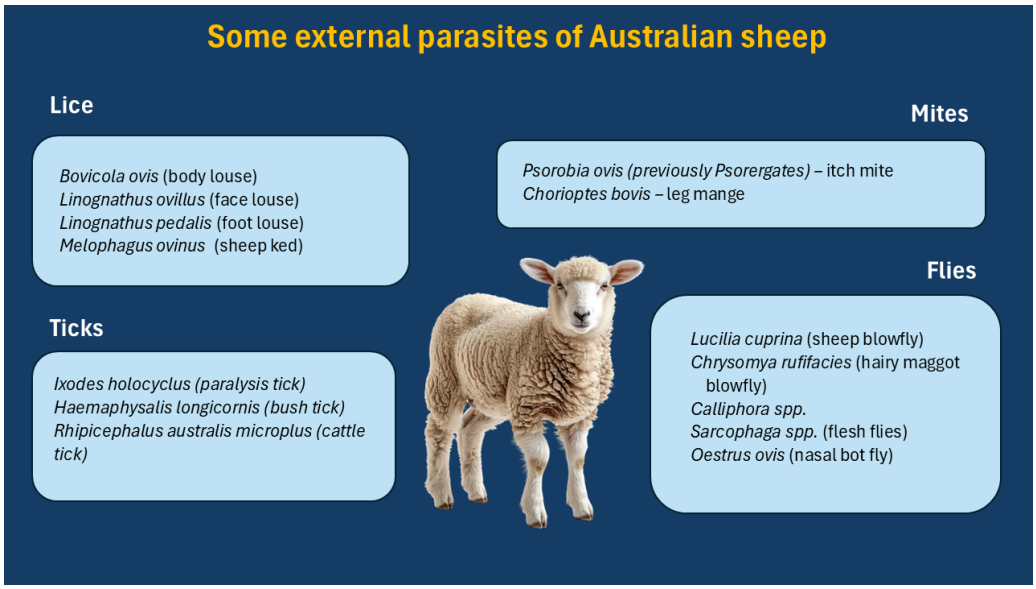


Image: White lamb standing © Netroder – stock.adobe.com

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26.

SOME PARASITES OF AUSTRALIAN SWINE

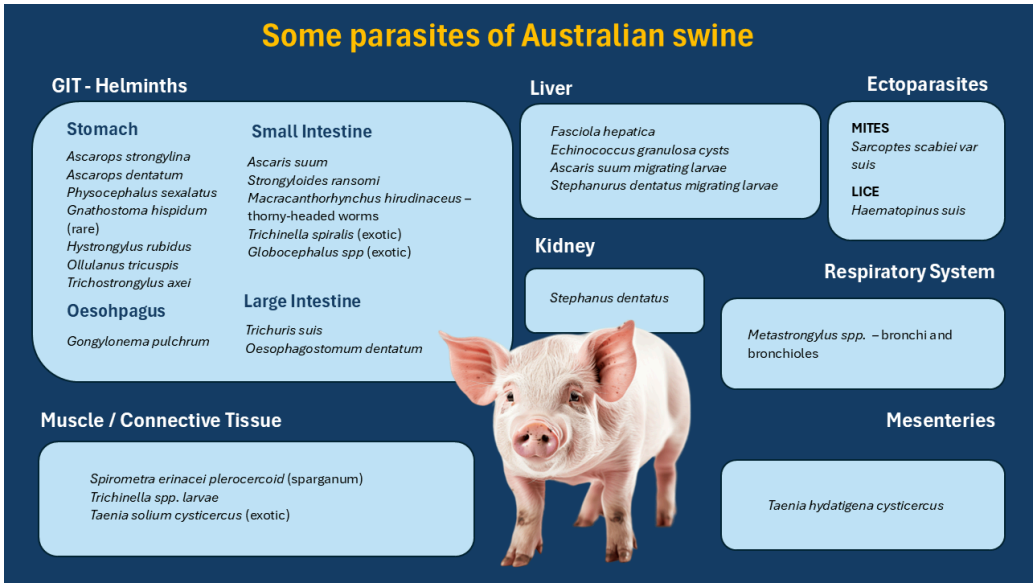


Image: Close-up portrait of a pink pig standing © mattegg – stock.adobe.com

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PART VII
KEYS AND IDENTIFICATION AIDS

27.

FLEAS

Identification of Fleas

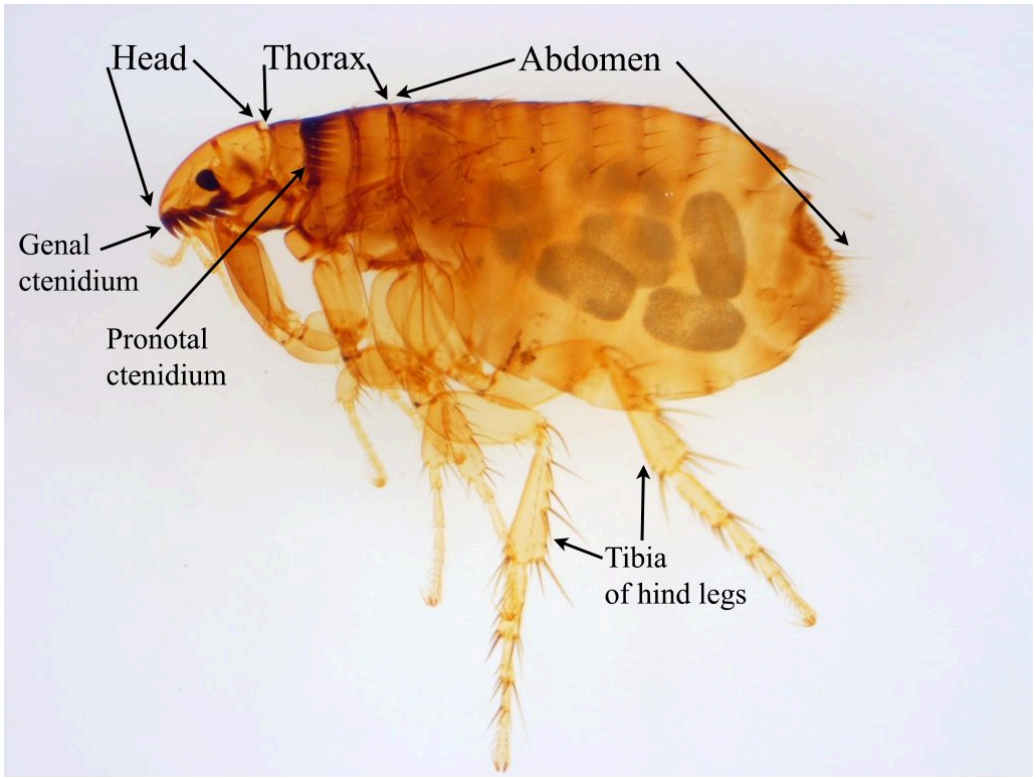
Taxonomy

Phylum Arthropoda

Class Insecta

Order Siphonaptera

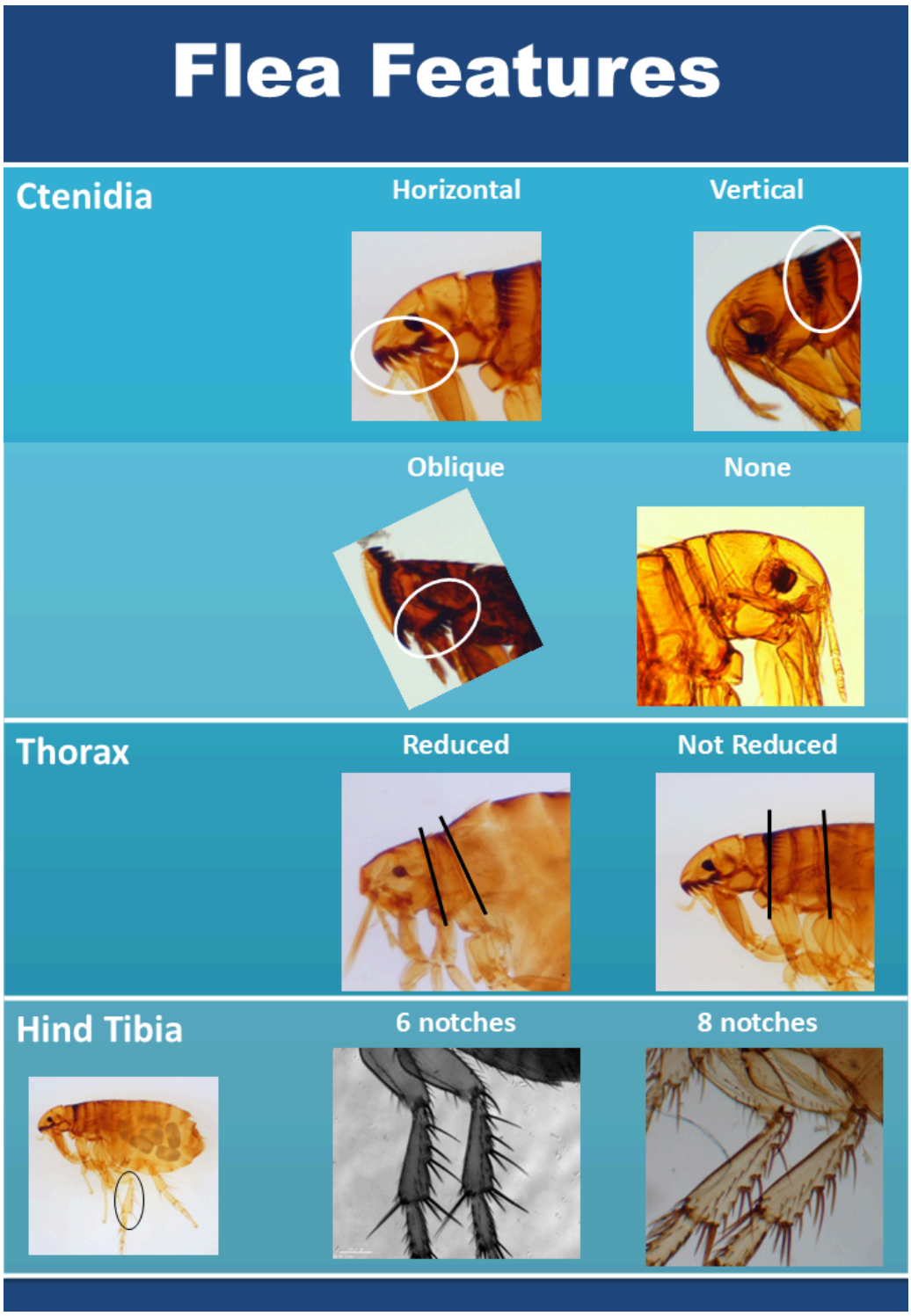
Morphology of Fleas



Key diagnostic characteristics of fleas.

