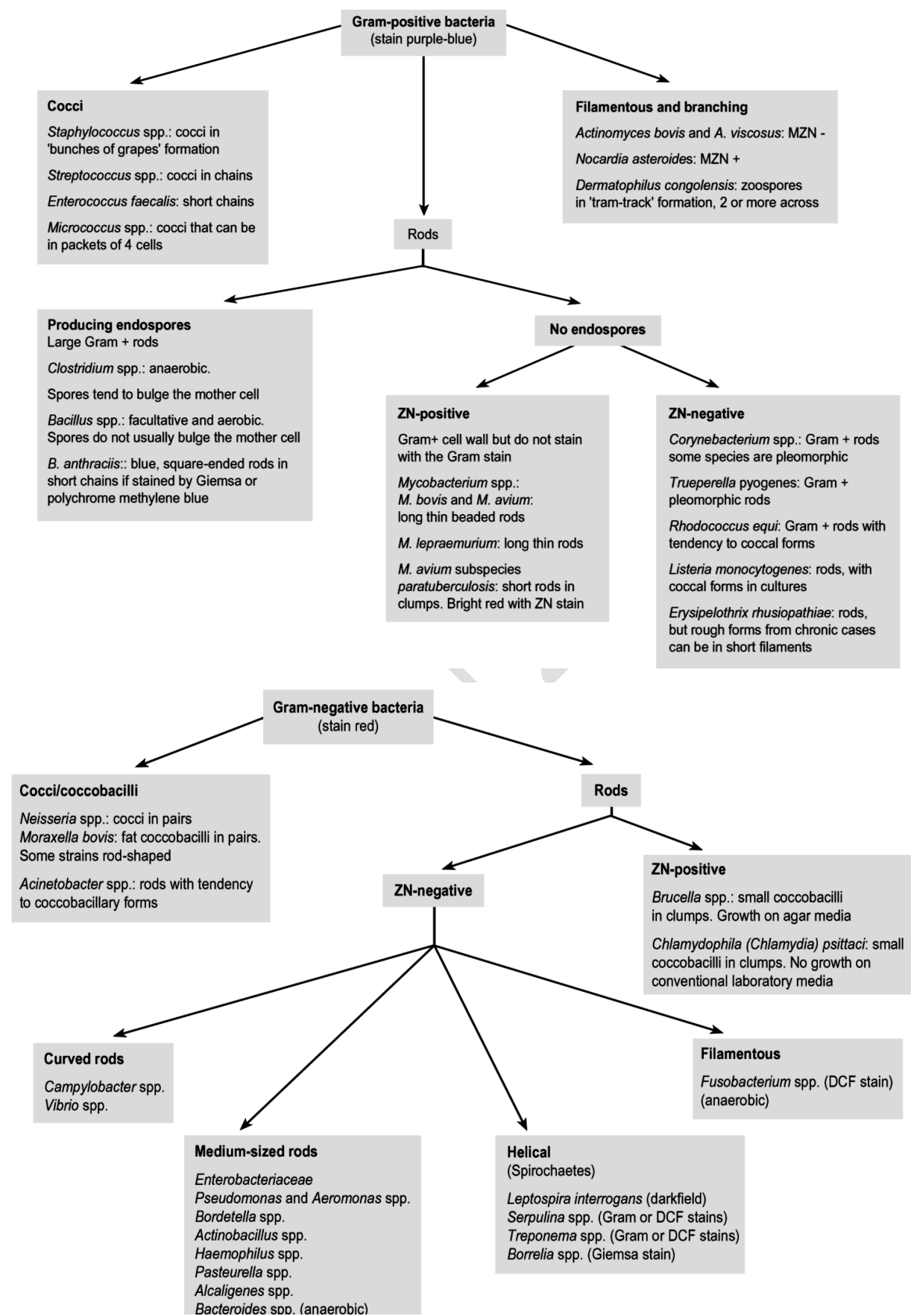


BACTERIOLOGY

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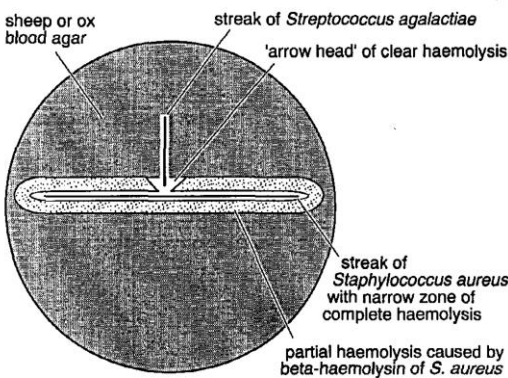
STAPHYLOCOCCUS

- Gram-positive cocci in clusters resembling bunches of grapes
- Grow on non-enriched media
- Moderately-sized white or golden colonies
- Colonies of *S. aureus* and *S. intermedius* produce double haemolysis
- Facultative anaerobes, non-motile, catalase-positive
- Commensals on mucous membranes and skin
- Coagulase production correlates with pathogenicity
 - **Slide and tube coagulase tests**
 - In these tests, a suspension of staphylococci is mixed with rabbit plasma either on a slide or in a small tube. The fibrinogen in rabbit plasma is converted to fibrin by coagulase.
 - The **slide test** detects the presence of a bound coagulase or clumping factor on the bacterial surface. A positive reaction is indicated by clumping of bacteria within 1 to 2 min.
 - The **tube test** detects free coagulase or staphylocoagulase which is secreted by the bacteria into the plasma. It is the definitive test for coagulase production and a positive reaction is indicated by clot formation in the tube following incubation at 37°C for 24 hours.
- Comparatively stable in the environment
- The coagulase-positive *S. aureus subsp. aureus* (referred to as *S. aureus*) and *S. intermedius*, and the coagulase-variable *S. hyicus* are important pathogens of domestic animals
- Cause pyogenic infections
 - **Exudative epidermitis** (greasy-pig disease),
 - Caused by *S. hyicus*
 - Occurs in sucklers and weaned pigs up to 3 months of age.
 - Characterized by widespread excessive sebaceous secretion, exfoliation and exudation on the skin surface.

- **Tick pyaemia**
 - An infection of lambs with *S. aureus*.
 - *Ixodes ricinus* is a vector for the rickettsia] agent of tick-borne fever, Ehrlichia phagocytophila, which can cause immunosuppression in lambs and may predispose to staphylococcal infection.
- **Botryomycosis**
 - A chronic, suppurative granulomatous condition, often caused by *S. aureus*.
 - It can occur within a few weeks of castration in the horse due to infection of the stump of the spermatic cord (scirrhous cord).

STREPTOCOCCUS

- Gram-positive cocci in chains
- Fastidious, requiring enriched media
- Small, usually haemolytic, translucent colonies
- Catalase-negative
- Facultative anaerobes, usually non-motile
- Commensals on mucous membranes
- Susceptible to dessication
- Cause pyogenic infections
- **Type of haemolysis on sheep or ox blood agar:**
 - **Beta-haemolysis** is complete haemolysis indicated by clear zones around colonies.
 - **Alpha-haemolysis** is partial or incomplete haemolysis indicated by greenish or hazy zones around colonies.
 - **Gamma-haemolysis** denotes no observable changes in the blood agar around colonies.
 - *Streptococcus agalactiae* elaborates a factor which completely lyses the red cells already damaged by the beta-haemolysin of *Staphylococcus aureus*, producing a characteristic **clear 'arrow head' pattern** of complete haemolysis



- **Lancefield grouping** is a serological method of classification based on the group-specific C-substance (polysaccharide) in the cell wall.

Species	Lancefield group	Hemolysis on blood agar
<i>S. pyogenes</i>	A	β
<i>S. agalactiae</i>	B	β
<i>S. dysgalactiae</i>	C	α
<i>S. equisimilis</i>	C	β
<i>S. equi</i> subsp. <i>equi</i>	C	β
<i>S. equi</i> subsp. <i>zooepidemicus</i>	C	β
<i>Enterococcus faecalis</i>	D	α
<i>S. suis</i>	D	α
<i>S. porcinus</i>	E	β
<i>S. canis</i>	G	β
<i>S. uberis</i>	Not assigned	α
<i>S. penumoniae</i>	Not assigned	α

- **Edwards medium** is highly selective for the streptococci and also indicates aesculin hydrolysis and the type of haemolysis.
- **Strangles**
 - A highly contagious disease of horses caused by *Streptococcus equi* (*S. equi* subsp. *equi*).
 - It is a febrile disease involving the upper respiratory tract with abscessation of regional lymph nodes.
 - Although non-immune Equidae of all ages are susceptible, outbreaks of the disease occur most commonly in young horses.
 - Guttural pouch empyema is a common finding.
 - **Purpura haemorrhagica**, considered to be an immune-mediated disease, may occur in some affected horses 1 to 3 weeks after initial illness.
 - Bastard strangles, in which abscessation develops in many organs, is a serious complication in about 1% of affected animals.

- ***Streptococcus suis***
 - Associated with meningitis, arthritis, septicaemia and bronchopneumonia in pigs of all ages, and with sporadic cases of endocarditis, neonatal deaths and abortion.
- ***Streptococcus agalactiae*, *S. dysgalactiae* and *S. uberis*** are the principal pathogens involved in streptococcal mastitis.

CORYNEBACTERIUM

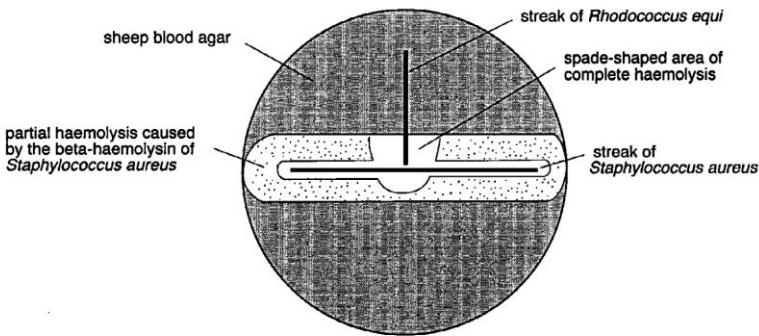
- Gram-positive, pleomorphic bacteria
- In stained smears, they occur singly, in palisades of parallel cells and in angular clusters resembling Chinese letters
- Fastidious, requiring enriched media
- Majority are commensals on mucous membranes
- Cause pyogenic infections
- Non-motile facultative anaerobes
- Catalase positive-oxidase negative
- Urease is produced by all pathogenic corynebacteria with the exception of *C. bovis*.
- **Caseous lymphadenitis**
 - Caused by the non-nitrate-reducing biotype of *C. pseudotuberculosis*
 - A chronic suppurative condition of sheep, goats and rarely cattle.
 - Infection results in abscessation and enlargement of superficial or internal lymph nodes.
 - Affected lymph nodes are enlarged and exhibit characteristic encapsulated abscesses which have an 'onion ring' appearance in cross-section.
 - *Corynebacterium pseudotuberculosis* has been isolated from the milk of affected goats.
- **Ulcerative lymphangitis** in horses and cattle
 - Sporadic cases caused by the nitrate-reducing biotype of *C. pseudotuberculosis*
 - The condition presents either as lymphangitis of the lower limbs or abscessation in the pectoral region.
- **Ulcerative (enzootic) balanoposthitis (pizzle rot)**
 - Common in Merino sheep and Angora goats
 - Caused by *C. renale*
 - Characterized by ulceration around the preputial orifice, with a brownish crust developing over the lesion.