Photo: © Lyn Knott

Morphological features that distinguish between the various flea species are:



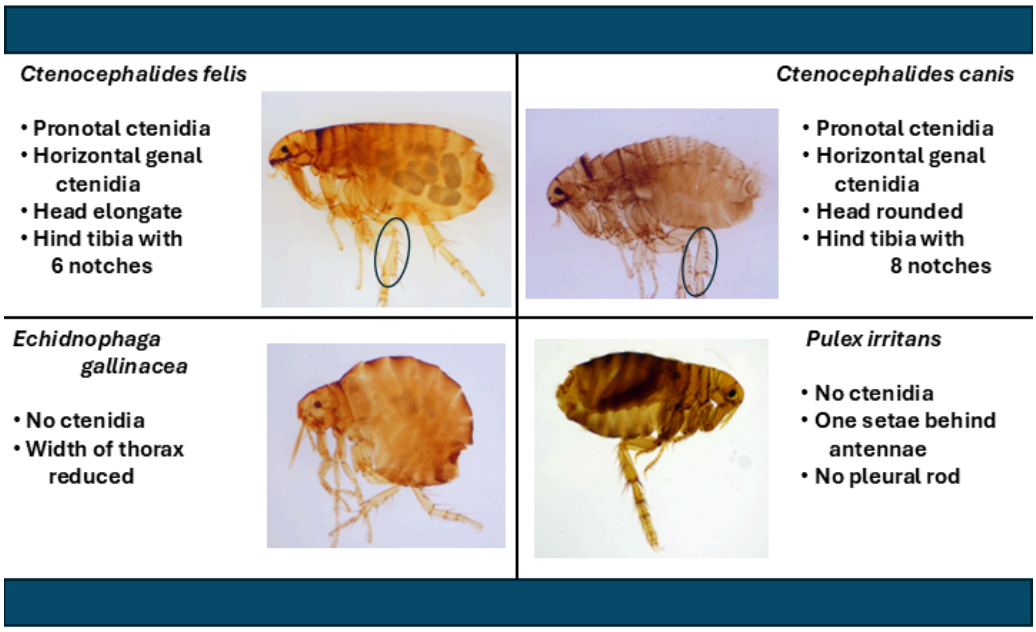
Photos: © Lyn Knott

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https://uq.pressbooks.pub/principles-disease-parasitology/?p=226#h5p-21

Visit Dichotomous Key for Fleas for identifying the different flea species of domestic animals.

Common Fleas

Photos and characteristics of some common fleas are shown below.



Photos: © Lyn Knott

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https://uq.pressbooks.pub/principles-disease-parasitology/?p=226#h5p-20

A more unusual flea species is the *Stephanocircus* genus – they are referred to as having a helmet. This example was found on a bandicoot.



Photo: © Lyn Knott

Return to Fleas chapter

28.

LICE

Identification of Lice

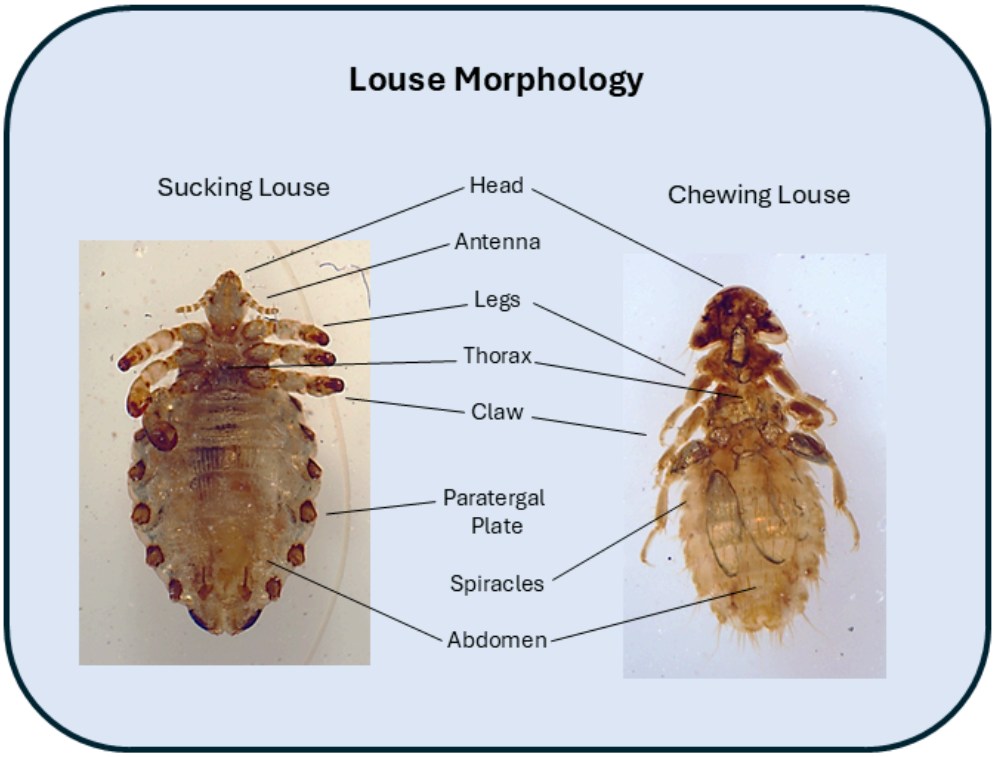
Taxonomy

Phylum Arthropoda

Class Insecta

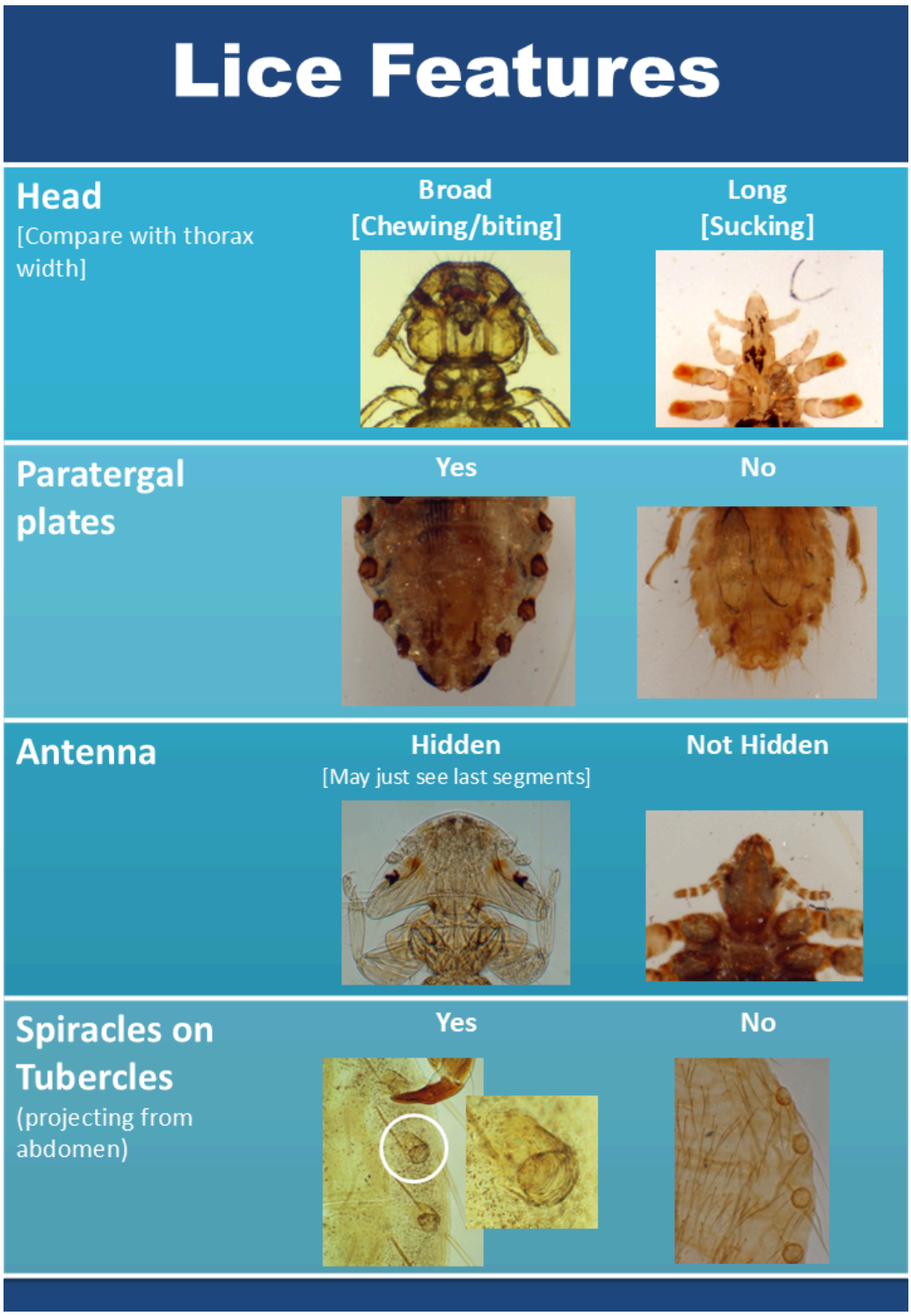
Order Psocodea (Clade Phthiraptera)

Overview of Lice Anatomy



Photos: © Lyn Knott

Morphological features that are used to help distinguish between the various lice species are:



Photos: © Lyn Knott

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https://uq.pressbooks.pub/principles-disease-parasitology/?p=228#h5p-24

A Modified Key to Include Human Louse Species

A dichotomous key can be used to identify the lice of domestic animals and humans. Because of the high host specificity, in most cases, identification of a louse to genus level should be sufficient to identify the species of louse in the genus. This rule does not always apply, however. The two species of *Pediculus* of humans, for example, are indistinguishable under a microscope, and can be identified by molecular tools or biology only.

Louse Morphology and Identification

Dichotomous key for lice of domestic animals

1	Head broad; front usually rounded, sometimes triangular..... Head long (narrower than thorax); front usually pointed	..[Chewing Lice]..*6* .....[Sucking Lice - Anoplura]....2
2	All legs of similar size; Paratergal plates on abdominal segments present and heavily chitinised ..... 1st pair of legs smaller than pairs 2 and 3. ('Pale Lice', human crab louse and 'spiny rat lice').....	.....3 4
3	On ungulates..... On humans.....	.....*Haematopinus* .....*Pediculus*
4	Lateral margin of abdominal segments with paratergal plates that are sharply angled at the postero-lateral margin. Para-tergal plates usually light in colour. On rodents and small mammals Lateral margins of abdominal segments either smooth, or sharply angled at the posterior margin	.....*Polyplax* 5
5	Lateral margins of abdominal segments either smooth, or sharply angled at the posterior margin; Spiracles do not protrude from lateral margin of abdomen Lateral margin of abdominal segments with spiracles on tubercles..... Small louse with broad squat body; thorax and abdomen apparently merged. On perineal regions of humans, also beards, eyelashes, armpits chest	.....*Linognathus* .....*Solenopotes* .....*Pthirus*
6	Antennae 3 to 5 segmented, not hidden in antennal grooves..... Antennae 4 segmented and hidden in antennal grooves.....	.....[Ischnocera]...7 ...[Amblycera]...13
7	On Birds; Antennae 5 segmented; Paired claws..... On mammals; Antennae 3 segmented; Single claws.....	.....8 11
8	Hind legs similar length to first two pairs of legs..... Hind legs at least twice as long as first two pairs; Body long and narrow; On poultry.....	.....9 .....*Lipeurus*
9	3 long bristles project from each side of the dorsal surface of the head; Barrel-shaped body; ~2m long..... 2 long bristles projecting from each side of the dorsal surface of the head.....	.....*Cuclotogaster* 10
10	Distinct hollow margin posterior to antennae; Marked angular corners at the posterior margins; 3-5mm long; On Poultry..... Head rounded; Less than 2mm long; On poultry.....	.....*Goniodes* .....*Goniocotes*
11	Head triangular; On cats..... Head rounded anteriorly.....	.....*Felicola* 12
12	On ruminants or horses..... On dogs.....	.....*Bovicola* .....*Trichodectes*
13	On birds..... On mammals.....	.....14 15
14	~2mm long; Abdomen with sparse covering of setae; Found on thigh or breast feathers..... Larger lice (~3.5mm); Abdomen with dense covering of setae; Found on thigh, breast or perivent feathers.....	.....*Menopan* .....*Menacanthus*
15	On guinea pigs; Oval abdomen; 6 pairs of ventrolaterally located abdominal spiracles..... On Guinea pigs; Slender abdomen (sides parallel); 5 pairs of ventrally located abdominal spiracles..... On dogs.....	.....*Gyropus* .....*Gliricola* .....*Heterodoxus*

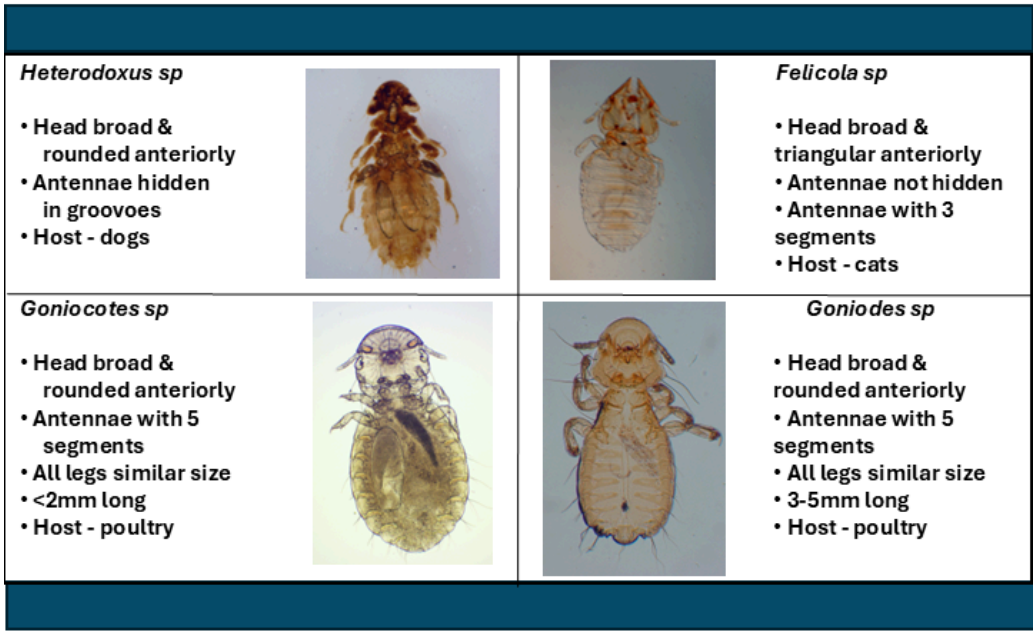
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online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=228#h5p-22

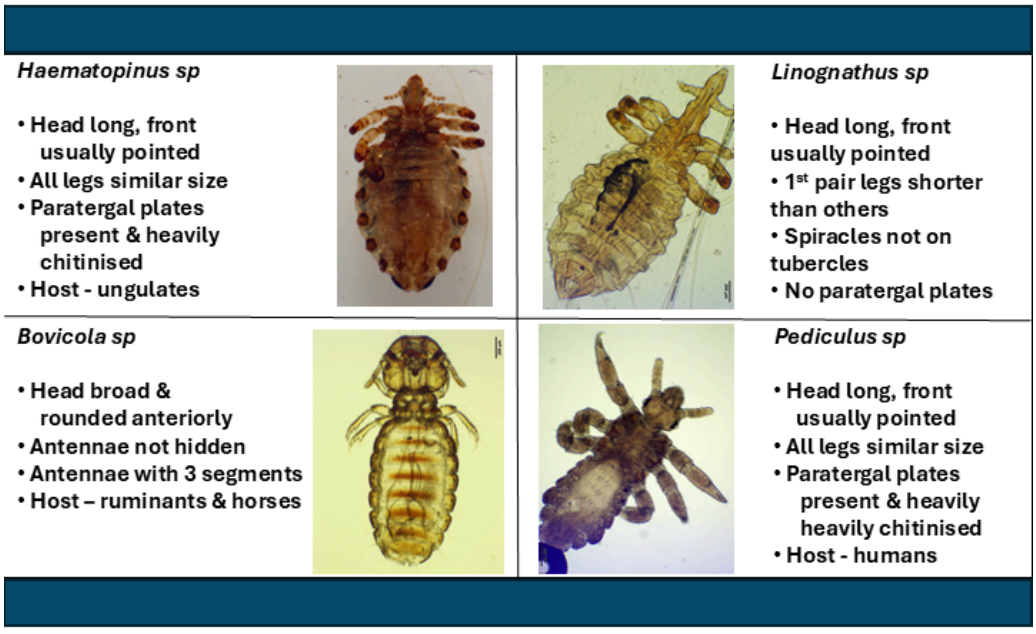
Visit Interactive Dichotomous Key for a slightly different dichotomous key for the identification of lice of domestic animals. This key is interactive with some images to help with the choices.

Common Lice

Some common lice and their characteristics are shown below:



Photos: © Lyn Knott



An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=228#h5p-23

Return to theory chapter on lice

29.

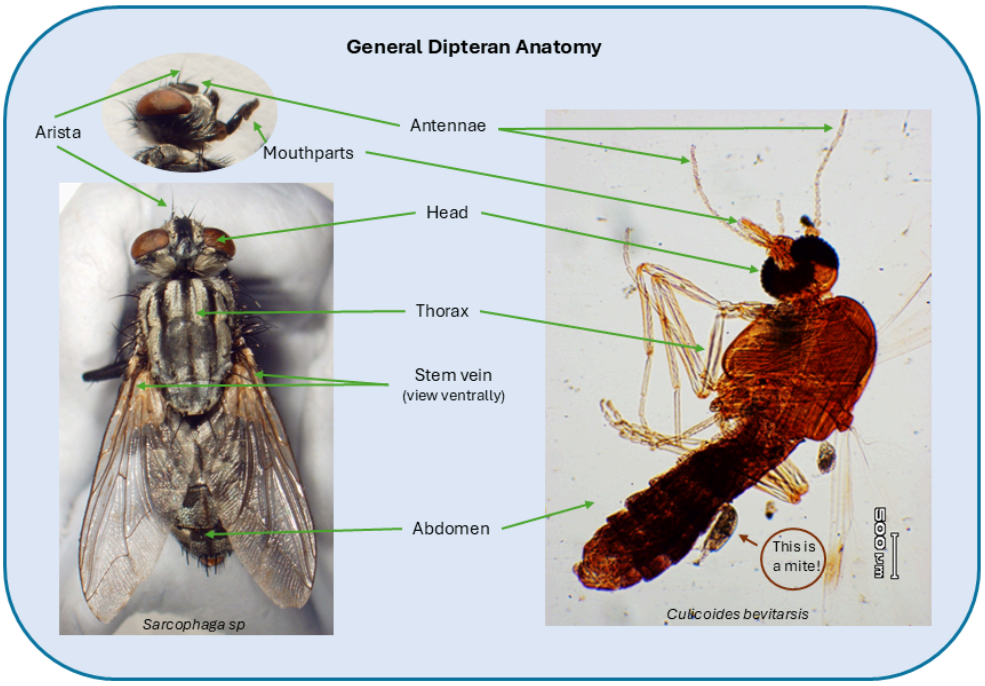
ADULT FLIES

Taxonomy

Phylum Arthropoda

Class Insecta

Order Diptera



General Dipteran anatomy

Images: © Lyn Knott

Morphological features

The morphological features that help to identify individual species are shown below:



Images: © Lyn Knott

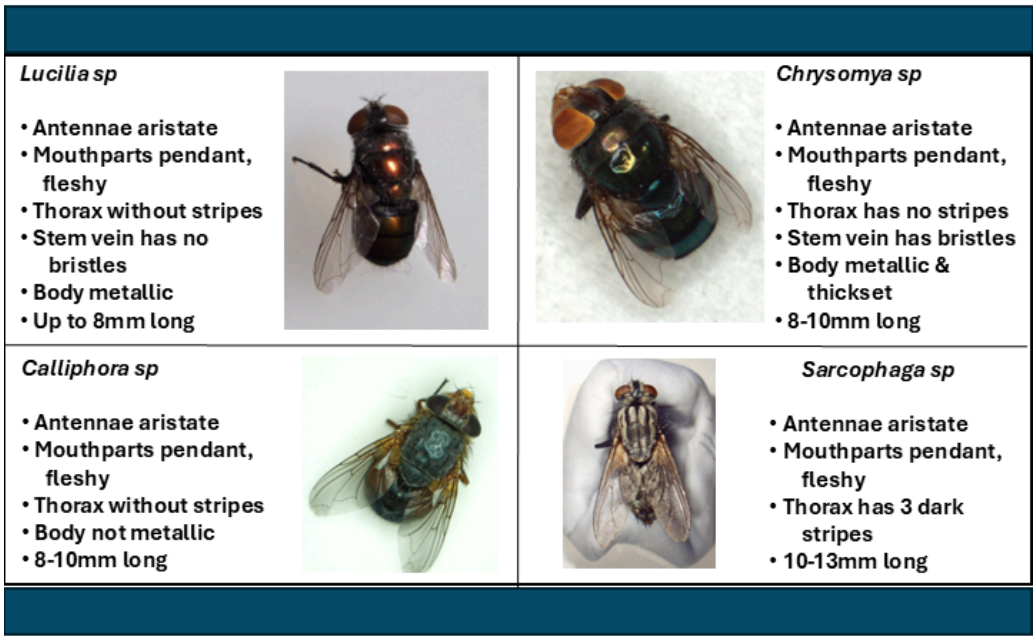
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https://uq.pressbooks.pub/principles-disease-parasitology/?p=230#h5p-25

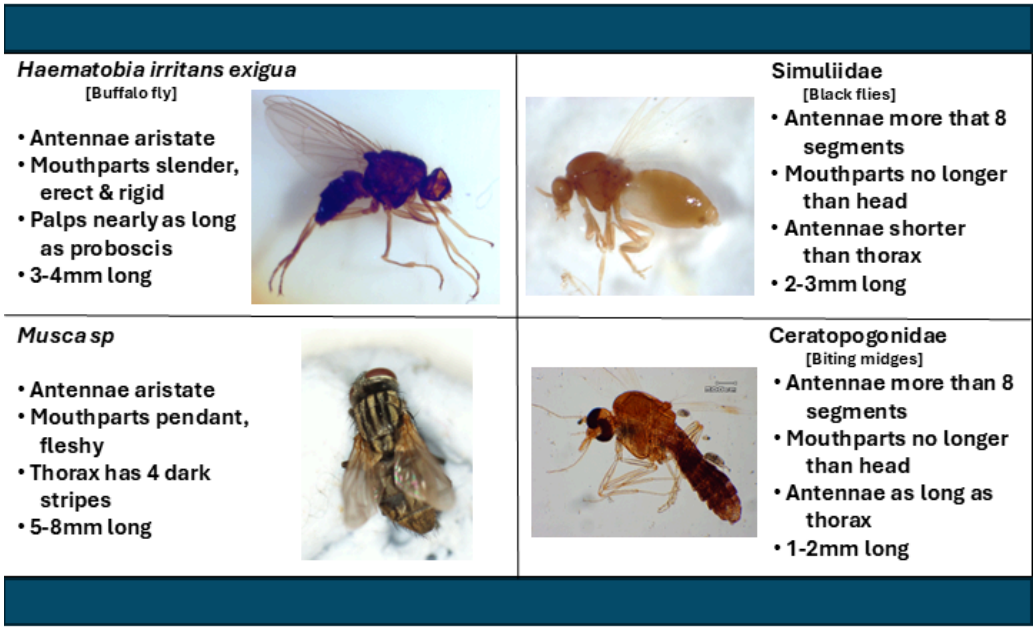
Keys for the identification of adult flies can be found at the following links:

- Dichotomous Key
- Interactive Dichotomous Key

Common Adult Flies

Photos and characteristics of some common mites are shown below.