- **Bovine pyelonephritis**
 - Organisms belonging to the *C. renale* group can be isolated from the vulva, vagina and prepuce of apparently normal cattle.
 - The stress of parturition and the shortness of the urethra in the cow predispose to infection of the urinary tract.
 - The most severe form of cystitis is associated with *C. cystitidis*.

Previous name	Present name
<i>C. equi</i>	<i>Rhodococcus equi</i>
<i>C. murium</i>	<i>C. kutscheri</i>
<i>C. ovis</i>	<i>C. pseudotuberculosis</i>
<i>Actinomyces</i> (<i>Corynebacterium</i>) <i>pyogenes</i>	<i>Trueperella</i> (<i>Arcanobacterium</i>) <i>pyogenes</i>
<i>Eubacterium</i> (<i>Corynebacterium</i>) <i>suis</i>	<i>Actinobaculum suis</i>
<i>C. renale</i> type I	<i>C. renale</i>
<i>C. renale</i> type II	<i>C. pilosum</i>
<i>C. renale</i> type III	<i>C. cystitidis</i>

RHODOCOCCUS

- Gram-positive rods or cocci
- Growth on non-enriched media
- Salmon-pink mucoid colonies with no haemolysis
- Aerobic, non-motile
- CAMP test-positive
 - *Rhodococcus equi* produces a factor which completely lyses the red cells previously damaged by the beta-haemolysin of *Staphylococcus aureus*, producing a **spade-shaped pattern of complete haemolysis** which extends across the streak of *S. aureus*.



- Soil saprophyte
- **Suppurative bronchopneumonia** of foals is the major disease caused by this pyogenic organism.
 - Generally acquired by inhalation of dust contaminated with *R. equi*.
 - The organism is often present in large numbers in the faeces of healthy foals under 3 months of age, and can

also be isolated from the faeces of older horses and many other mammals and birds.

- A combination of oral rifampin and erythromycin for 4 to 10 weeks, although expensive, is the preferred treatment.

ACTINOMYCETES

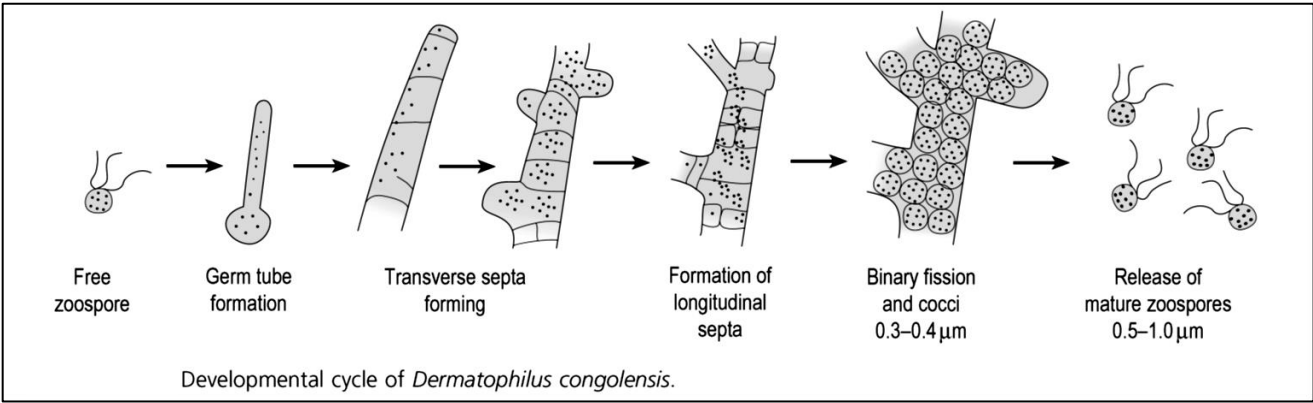
- Gram-positive bacteria, many species with branching filaments
- Relatively slow growth on laboratory media
- Opportunistic pathogens producing diverse inflammatory responses
- **Actinomyces, Arcanobacterium and Actinobaculum species**
 - Anaerobic or facultatively anaerobic
 - Morphologically heterogeneous
 - Non-spore-forming, non-motile
 - MZN-negative
 - Colonize mucous membranes
 - **Actinomyces viscosus** is the aetiological agent of canine actinomycosis.
 - In the acute bovine mastitis, referred to as **'summer mastitis'**, the anaerobic bacterium *Peptostreptococcus indolicus* is usually associated with *Trueperella (Arcanobacterium) pyogenes*.
 - **Bovine actinomycosis (lumpy iaw)**
 - Invasion of the mandible and, less commonly, the maxilla of cattle by *Actinomyces bovis* causes a chronic rarefying osteomyelitis.
 - The organism is presumed to invade the tissues following trauma to the mucosa from rough feed or through dental alveoli during tooth eruption.
 - A painless swelling of the affected bone enlarges over a period of several weeks.
 - In infections caused by *A. bovis*, pinhead-sized, **yellowish 'sulphur granules'** are found.
 - **Porcine cystitis and pyelonephritis**
 - Affects the urinary tract of pregnant sows
 - Transmitted at coitus
 - The pathogen, *Actinobaculum suis* can be isolated from the prepuce and preputial diverticulum of healthy boars but not from

the urogenital tract of healthy sows.