Images: © Lyn Knott

An interactive H5P element has been excluded from this version of the text. You can view it

online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=230#h5p-26

Return to Fly (Diptera) Theory

30.

LARVAL FLIES: MAGGOTS

Taxonomy

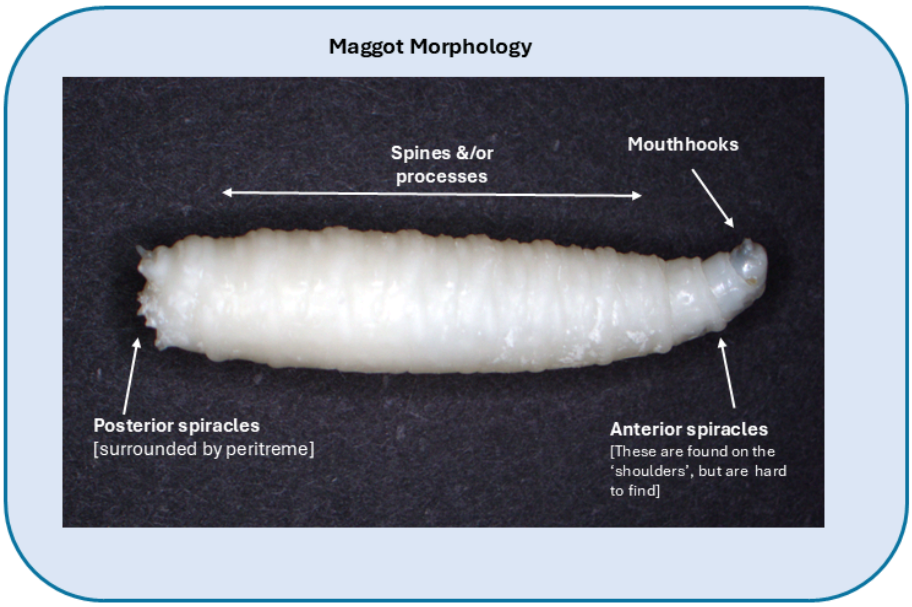
Phylum Arthropoda

Class Insecta

Order Diptera

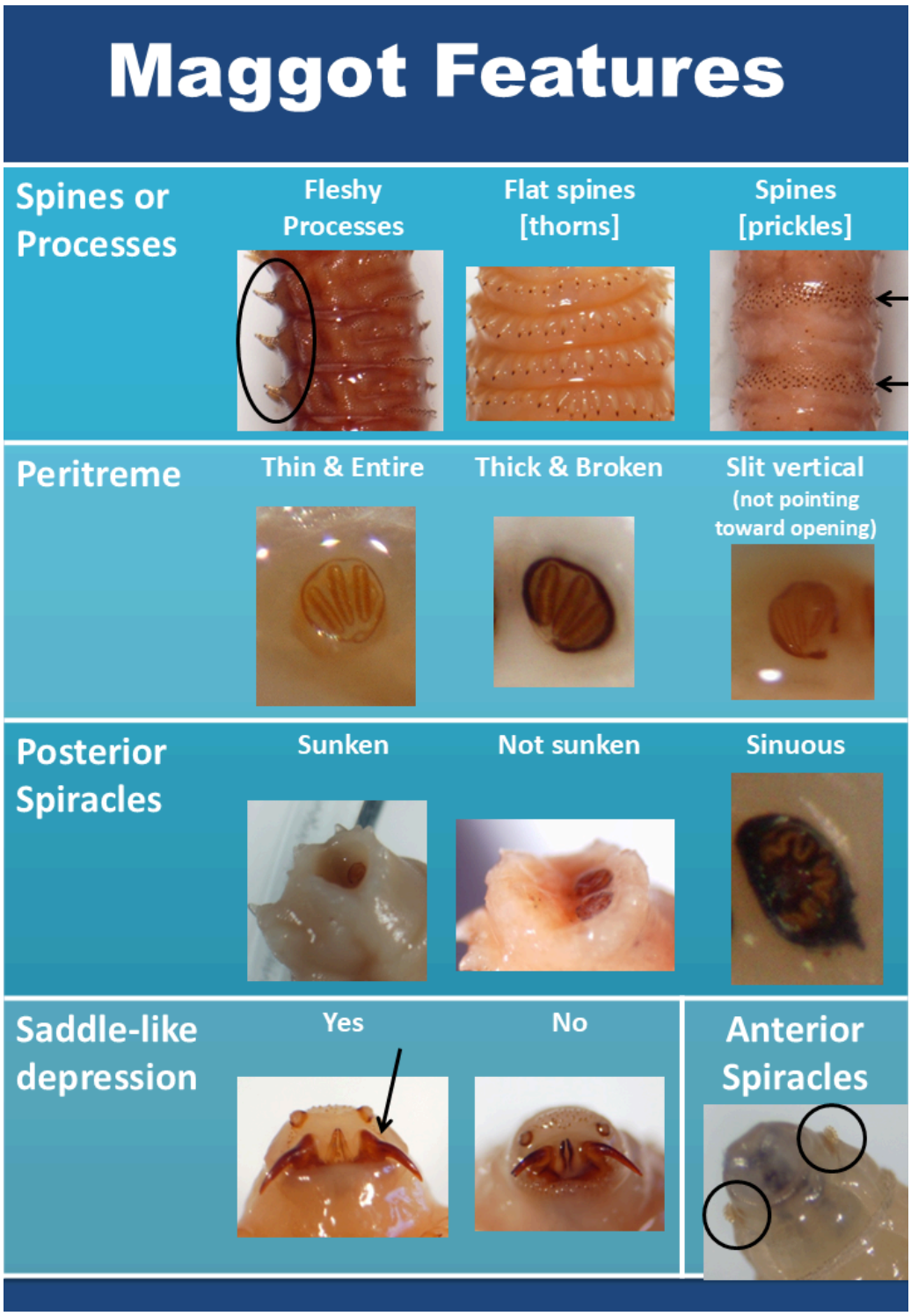
Visit Introduction to maggots for an introduction to the variety of maggots found in domestic animals.

Image: © Lyn Knott



Morphological Features

Morphological features that help in the identification of the various maggots are shown below:



Maggot features

Photos: © Lyn Knott

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=232#h5p-27

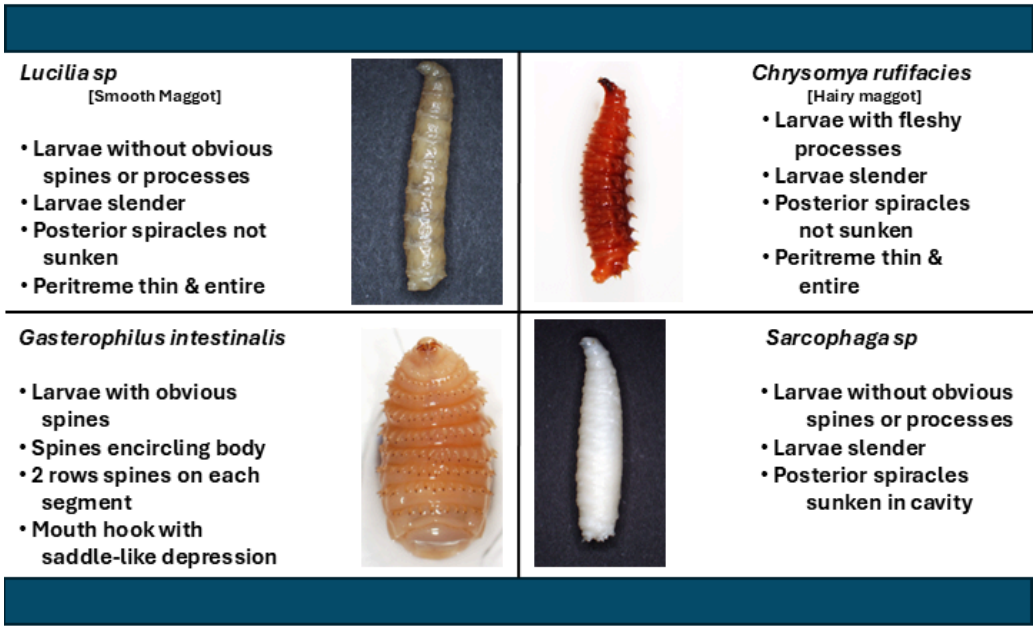
For help locating these features on a maggot, this image may help.

Keys for the identification of maggots:

- Dichotomous key
- Key for smooth maggot wound myiasis
- Interactive dichotomous key

Common Maggots

Photos and characteristics of some common maggots are shown below.



Images: © Lyn Knott

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=232#h5p-28

Return to Fly (Diptera) theory chapter

31.