- **Nocardia species**
 - Aerobic, non-motile
 - Spores from aerial filaments
 - Growth on Sabouraud dextrose agar
 - MZN-positive
 - Soil saprophytes
 - ***Nocardia asteroides*** accounts for most nocardial infections in domestic animals
 - The most commonly encountered conditions are cutaneous and systemic infections in dogs and mastitis in cattle.
 - ***Nocardia farcinica*** is implicated in **bovine farcy or bovine nocardiosis**.
 - A chronic infection of superficial lymphatic vessels and lymph nodes.
- ***Dermatophilus congolensis***
 - Aerobic and capnophilic
 - This actinomycete is unusual because it produces motile coccal zoospores.
 - Mature filaments contain columns of zoospores which impart a 'tram-track' appearance to the filaments.
 - No growth on Sabouraud dextrose agar
 - Found in scabs and in foci on skin of carrier animals
 - Infections with *D. congolensis* are usually confined to the epidermis.
 - Commonly used designations for infection with this organism are **dermatophilosis** and **cutaneous streptothricosis**.
 - **Lumpy wool** is used to describe infection of woolled areas of the skin in sheep.
 - When the skin of the lower limbs of sheep is involved, the condition is termed **strawberry footrot**.

LISTERIA

- Small, Gram-positive rods
- Grow on non-enriched media
- Tolerates wide temperature and pH ranges
- Small haemolytic colonies on blood agar
- Facultative anaerobes, catalase-positive, oxidase-negative
- **Tumbling motility** at 25°C
- Aesculin hydrolysed
- Environmental saprophytes
- **Listeriosis** in ruminants may present as encephalitis, abortion, septicaemia or endophthalmitis.
 - Outbreaks of listeriosis often related to silage and feeding
 - *Listeria monocytogenes* can replicate in the surface layers of poor-quality silage with pH values above 5.5.
 - In good quality silage, multiplication of the organisms is inhibited by the acid produced by fermentation.
 - **Cold-enrichment procedure** is necessary for isolating the organism from brain tissue.
 - Small pieces of medulla are homogenized and a 10% suspension is made in nutrient broth.
 - The suspension is held at 4°C in a refrigerator and subcultured weekly onto blood agar for up to 12 weeks.
 - Most isolates of animal origin are virulent, a characteristic which can be confirmed by animal inoculation. Instillation of a drop of broth culture into the eye of a rabbit induces keratoconjunctivitis (**Anton test**).



ERYSIPELOTHRIX

- Gram-positive, small rods (smooth form) or filaments (rough form)
- Growth on non-enriched media
- Small colonies, with incomplete haemolysis in 48 hours
- Growth over wide temperature and pH ranges
- Catalase-negative
- Coagulase-positive
- Non-motile, oxidase-negative, facultative anaerobe
- H₂S formed along stab line in TSI agar
- Found in porcine tonsils
- **Clinical manifestations of *Erysipelothrix rhusiopathiae* infection in domestic animals**
 - Pigs (swine erysipelas)
 - The septicaemic and cutaneous ('diamond') forms are acute while arthritis and vegetative endocarditis are chronic forms of the disease.
 - Abortion
 - Infection is usually acquired through ingestion of contaminated food or water and less commonly through minor skin abrasions.
 - Sheep
 - Polyarthritis in lambs
 - Post-dipping lameness
 - Pneumonia
 - Valvular endocarditis
 - Turkeys (turkey erysipelas)
 - Septicaemia
 - Arthritis
 - Valvular endocarditis
 - Dark-coloured, swollen snoods are characteristic of the disease.
 - Postmortem findings include enlarged friable livers and spleens.

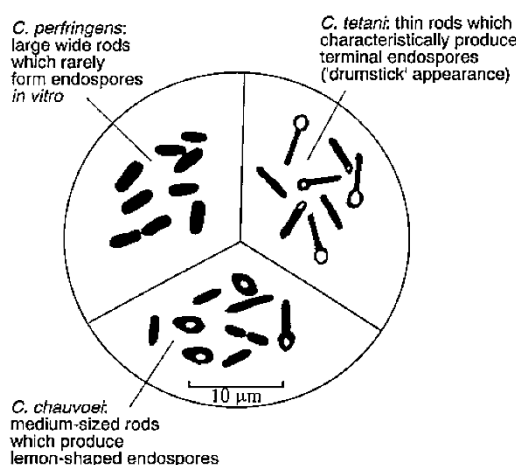
BACILLUS

- Large, Gram-positive rods
- Endospores produced
- Aerobes or facultative anaerobes
- Growth on non-enriched media
- Most species motile, catalase-positive and oxidase-negative
- Majority are non-pathogenic environmental organisms

- *Bacillus anthracis* causes **anthrax**
 - Colonies with a '**ground glass**' **appearance** after incubation for 48 hours.
 - At low magnification, curled outgrowths from the edge of the colony impart a characteristic, '**medusa head**' **appearance**.
 - Polychrome methylene-blue-stained smears reveal square-ended, blue rods arranged singly, in pairs or in short chains surrounded by pink to purplish capsular material (**M'Fadyean's reaction**) which is characteristic for *B. anthracis*.
 - Ruminants are highly susceptible, often developing a rapidly fatal septicaemic form of the disease.
 - Pigs and horses are moderately susceptible to infection, while carnivores are comparatively resistant.
 - Birds are almost totally resistant to infection, a characteristic attributed to their relatively high body temperatures.
 - In **cattle**, postmortem findings include rapid bloating, incomplete rigor mortis, widespread ecchymotic haemorrhages and oedema, dark unclotted blood and blood-stained fluid in body cavities. An extremely **large soft spleen** is characteristic of the disease in cattle.
 - In **pigs**, infection generally results in **oedematous swelling of the throat** and head along with regional lymphadenitis.
 - The carcasses of such animals should not be opened because this will facilitate sporulation, with the risk of long-term environmental contamination.
 - Peripheral blood from the tail vein of ruminants or peritoneal fluid from pigs should be collected into a sterile syringe.
 - The **Ascoli test** is a thermoprecipitation test designed to detect antigens of *B. anthracis* in biological materials such as hides.
 - **Three main forms of the disease** occur in man.
 - **Cutaneous** anthrax (malignant pustule) is the result of endospores entering abraded skin.

- **Pulmonary** anthrax ('woolsorters' disease') follows inhalation of spores
- **Intestinal** anthrax results from ingestion of infective material.
- *Bacillus licheniformis* is implicated in sporadic abortions in cattle and sheep and occasionally causes bovine mastitis.
- *Bacillus cereus* is best known as a cause of food-borne illness in humans and occasionally affects animals, mainly dogs and cats
 - Produce **two types of food-poisoning**: the diarrhoeal type and the emetic type. *Bacillus licheniformis* is an important cause of
- *Bacillus subtilis* has also been implicated in cases of food poisoning and in cases of bovine mastitis and ovine abortion
- *B. pumilus* has been isolated from cases of bovine mastitis.

CLOSTRIDIUM



- Large, Gram-positive rods
- Endospores produced
- Anaerobic, catalase- and oxidase-negative
- Motile (except *C. perfringens*)
- Enriched media required for growth
- Colonies of *C. perfringens* surrounded by zones of double haemolysis
- Present in soil, in alimentary tracts of animals and in faeces
- Pathogens can be grouped according to the mode and sites of action of their potent exotoxins:
 - Neurotoxic clostridia
 - Affect neuromuscular function without inducing observable tissue damage.
 - *C. tetani*
 - *C. botulinum* (types A-G)
 - Histotoxic clostridia
 - produce relatively localized lesions in tissues such as muscle and liver, and may subsequently cause toxæmia
 - *C. chauvoei*
 - *C. septicum* in muscle tissue
 - *C. novyi* type B and *C. haemolyticum* in the liver
 - *C. novyi* type A
 - *C. perfringens* type A
 - *C. sordellii*
 - Enteropathogenic and enterotoxæmia producing clostridia
 - *C. perfringens* (types A-E)
- Produce diverse forms of disease in many animal species
- **Tetanus**
 - Horses and man are highly susceptible, ruminants and pigs moderately so, and carnivores are comparatively resistant.
 - Poultry are not susceptible to tetanus.
 - The clostridial organisms may replicate more readily in the tissues when the haemolytic toxin, tetanolysin, is released.
 - Vegetative bacteria multiplying in necrotic tissues produce the potent tetanospasmin which is responsible for the clinical signs of tetanus.
 - Spasm of masticatory muscles may lead to 'lockjaw'.
 - Generalized muscle stiffness can result in a 'saw-horse' stance especially in horses
- **Botulism**
 - Acquired by ingestion of pre-formed toxin.
 - The difference between the effects of tetanus and botulinum toxins is due to their different sites of action. Tetanus toxin travels up the nerve axon to the ventral horn whereas botulinum toxin remains at the neuromuscular junction.
 - The traditional method for demonstrating toxin is by mouse inoculation. Injected mice develop a characteristic '**wasp-waist**' appearance, a consequence of abdominal breathing following paralysis of respiratory muscles.
- **Blackleg**
 - An acute disease of cattle and sheep caused by *C. chauvoei*,
 - Gangrenous cellulitis and myositis caused by exotoxins produced by the



Clostridium species	Hosts	Diseases
Neurotoxic clostridia		
<i>Clostridium tetani</i>	Horses, ruminants, humans and other animals	Tetanus
<i>Clostridium botulinum</i> (types A to F)	Many animal species and humans	Botulism
<i>Clostridium argentinense</i> (<i>Clostridium botulinum</i> type G)	Humans	Botulism
Histotoxic clostridia		
<i>Clostridium chauvoei</i>	Cattle, sheep (pigs)	Blackleg (black quarter)
<i>Clostridium septicum</i>	Cattle, sheep and pigs	Malignant oedema
	Sheep	Braxy
	Chickens	Necrotic dermatitis
<i>Clostridium novyi</i>		
Type A	Sheep	Big head of rams
	Cattle and sheep	Gas gangrene
Type B	Sheep (cattle)	Black disease (necrotic hepatitis)
<i>Clostridium sordellii</i>	Cattle, sheep, horses	Gas gangrene
Enterotoxigenic and enteropathogenic clostridia		
<i>Clostridium perfringens</i>		
Type A	Humans	Food poisoning, gas gangrene
	Lambs	Enterotoxaemic jaundice
	Dogs	Haemorrhagic gastroenteritis
	Pigs	Necrotizing enterocolitis (mild)
	Chickens	Necrotic enteritis (occasional cases)
Type B	Lambs (under three weeks old)	Lamb dysentery
	Neonatal calves and foals	Enterotoxaemia
Type C	Piglets, lambs, calves, foals	Haemorrhagic enterotoxaemia
	Adult sheep	Struck
	Chickens	Necrotic enteritis
Type D	Sheep (all ages except neonates) (goats, calves)	Pulpy kidney disease
Type E	Calves	Haemorrhagic enteritis
	Rabbits	Enteritis
<i>Clostridium spiroforme</i>	Rabbits and guinea pigs	Spontaneous and antimicrobial-induced diarrhoea
<i>Clostridium difficile</i>	Foals, pigs, dogs, hamsters, rabbits (calves)	Spontaneous and antimicrobial-induced diarrhoea
	Humans	Antimicrobial-induced diarrhoea, important nosocomial infection
<i>Clostridium colinum</i>	Game birds, young chickens and turkey poults	Quail disease (ulcerative enteritis)
Atypical clostridia		
<i>Clostridium piliforme</i>	Foals, laboratory animals (other wild and domesticated animals)	Tyzzer's disease, hepatic necrosis

replicating organisms usually lead to rapid death.