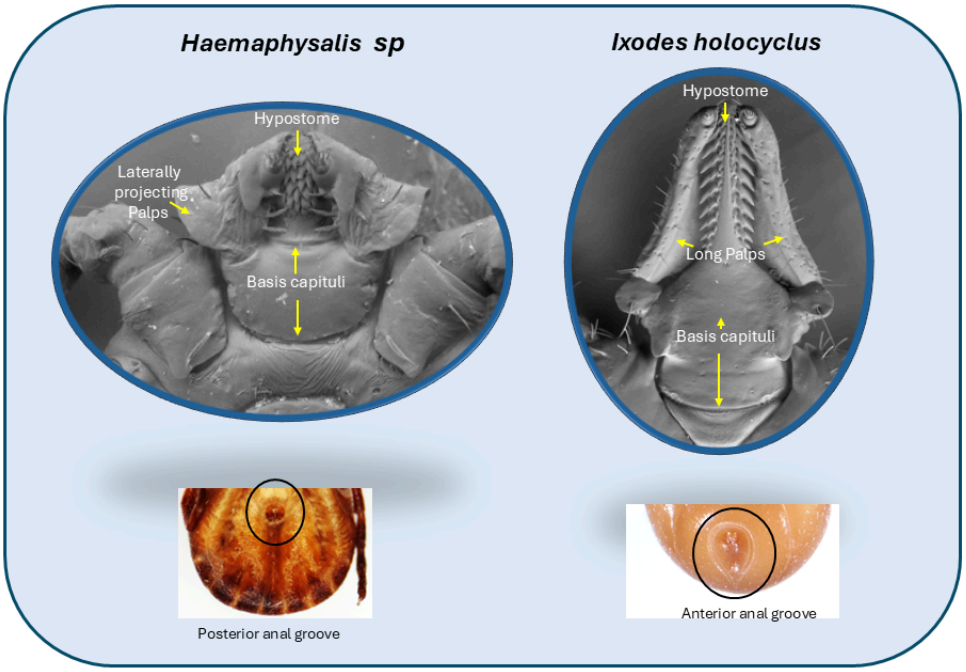
TICKS

Taxonomy

Phylum Arthropoda

Class Chelicerata

Order Ixodida



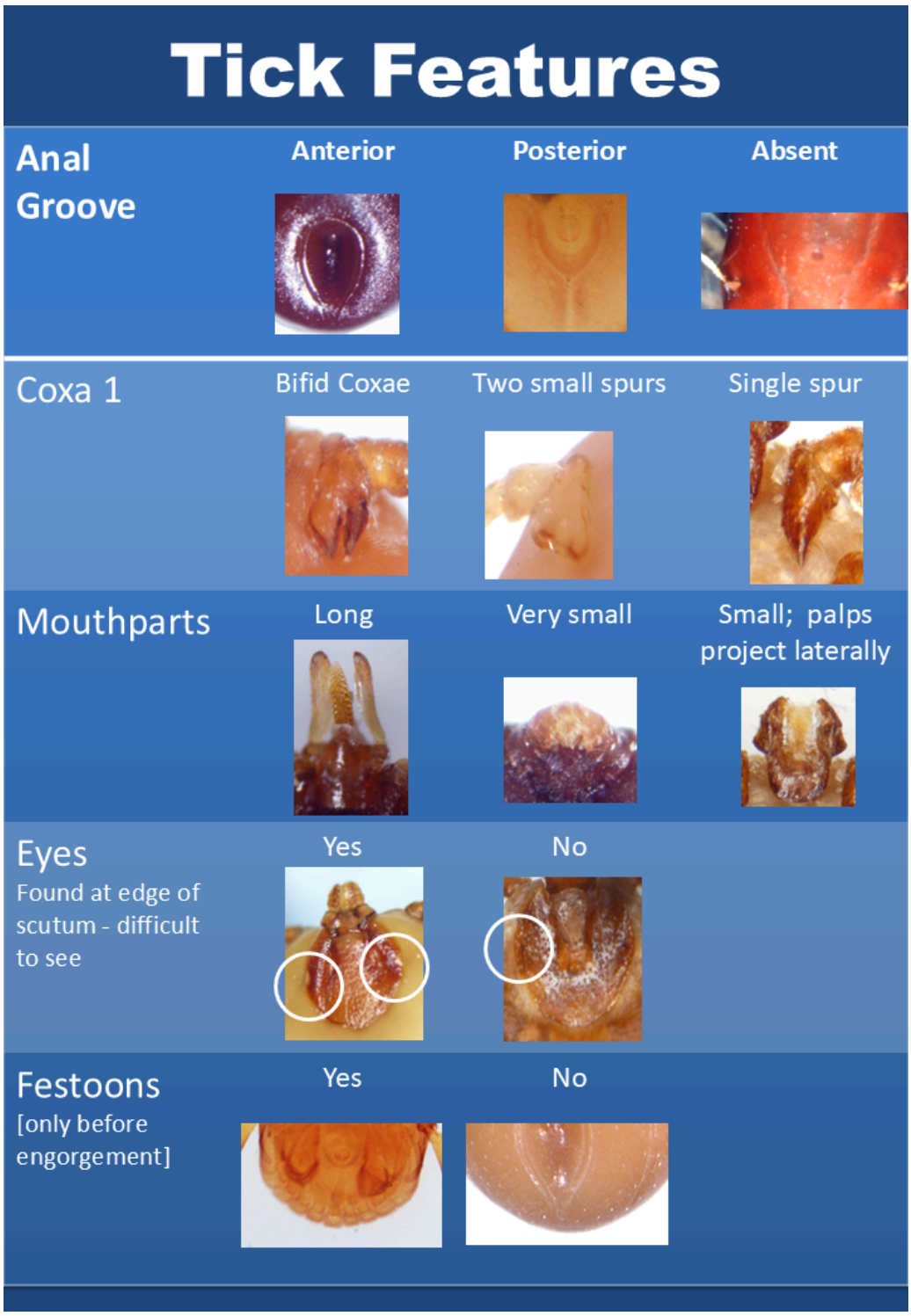
Haemaphysalis sp and *Ixodes holocyclus* features

Images: © Lyn Knott

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https://uq.pressbooks.pub/principles-disease-parasitology/?p=234#h5p-41

Morphological Features

The morphological features used to help in the identification of ticks are shown below:



Images: © Lyn Knott

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https://uq.pressbooks.pub/principles-disease-parasitology/?p=234#h5p-29

Due to taxonomic changes in the last few years, some ticks have been renamed:

- *Rhipicephalus sanguineus* = *Rhipicephalus linnaei*
- *Rhipicephalus australis* = *Rhipicephalus microplus* = *Boophilus microplus*
- *Aponomma* genus = *Bothriocroton* genus

The table below shows the key characteristics of important ticks.

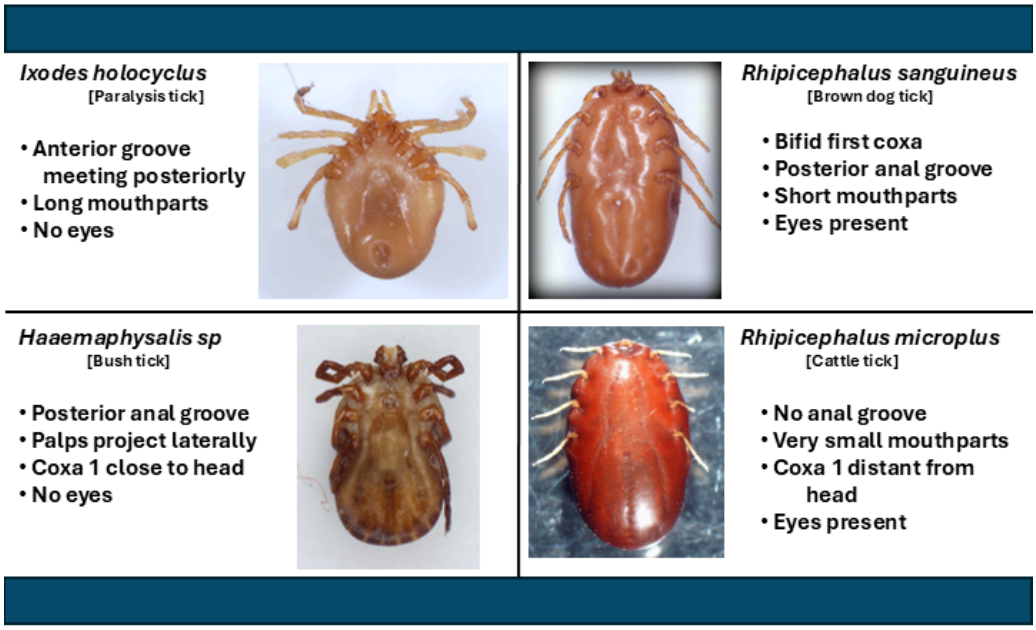
Tick group	***Ixodes***	***Haemaphysalis***	***Rhipicephalus linnaei* [*R sanguineus*]**	***Rhipicephalus australis* [*R microplus*]**	***Amblyomma***	***Bothriocroton***
Anal Groove	Anterior to anus	Posterior to anus	Posterior to anus	Absent	Posterior to anus	Posterior to anus
Mouthparts	Long in females	Short	Short	Short	Long	Long
Palps	Elongated	Sharply angular & laterally projecting	Short	Short	Do not project laterally	Do not project laterally
Eyes	Absent	Absent	Present	Present	Present	Absent
Scutum	Inornate, yellowish	Inornate, brown	Inornate, brown	Inornate, brown	Ornate, often with white patches	Either ornate or inornate
Festoons	Absent	Present	Present	Absent	Present	Present
Coxa I	May have short spurs	No	Two long spurs (bifid coxa)	Two short spurs	n/a	n/a
Leg colour	2 brown, 2 yellowish	Dark brown	Dark brown	Pale	Often dark brown with white rings	Dark brown

Keys for the identification of the various ticks can be found by following these links.

- Simple key for identification of the common ticks of domestic animals
- Tick identification table

Common Ticks

Characteristics of some common ticks are shown below:



Images: © Lyn Knott

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=234#h5p-30

Return to Ticks theory chapter

32.

MITES

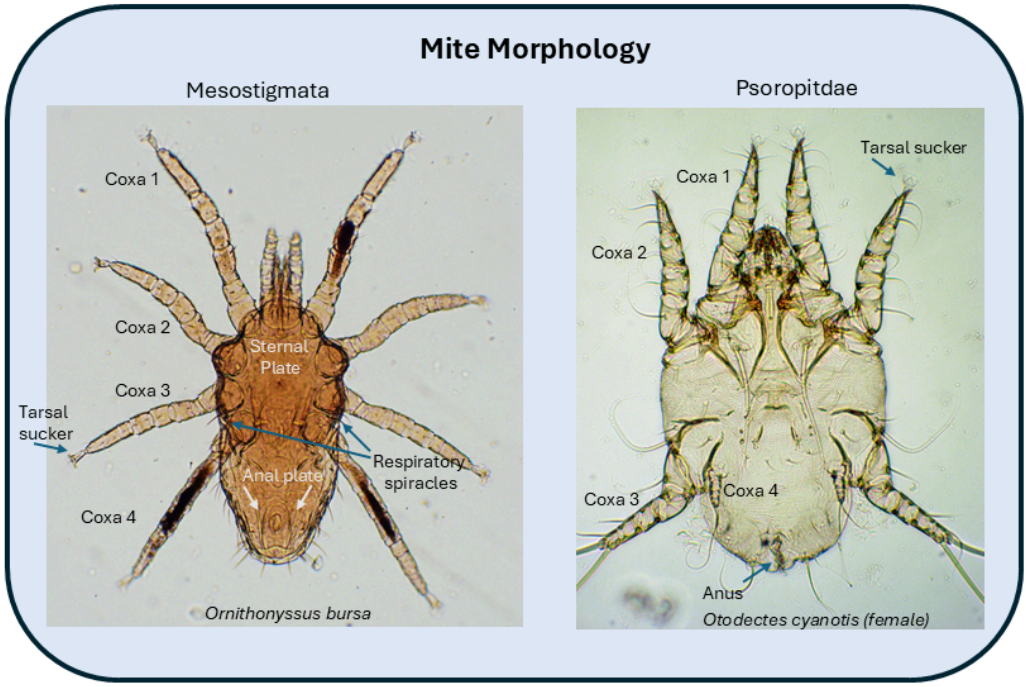
Taxonomy

Phylum Arthropoda

Class Chelicerata

Orders

- **Mesostigmata** – mesostigmatan mites
- **Acariformes** – Suborders Trombidiformes (Prostigmatan mites) and Sarcoptiformes (Astigmatan mites)



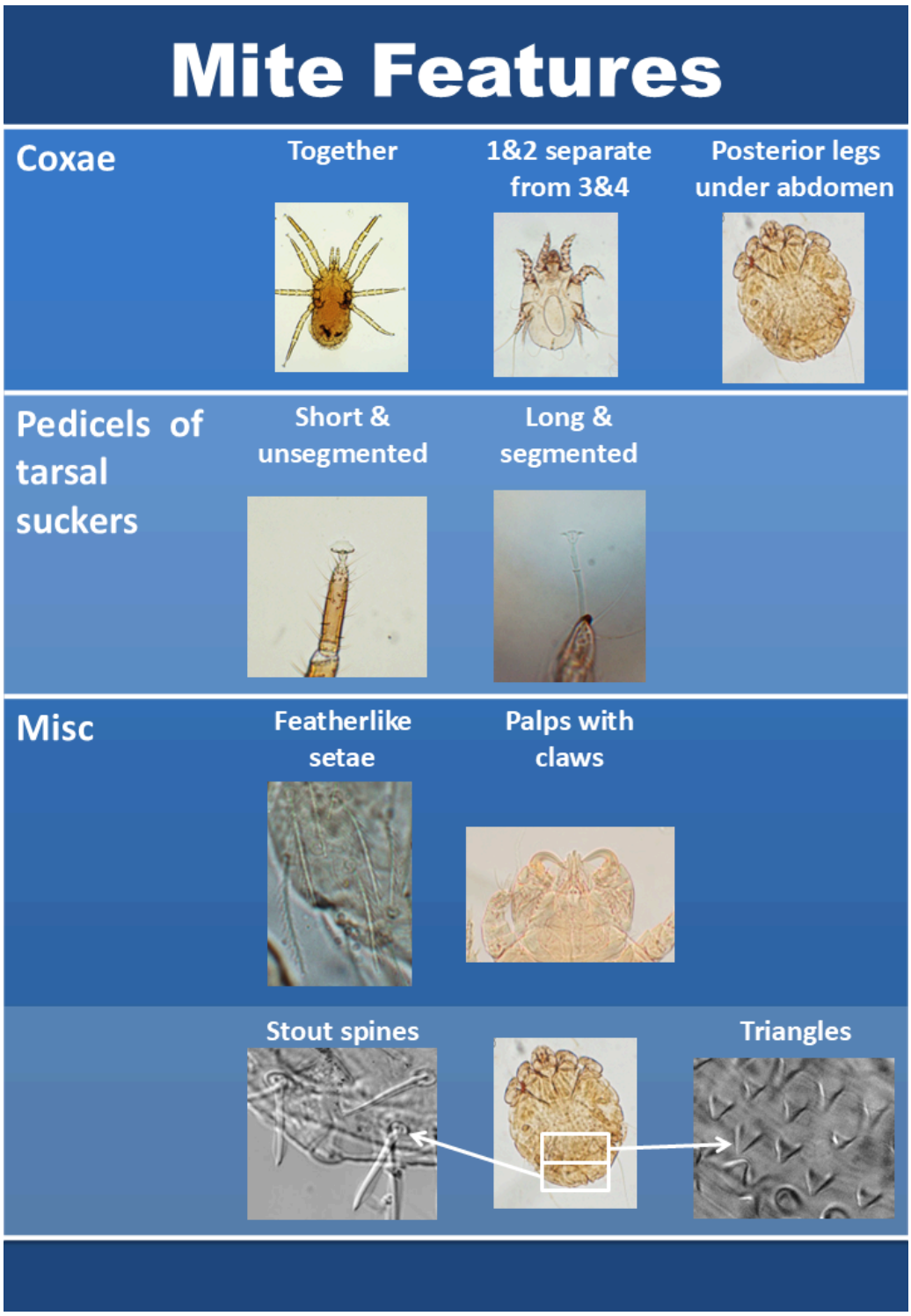
Mite morphology

Images: © Lyn Knott

Visit Mites for an overview of *Sarcopotes* characteristics.

Morphological Features

Morphological features used to distinguish between the various species of mite are shown below:



Images: © Lyn Knott

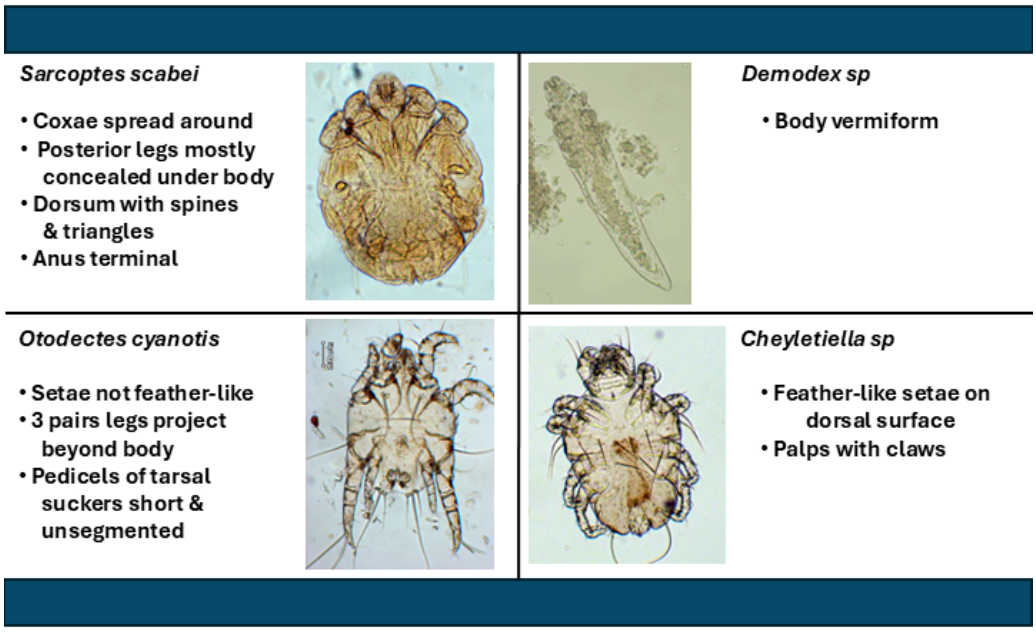
An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=244#h5p-31

Dichotomous keys that can be used to identify the mites include:

- Dichotomous key
- Interactive pictorial key to the mites

Common Mites

Photos and characteristics of some common mites are shown below.



Images: © Lyn Knott

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=244#h5p-32

Return to Mites theory chapter

33.

HELMINTHS

How to Identify Helminth Parasites of Mammals

We **don't** provide formal keys for helminths (flukes, cestodes and nematodes) because in some cases, the organisms of interest have (usually) distinctive morphology, reasonably high host specificity and high specificity in sites (organs) they infect. In other cases, the keys would be excessively complex. When you look at a parasitic worm, or any parasite in fact, consider:

1. **Look carefully at the specimen. Describe its general features.** Is the parasite long, flat and segmented – i.e. is it a tapeworm? Is the parasite flattened and leaf-like-a fluke? Is it bladder-like? Gourd-like? Is it a macroscopic cyst in solid tissues?

2. **What host species did this parasite come from?** Is the host a ruminant? Dog? Cat? Rodent?

3. **In what organ was the parasite found?** Intestine? Then the parasite could be an adult tapeworm, or perhaps a nematode. In body organs? Then it is likely a metacestode. In the bile ducts of the liver? Probably the liver fluke.

Helminth Differentiation Table

This Table is a simple tool to assist you to quickly differentiate various helminths.

Appearance	Grouping	General Information	Further Identification
Flat and leaf-shaped with suckers	Trematode (Liver fluke)	Lifecycle - complex Intermediate host - mollusc Hermaphroditic 2 suckers Soft-bodied	Trematodes
Pear-shaped with suckers	Trematode (Stomach fluke)	Lifecycle - complex Intermediate host - mollusc Hermaphroditic 2 suckers Soft-bodied	Trematodes
Flat with proglottids	Cestode Various genera	Lifecycle - complex 1, 2 or 3 intermediate hosts Hermaphroditic No alimentary tract	Cestode identification
Cylindrical - definitive head and tail	Nematode Various superfamilies	Lifecycles - simple OR complex Separate sexes Morphology - mouth, pharynx, gut, cloaca, tail	Nematode superfamily identification

34.

TREMATODES

How to Identify Adult Flukes of Domestic Animals in Australia

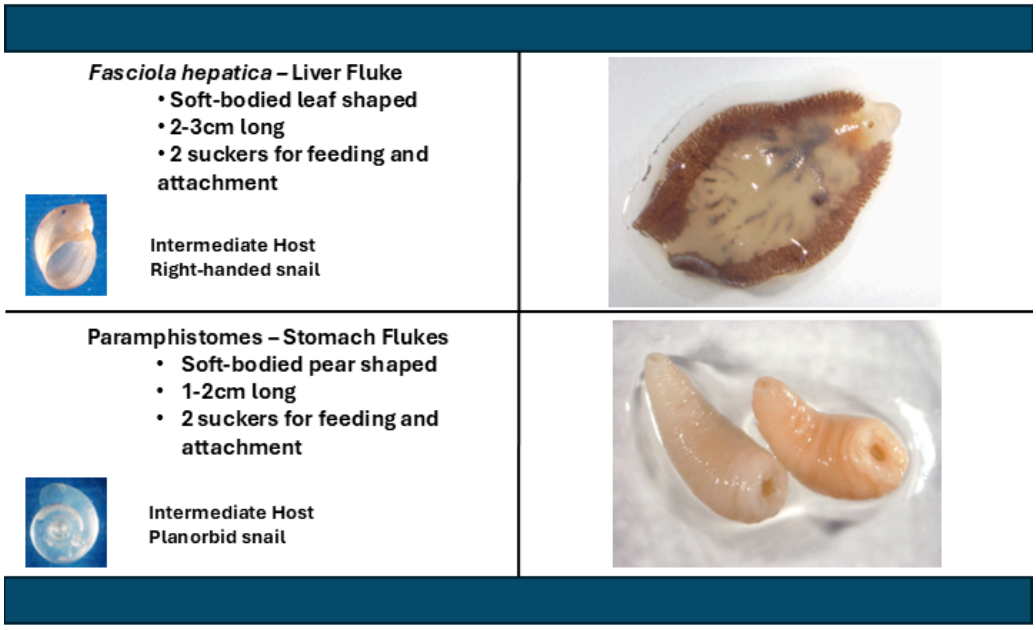
The most significant species of trematodes of Australian domestic animals are the liver fluke and the stomach flukes. These are easily distinguished by site of parasitism and their distinctive morphologies.

Visit Trematodes for a quick overview of flukes.

Fresh Water Snails provides a guide to the identification of snail hosts of Australian trematodes.

Common Trematodes

Two common trematodes of domestic animals are shown below:



Photos: © Lyn Knott

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online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=236#h5p-8

Return to Trematodes Theory chapter

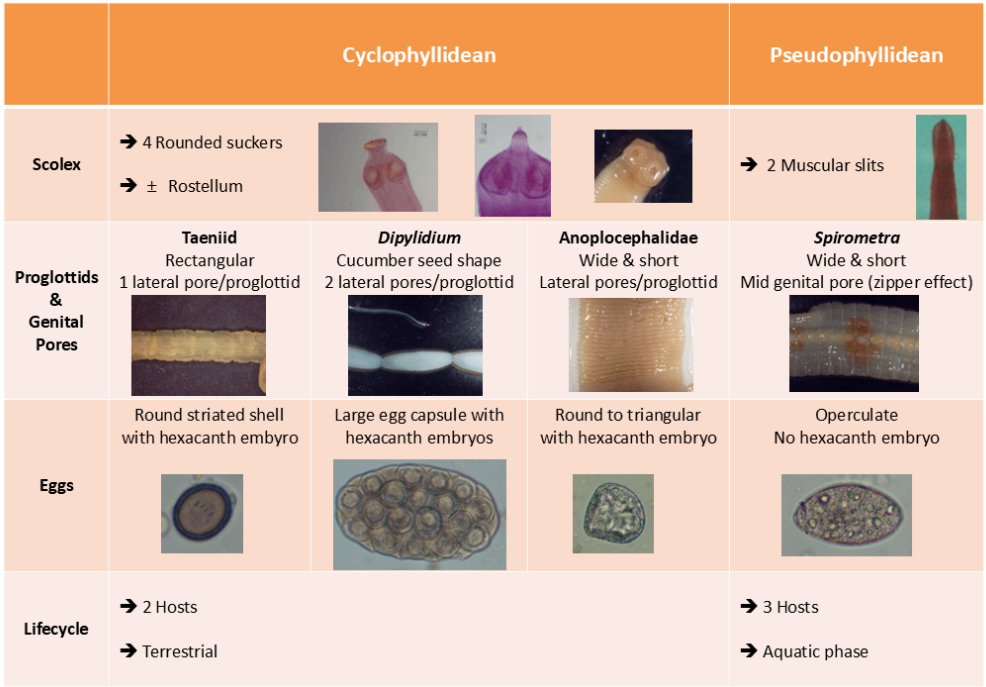
35.