- **Malignant oedema and gas gangrene** are exogenous, necrotizing, soft tissue infections.
 - The bacteria most commonly implicated are *C. septicum* in malignant oedema and *C. perfringens* type A in gas gangrene.
- **Braxy**, an abomasitis of sheep, is caused by the exotoxins of *C. septicum*.
- **Infectious necrotic hepatitis (black disease)**
 - An acute disease affecting sheep and occasionally cattle.
 - The hepatic necrosis is caused by exotoxins of *C. novyi* type B replicating in liver tissue which has

been damaged by immature *Fasciola hepatica* or other migrating parasites.

- The term 'black disease' relates to the dark discolouration of the skin caused by the marked subcutaneous venous congestion observed at postmortem examination.

- **Bacillary haemoglobinuria**
 - Occurs primarily in cattle and occasionally in sheep.
 - In this endogenous infection with *C. haemolyticum*, the clostridial endospores are dormant in the liver, probably in Kupffer cells.
- **Pulpy kidney disease**
 - Caused by *C. perfringens* type D



- The condition is also described as 'over-eating disease' because gorging on a high grain diet or on succulent pasture predisposes to its development.
- Rapid kidney autolysis which leads to pulpy cortical softening is a typical postmortem finding.
- Infection with *C. piliforme*, **Tyzzler's disease**, results in severe hepatic necrosis.
 - Hepatomegaly with extensive areas of necrosis is the principal postmortem finding.
- **Nagler reaction**
 - A plate neutralization test
 - Identifies the alpha toxin of *C. perfringens*, which has lecithinase activity

Clostridium perfringens type	Hosts	Disease
A	Humans	Food poisoning
	Chickens	Necrotic enteritis
	Pigs	Necrotizing enterocolitis
	Horses	Neonatal enteritis, antibiotic-induced diarrhoea in adults
	Dogs	Haemorrhagic gastroenteritis
B	Lambs	Lamb dysentery
	Calves and foals	Haemorrhagic enteritis
C	Piglets (usually one to three days old), foals, calves and lambs	Haemorrhagic enterotoxaemia in young farm animals
	Adult sheep	'Struck'
D	Sheep (all ages except neonates), rare cases in calves and goats	Pulpy kidney disease, enterotoxaemia
E	Calves	Haemorrhagic enteritis
	Rabbits	Enteritis

Comparison of the toxins of *C. tetani* and *C. botulinum*

	<i>C. tetani</i>	<i>C. botulinum</i>
Site of production	Wounds	Carcasses, decaying vegetation and occasionally wounds and intestine
Type of paralysis	Spastic	Flaccid
Mode of action	Toxin acts centrally. Cleaves proteins that mediate fusion of neurotransmitter vesicles with presynaptic membrane of inhibitory interneurons	Toxin acts peripherally. Cleaves proteins that mediate fusion of neurotransmitter vesicles with presynaptic membrane of cholinergic nerves

MYCOBACTERIUM

- Acid-fast (Ziehl-Neelsen-positive) rods
 - The high lipid and mycolic acid content of their cell walls prevents uptake of the dyes employed in the Gram stain.
 - The cell wall lipids bind carbol fuchsin which is not removed by the acid-alcohol decolourizer used in the ZN staining method.
- Complex egg-enriched media required for growth of pathogenic species
- Aerobic, non-motile, non-spore-forming
- Genus includes obligate pathogens, opportunistic pathogens and saprophytes
- Pathogenic species grow slowly, colonies visible after several weeks
- Some mycobacteria produce carotenoid pigments
- Resistant to chemical disinfectants and environmental influences but susceptible to heat treatment (pasteurization)
- Multiply intracellularly and cause chronic, granulomatous infections
- Major diseases include tuberculosis, Johne's disease and feline leprosy
- **Tuberculosis**
 - Transmitted by aerosols or fomites
 - The virulence of *M. bovis* relates to its ability to survive and multiply in host macrophages
 - Lesions are principally found in the lungs and lymph nodes.
 - Pasteurization of milk has eliminated exposure of humans to infection from dairy products.
 - **Tuberculin test**
 - Based on a delayed-type hypersensitivity to mycobacterial tuberculo-protein
 - The standard antemortem test in cattle.
 - Tuberculin, prepared from mycobacteria and called purified protein derivative (PPD), is injected intradermally to detect sensitization.
 - **Two main methods of tuberculin testing are employed:**
 1. In the **single intradermal (caudal fold) test**, 0.1 ml of bovine PPD is injected intradermally into the caudal fold of the tail. The injection



site is examined 72 hours later and a positive reaction is characterized by a hard or oedematous swelling.

2. In the **comparative intradermal test**, 0.1 ml of avian PPD and 0.1 ml of bovine PPD are injected intradermally into separate clipped sites on the side of the neck about 12 cm apart. of tuberculins and after 72 hours. An increase in skin thickness at the injection site of bovine PPD which exceeds that at the avian PPD injection site by 4 mm or more is interpreted as evidence of infection and the animal is termed a reactor.

- **Feline leprosy**
 - A cutaneous disease of worldwide distribution
 - Caused by *M. lepraemurium*, the aetiological agent of rat leprosy.
 - Characterized by the formation of single and multiple nodules or granulomas in the skin, often with the development of nonhealing ulcers.
- **Paratuberculosis (Johne's disease)**
 - The aetiological agent is *M. avium subsp. paratuberculosis*
 - Infection is acquired by calves at an early age through ingestion of organisms shed in the faeces of infected animals.
 - Ingested mycobacteria, engulfed by macrophages in which they survive and replicate, are found initially in Peyer's patches.
 - The main clinical feature in cattle is

diarrhoea, initially intermittent but becoming persistent and profuse.

- **Johnin**, the counterpart of tuberculin PPD, may be used as a field test.