CESTODES

Cestode Summary Table

Genus	Genital Pore	Proglottid Shape
Spirometra	Central	Narrow, rectangular
Dipylidium	2 per proglottid	Cucumber seed shape
Taenia	1 per proglottid	Square, rectangular
Echinococcus	1 per proglottid	Only ~4 proglottids long (0.5 cm)
Moniezia	2 per proglottid	Narrow, rectangular
Anoplocephala	1 per proglottid	Narrow, rectangular

A general overview of the tapeworms is shown below.



Photos: © Lyn Knott

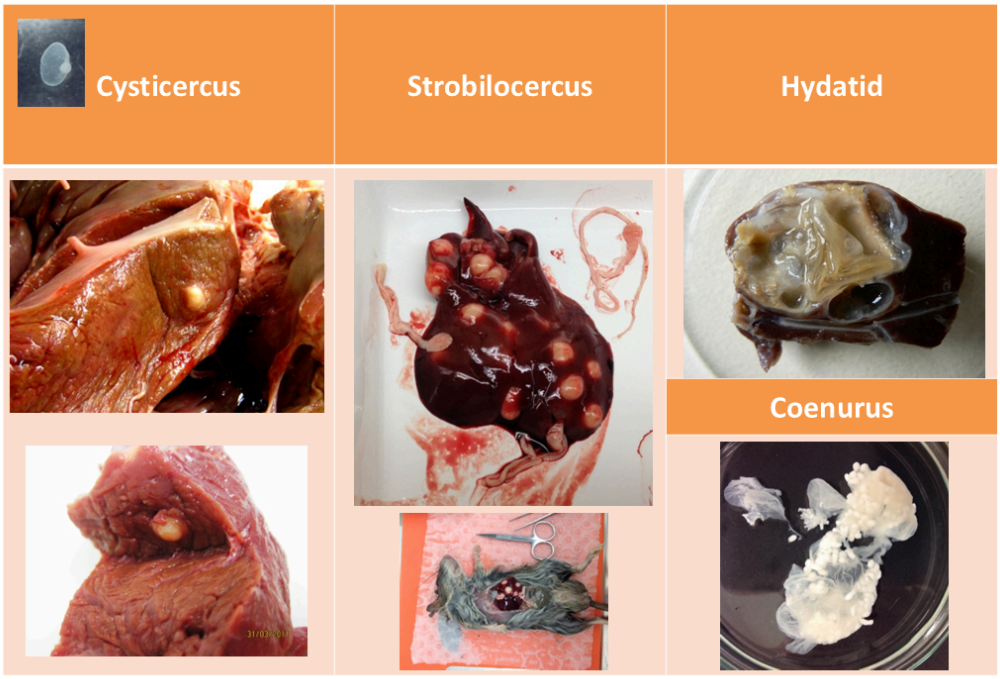
An interactive H5P element has been excluded from this version of the text. You can view it

online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=238#h5p-34

The Taenia Lifecycle Table has information on the hosts (definitive and intermediate) and sites of infection of the taeniid cestodes.

Metacestode Forms

Photos of the various metacestode forms of the Taeniid tapeworms are shown below:



Photos © Lyn Knott

Visit Hydatid cyst – wallaby for the morphology of the removed cyst.

Visit Cestode gallery to see photos of the various individual tapeworms commonly associated with domestic species.

Other Chapters

Also visit:

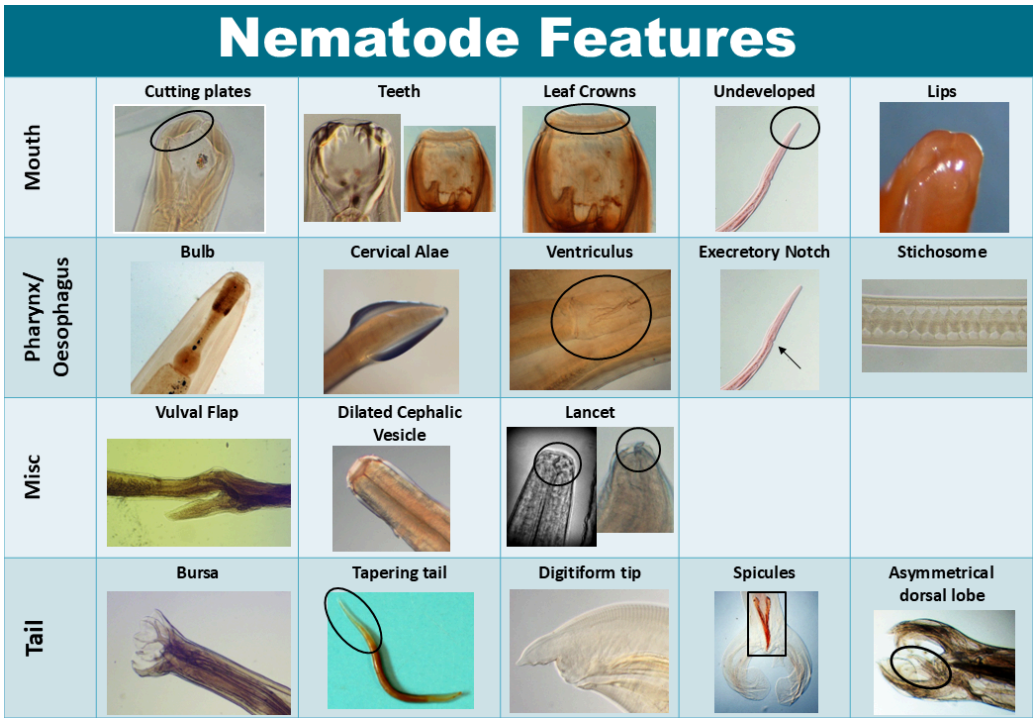
- Trematodes
- Nematodes.

36.

NEMATODES

Identification

Morphological features of nematodes are used to differentiate them. The more common of these features are shown below.



Photos: © Lyn Knott

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https://uq.pressbooks.pub/principles-disease-parasitology/?p=177#h5p-35

Nematode superfamily summary table

There are many important nematode parasites of domestic animals. The table below lists the superfamilies that incorporate these nematodes, and some general identification features. Superfamilies of the order

Strongylida (the bursate nematodes) are shown in bold in the first column. You can follow the links for more detailed identification of species within each superfamily.

Superfamily	Common Name	Anterior Features	Posterior Features	Size	Site Within Host	Further identification
Ancylostomatoidea	Hookworms	Large, bent buccal capsule, teeth/plates	Male - bursa	1 cm	Small intestine	Hookworm identification
Strongyloidea	Strongylids	Large buccal capsule, leaf crowns	Male - bursa	1 - 8 cm	Large intestine	Strongylid identification
Trichostrongyloidea	Trichostrongylids	Vestigial buccal capsule	Male - large bursa	0.7 - 3 cm	Small intestine or stomach	Trichostrongylid identification
Metastrongyloidea	Lungworms	N/A	L1 has distinctive kink in tail	N/A	Lung	Lungworm identification
Rhabditoidea	Threadworms	Vestigial buccal capsule, long pharynx	N/A	0.6 cm	Small intestine	Threadworm identification
Ascaridoidea	Ascarids	3 lips	N/A	5 - 50 cm	Small intestine	Ascarid identification
Oxyuroidea	Pin worms	Bulb oesophagus	Long pointed ('pin') tail	1 - 8 cm	Large intestine	Pinworm identification
Trichuroidea	Whip worms	Distinctive 'whip-like' shape, anterior long and slender	Posterior is thicker and shorter than anterior	1 - 4 cm	Large intestine	Whipworm identification
Filariodidea	Heartworms	Long, thin worm	N/A	10 - 20 cm	Heart	Heartworm identification
Spiruroidea	Spirurids	Distinctive buccal capsule	N/A	1 - 3 cm	Stomach	N/A

Superfamily Trichostrongyloidea (Trichostrongyles)

The superfamily Trichostrongyloidea (the trichostrongyles) includes some important bursate nematodes infecting ruminants and horses.

Host	Genus	Size	Site Within Host	Dorsal Ray	Anterior Features	Spicules	Gubernaculum	Vulval Flap
Ruminant	*Haemonchus*	1 - 3 cm	Abomasum	Asymmetrical	Stylet, cervical spines	Short	Yes	Yes
Ruminant, horse	*Trichostrongylus*	<1 cm	Abomasum and small intestine	Symmetrical	Excretory notch behind mouth	Short	Yes	No
Ruminant	*Cooperia*	<1 cm	Small intestine	Symmetrical	Cephalic dilation	Short	No	No
Ruminant	*Nematodirus*	1 - 2 cm	Small intestine	Symmetrical	Cephalic vesicle	Long, fused tips	No	No
Sheep	*Teladorsagia*	<1 cm	Abomasum	Symmetrical				Yes
Cattle	*Ostertagia*	<1 cm	Abomasum	Symmetrical				Yes

Superfamily Strongyloidea (Strongyles)

The superfamily Strongyloidea (the strongyles) includes some important bursate nematodes infecting ruminants, horses and swine.

Host	Species	Size	Anterior Features
Horse	*Strongylus equinus*	3 - 5 cm	leaf crowns, 3 pointed teeth, globular buccal capsule
Horse	*Strongylus edentatus*	3 - 5 cm	Leaf crowns, no teeth, globular buccal capsule
Horse	*Strongylus vulgaris*	3 - 5 cm	Leaf crowns, 2 rounded teeth, globular buccal capsule
Horse	*Triodontophurus spp.*	2 - 4 cm	Leaf crowns, 5 pointed teeth, cyclindrical buccal capsule
Horse	*Cyathostomins*	1 - 1.5 cm	Leaf crowns, small and ornate anterior
Ruminant	*Chabertia ovina*	1.5 - 3 cm	Tiny leaf crowns, large and plain buccal capsule
Ruminant and swine	*Oesophagostomum spp.*	1.5 - 3 cm	Leaf crowns, small and ornate anterior

Superfamily Ancylostomatoidea (Hookworms)

The superfamily Ancylostomatoidea (the hookworms) includes some important bursate nematodes of dogs, cats and ruminants.

Host	Species	Anterior Features
Dog	*Ancylostoma caninum*	2 x 3 teeth at mouth opening
Dog/Cat	*Ancylostoma braziliense*	2 x 2 teeth at mouth opening
Cat	*Ancylostoma tubaeforme*	2 x 3 teeth at mouth opening
Dog/Cat	*Uncinaria stenocephala*	2 x cutting plates at mouth opening
Ruminant	*Bunostomum spp.*	Well-developed dorsal cone 2 x small triangular lancets near oesophageal opening Cutting plates (hard to see)

Superfamily Metastrongyloidea (Lungworms)

The superfamily Metastrongyloidea (the lungworms) includes some important bursate nematodes of cats, rats, ruminants and donkeys.

Host	Species	Size	Features
Cat	*Aelurostrongylus abstrusus*	1 cm	L1 found in faeces (kinked tail)
Rat	*Angiostrongylus cantonensis*	1 - 2 cm	L1 found in faeces (kinked tail)
Ruminants and donkeys	*Dictyocaulus spp.*	3 - 10 cm	L1 in faeces, no kink in tail

Superfamily Rhabditoidea (Threadworms)

The superfamily Rhabditoidea (the threadworms) includes some important non-bursate nematodes of domestic animals.