PSEUDOMONAS/BURKHOLDERIA

- Medium-sized, Gram-negative rods
- Obligate aerobes
- Most isolates are oxidase-positive and catalase-positive
- *Pseudomonas* species and *Burkholderia pseudomallei* are motile by polar flagella
- *Burkholderia mallei* is non-motile and requires 1 % glycerol in media for optimal growth
- **Diffusable pigments** are produced by *P. aeruginosa*
 - **Pyocyanin** (blue green)
 - **Pyoverdin** (greenish-yellow)
 - **Pyorubin** (red)
 - **Pyomelanin** (brownish-black)
- *Pseudomonas aeruginosa* causes opportunistic infections
- *Pseudomonas fluorescens* and *P. putidu* occasionally infect freshwater fish.
- **Melioidosis**
 - Caused by *Burkholderia pseudomallei*
 - In horses, it mimic glanders and is often referred to as pseudoglanders.
- **Glanders**
 - Caused by *B. mallei*
 - A contagious disease of Equidae characterized by the formation of nodules and ulcers in the respiratory tract or on the skin.
 - Humans and carnivores are also susceptible to infection.
 - An acute septicaemic form of the disease is characterized by fever, mucopurulent nasal discharges and

! Susceptibility of animals to the mycobacteria that cause tuberculosis			
	<i>Mycobacterium tuberculosis</i>	<i>Mycobacterium bovis</i>	<i>Mycobacterium avium subsp. avium</i>
Primates	+	+	–
Cattle	(+)	+	(+)
Sheep and goats	–	+	(+)
Pigs	(+)	+	(+)
Horses	–	+	+ (intestinal)
Dogs	+	+	–
Cats	+	+	–
Poultry	–	–	+
Canaries	+	–	+
Psittacine birds	+	–	–
+ = susceptible, (+) = slightly susceptible or may become sensitized, – = resistant to infection			



respiratory signs.

- Chronic disease is more common and presents as nasal, pulmonary and cutaneous forms, all of which may be observed in an affected animal.
- The **mallein test** is an efficient field test both for confirmation and for screening in-contact animals.
 - Mallein, a glycoprotein extract of *B. mallei*, is injected intradermally (0.1 ml) just below the lower eyelid.
 - A positive reaction is indicated by local swelling and mucopurulent ocular discharge after 24 hours.

AEROMONAS, PLESIOMONAS AND VIBRIO

- Medium-sized Gram-negative rods, some *Vibrio* species are curved
- Grow on non-enriched media; NaCl supplementation required for most *Vibrio* species
- Catalase-positive, oxidase-positive, facultative anaerobes
- Majority motile by polar flagella
- Found in aquatic environments
 - *Aeromonas hydrophila* is part of the normal flora of freshwater fish and is commonly present in fish ponds and tanks.
 - *P. shigelloides* is also present in fresh water.
 - Most *Vibrio* species are found in brackish and salt water.
- Opportunistic pathogens of fish and reptiles and rarely of mammals
- *Aeromonas salmonicida* is an obligate parasite of salmonid fish, causing **furunculosis**.
- **Food poisoning** caused by *Vibrio parahaemolyticus* is associated with the consumption of raw or undercooked seafoods.
- Only *V. metschnikovii* is associated with disease in domestic animals. It causes a cholera-like disease in chickens and other birds

ACTINOBACILLUS

- Medium-sized, non-motile, Gram-negative rods
- Facultative anaerobes

- Most species are oxidase-positive and produce urease
- Species of veterinary importance grow on MacConkey agar, apart from *Actinobacillus pleuropneumoniae*
- Commensals on mucous membranes
- Produce a wide range of disease conditions in domestic animals
- **Actinobacillosis in cattle**
 - A chronic pyogranulomatous inflammation of soft tissues
 - Most often manifest clinically in cattle as induration of the tongue, referred to as timber tongue.
 - The aetiological agent is *Actinobacillus lignieresii*.
 - The lesions, numerous small abscesses, are usually limited to the soft tissues of the jaw, throat and tongue.
 - The pyogranulomatous lesions formed by *A. lignieresii* resemble those of *Actinomyces bovis* (actinomycosis).

Characteristics	<i>A. lignieresii</i>	<i>A. bovis</i>
Specific disease	Bovine actinobacillosis or wooden (timber) tongue	Bovine actinomycosis or lumpy jaw
Granulomatous abscesses	Jaw, head, neck and limbs	Jaw region
Granules in exudates	Greyish white	Yellow ‘sulphur’ granules
Club colonies	+	+
Spread via lymphatics	+	-
Bone affected (osteomyelitis)	Uncommon	Common
Gram stain reaction	Gram - rods	Gram + branching filaments or diphtheroidal forms
Atmospheric requirements	Growth in air (facultative anaerobe)	Anaerobic

- **Pleuropneumonia**
 - Caused by *A. pleuropneumoniae*
 - Can affect susceptible pigs of all ages and occurs in major pig-rearing regions worldwide.
 - Areas of haemorrhagic consolidation close to the main bronchi and severe fibrinous pleuritis may suggest this condition.
 - Concurrent infections with *Pasteurella multocida* and mycoplasmas may exacerbate the condition.
- **Sleepy foal disease**

- An acute, potentially fatal septicaemia of newborn foals caused by *Actinobacillus equuli*.
- Infection of the foal is thought to occur via the upper respiratory tract or the umbilicus soon after birth.