Host	Species	Size	Site Within Host	Features
Most domestic animals	*Strongyloides spp.*	5 - 7 mm	Small intestine	Long pharynx (up to 1/3rd of length)

Superfamily Ascaridoidea (Ascarids)

The superfamily Ascaridoidea (the ascarids) includes some important non-bursate nematodes infecting dogs, cats, horses, pigs, ruminants and poultry.

Host	Species	Size	Features
Dog	*Toxocara canis*	10 - 18 cm	Narrow cervical alae Ventriculus Male tail - digitiform
Cat	*Toxocara cati*	3 - 10 cm	Broad cervical alae Ventriculus Male tail - digitiform
Dog/Cat	*Toxascaris leonina*	7 - 10 cm	Narrow cervical alae No vetriculus Male tail - tapered point
Horse	*Parascaris equorum*	15 - 50 cm	Size & location in host
Pig	*Ascaris suum*	20 - 40 cm	Size & location in host
Ruminant	*Toxocara vitulorum*	15 - 30 cm	Size & location in host
Poultry	*Ascaridia galli*	6 - 12 cm	Size & location in host
Poultry	*Heterakis gallinarum*	1 - 2 cm	Size & location in host

Superfamily Oxyuroidea (Pinworms)

The superfamily Oxyuridoidea (the pinworms) includes some important non-bursate nematodes infecting horses and rabbits.

Host	Species	Size	Features
Horse	*Oxyuris equi*	3 - 10 cm	Long tapered tail Eggs cemented to perianal skin
Rabbit	*Passalarus ambiguus*	1 cm	Long tapered tail

Superfamily Habronematoidea

The superfamily Habronematoidea (the hairworms) includes some important non-bursate nematodes infecting horses.

Host	Species	Size	Features
Horse	*Habronema spp.*	20 mm	2-part buccal capsule
Horse	*Draschia megastoma*	10 - 15 mm	1-part buccal capsule

Superfamily Filaroidea

The superfamily Filaroidea includes heartworm of dogs.

Host	Species	Size	Adult location	Microfilaria
Dog	*Dirofilaria immitis*	12 - 39 cm	Pulmonary arteries	Circulatory system
Dog	*Dipetalonema reconditum*		Peritoneal cavity & adipose/ subcutaneous connective tissue	Circulatory system
Horse	*Onchocerca cervicalis*	3 – 60 cm	Ligamentum nuchae	Dermis, especially ventral midline skin (skin scrapings)
Cattle	*Onchocerca gibsoni*	3 - 20 cm	Muscle tissue (brisket)	Dermis, especially at vector feeding sites

Superfamily Trichuroidea (includes Whipworms)

The superfamily Trichuroidea (the whip worms) includes some important non-bursate nematodes infecting dogs, sheep, pigs and poultry.

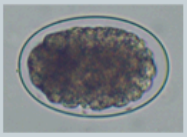
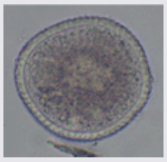
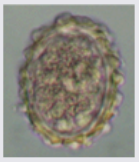
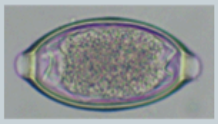
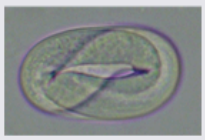
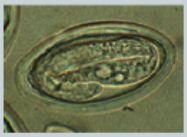
Host	Species	Features
Dog	*Trichuris vulpis*	Whip shape
Sheep	*Trichuris ovis*	Whip shape
Swine	*Trichuris suis*	Whip shape
Poultry	*Capillaria*	Thin and filamentous

Summarised Helminth Tables by Host

37.

HELMINTH EGGS AND PROTOZOA

Identifying Eggs and Protozoan Cysts of Domestic Animals

Nematode Eggs	Example	Features
Strongylid [All bursate nematodes except for *Nematodirus sp*]		• Oval • Thin shell • Usually with gap between shell and cells • Detection – faecal float
Ascarid	 	• Round to oval • Thick shell • Shell pitted, smooth or lumpy • Detection – faecal float
Trichurid		• Lemon shaped egg • Plug at each end • Detection – faecal float
Strongyloides sp		• Oval • Thin shell • Larvated • Detection – faecal float
Oxyurid		• Asymmetrical shape • Ovoid • Usually found in perianal area • Detection – sticky tape impression

Photos: © Lyn Knott

The table below describes the general appearance of the eggs from the various nematode groups.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=795#h5p-36

This table describes the eggs from the common trematodes (flukes) found in domesticated animals.

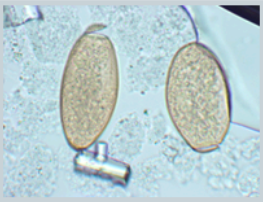
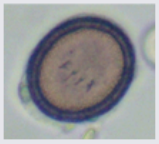
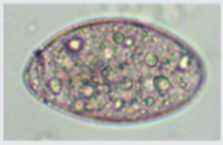
Trematode Eggs	Example	Features
Fasciola hepatica		• Distinctly yellow • Large & ovoid • Operculate • Detection - Sedimentation
Paramphistome		• White to colourless • Large & ovoid • Operculate • Detection - Sedimentation

Photo: © Lyn Knott

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=795#h5p-37

This table describes the eggs from the common cestodes (tapeworms) of domesticated animals

Cestode Eggs	Example	Features
Dipylidium caninum		• Egg capsule containing many eggs • Large & oval • Each egg contains an hexacanth embryo • Detection – from proglottid
Taeniid [*Taenia sp & Echinococcus granulosus*]		• Small round egg • Contains hexacanth embryo • Striated shell • Detection – faecal float
Moniezia sp		• Triangular shaped egg • Contains hexacanth embryo • Detection – faecal float
Anoplocephala perfoliata		• Round to 'D' shaped egg • Contains hexacanth embryo • Detection – faecal float
Thysaniezia sp		• Egg capsule containing several eggs • Each egg contains hexacanth embryo • Detection – faecal float
Spirometra erinacei		• Rounded diamond shaped egg • Solid egg • Operculate • Detection – faecal float

Photos: © Lyn Knott

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://uq.pressbooks.pub/principles-disease-parasitology/?p=795#h5p-38

Visit Eggs Found in Faecal Floats for images of common eggs and protozoal cysts from the various domestic animal species. Note their size in relation to each other.

Most worms of veterinary significance pass their eggs in faeces, so you will be looking for eggs in faecal preparations.

Always ask:

1. What host is the preparation from?
2. If possible, determine the size of the egg- this helps enormously.
3. Eggs of parasites have very distinctive morphology. So by knowing the host and the general egg morphology, you should be able to identify the superfamily and often the genus of the eggs.

Finally, sometimes parasites don't obey the rules, so always be prepared to be surprised and perplexed by odd-looking parasites as you examine hosts or faeces.

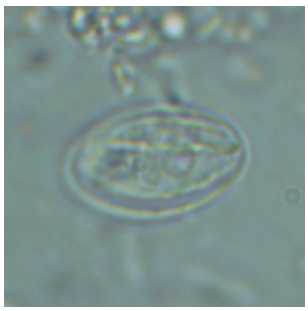
Information on Various Protozoa

This table lists common protozoa of domestic animals. Follow the links for more detailed information.

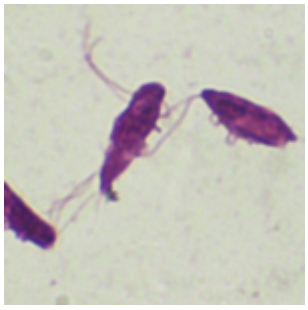
Note that *Anaplasma marginale*, although a rickettesia, is included as it is a differential in Tick Fever diagnosis.

Flagellates

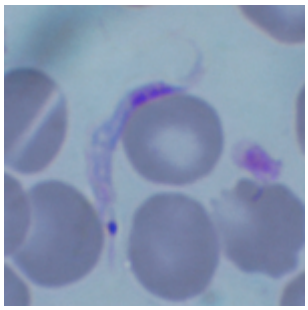
[Giardia](#)



[Trichomonas](#)



[Trypanosoma](#)



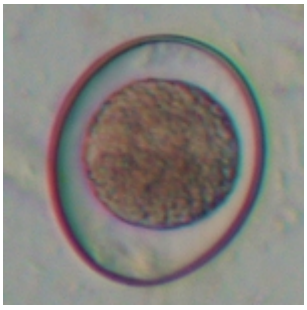
Apicomplexa

Eimeriida/Coccidia

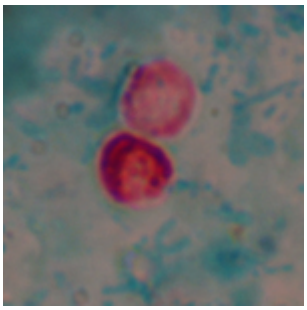
[Eimeria](#)



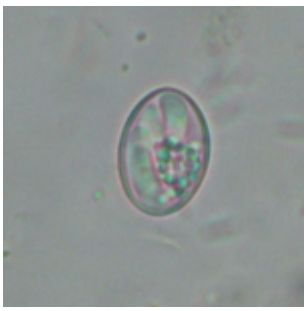
[Isospora](#)



[Cryptosporidium](#)



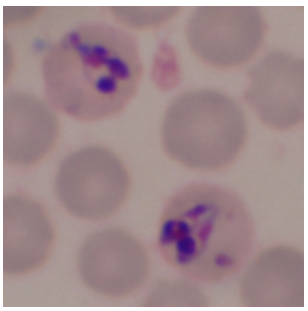
[Sarcocystis](#)



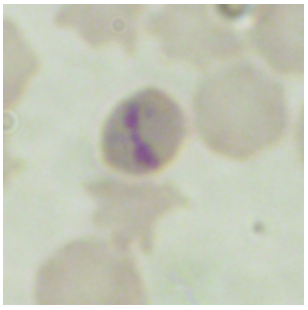
Apicomplexa

Piroplasmida

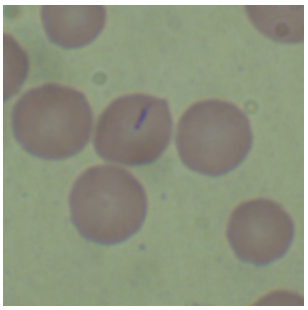
[Babesia bigemina](#)



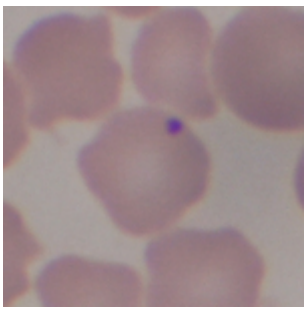
[Babesia bovis](#)



[Theileria](#)



[Anaplasma marginale](#)



Visit Tick Fever Comparison for a comparison of the tick fever organisms.

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This book has undergone peer review by a subject expert from a higher education institution.

The reviewer is a Specialist, Research Technology and Academic in the School of Veterinary Science, at The University of Queensland.

The review was structured around considerations of the intended audience of the book, and examined the relevance, accuracy, structure and clarity of the content. The Open Textbooks @ UQ Peer review guide has more details of the process. Changes suggested by the reviewer were incorporated by the authors.

We would like to thank Dr Tasmin Barnes for her time, care and commitment she contributed to the book. This book would not be the robust, valuable resource that it is were it not for her feedback and input.

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