PASTEURELLA/MANNHEIMIA

- Small Gram-negative rods
- Optimal growth on enriched media
- *P. multocida* colonies have a subtle but characteristic sweetish odour.
- Non-motile, oxidase-positive, facultative anaerobes
- Most species are catalase-positive
- Some species grow on MacConkey agar
- Bipolar staining is prominent in smears from lesions, using the Giemsa method
- Commensals in the upper respiratory tract
- Respiratory pathogens
- **Haemorrhagic septicaemia or barbone**
 - *Pasteurella multocida* serotype B:2 (6:B) causes the disease in Asia
 - Buffaloes tend to be more susceptible to the disease than cattle.
 - All ages can be affected but in endemic areas the disease is most common in animals between 6 and 24 months of age.
 - Predisposing factors such as overwork, poor body condition and monsoon rains are important in its development.
 - Sudden onset of high fever, respiratory distress and a characteristic oedema of the laryngeal region are features of the disease.
- **Bovine pneumonic pasteurellosis (shipping fever)**
 - Characterized by severe bronchopneumonia and pleurisy
 - Occurs most commonly in young cattle within weeks of being subjected to severe stress, such as transportation, assembly in feedlots and close confinement.
 - Commonly associated with *M. haemolytica*, although *P. multocida* has also been isolated from lungs of affected cattle.
 - Several respiratory viruses including parainfluenzavirus 3, bovine herpesvirus 1 and bovine respiratory syncytial virus may predispose to the bacterial invasion.

• Atrophic rhinitis

- Toxigenic strains of *P. multocida* type D or A cause a severe, progressive form of the disease.
- Infection with *Bordetella bronchiseptica* may cause mild, nonprogressive turbinate atrophy without significant distortion of the snout. However, the presence of this organism predisposes to infection with *P. multocida*.
- In severely affected pigs characteristic facial deformities are diagnostic.
- Visual assessment of the extent of turbinate atrophy can be made following slaughter by transverse section of snouts between the first and second premolar teeth.

• Fowl cholera

- A primary avian pasteurellosis caused by *P. multocida* capsular type A.
- The disease usually presents as an acute septicaemia which is often fatal.
- Turkeys tend to be more susceptible than chickens.
- Postmortem lesions include haemorrhages on serous surfaces and accumulation of fluid in body cavities.

• Snuffles

- A common, recurring, purulent rhinitis in rabbits
- Caused by type A strains of *P. multocida*.
- Clinical disease is often precipitated by stress factors such as overcrowding, chilling, transportation, concurrent infections and poor ventilation resulting in high levels of atmospheric ammonia

FRANCISCELLA

- Gram-negative coccobacillary rods
- Non-motile, obligate aerobes
- Fastidious, cysteine required for growth
- No growth on MacConkey agar
- Oxidase-negative, catalase-positive
- Facultative intracellular pathogen
- Survives in the environment for up to 4 months
- Causes **tularemia** in animals and humans
 - Reservoir hosts of *F. tularensis* include lagomorphs, rodents, galliform birds and deer.

- Ticks and the deerfly (*Chrysops discalis*) are important vectors in North America.
- The main tick species, in which *F. tularensis* can be passed transstadially and transovarially, include *Dermacentor variabilis*, *D. andersoni* and *Amblyomma americanum*.
- Adult pigs and cattle appear to be comparatively resistant to infection.
- Dogs and cats may be infected and seroconvert without clinical signs of disease.
- Infection with *F. tularensis* usually occurs through skin abrasions or by arthropod bites. Animals can also acquire infection through inhalation or by ingestion.
- Lymphadenitis, either local or generalized, is a constant finding and septicaemia is common.

HAEMOPHILUS/HISTOPHILUS /AVIBACTERIUM

- Small, motile Gram-negative rods
- Fastidious, requiring one or both of the growth factors **X (haemin)** and **V (nicotinamide adenine dinucleotide, NAD)**.
 - Two common methods for ensuring the availability of both factors in culture media:
 - Chocolate agar, which supplies both factors, is prepared by heating molten blood agar in a water bath at 80°C for about 10 minutes. The chocolatebrown colour of the medium is due to lysis of the red cells. The heat-stable X factor, released from the lysed cells, is unaffected by this procedure. The V factor, which is also released from the lysed cells, tolerates a temperature of 80°C for a short period whereas the plasma NADases which degrade V factor are destroyed.
 - *Staphylococcus aureus* growing on blood agar releases V factor into the medium. Colonies of *Haemophilus* species which require V factor grow close to the *S. aureus* colony, a

phenomenon referred to as satellitism.

- The porphyrin test is an accurate method for determining the growth requirement for X factor. The *Haemophilus* isolate is grown at 37°C for 4 hours in broth containing a porphyrin precursor. When the culture is exposed to UV light in the dark, porphyrin productin is detected by a red fluorescence, indicating that the isolate does not have a requirement for the X factor.
- **Porphyrin test** is the most satisfactory method for testing the requirement for the X factor.
- Small, transparent, dewdrop-like colonies are formed by most *Haemophilus* species after incubation for 48 hours.
- Optimal growth in 5-10% CO
- Facultative anaerobes
- Commensals on mucous membranes of many animal species
- Important pathogens include *Histophilus somnus*' (cattle), *H. parasuis* (pigs) and *A. paragallinarum* (poultry)
 - **Glasser's disease**
 - Caused by *H. parasuis*
 - Manifests as polyserositis and leptomeningitis usually affecting pigs from weaning up to 12 weeks of age.
 - Some cases present as polyarthritis.
 - Part of the normal flora of the upper respiratory tract of pigs.
 - Piglets acquire the organism from sows shortly after birth either by direct contact or through aerosols.
 - The presence of maternally-derived antibodies prevents the development of clinical signs.
 - ***Histophilus somnus***
 - Because septicaemia is commonly associated with 'H. somnus' infection, many organ systems may be involved and the resulting clinical presentation can be variable.
 - Thrombotic meningoencephalitis (TME), a common consequence of



septicaemia, is encountered sporadically in young cattle recently introduced to feedlots.

- **Infectious coryza**
 - Caused by *A. paragallinarum*
 - Affects the upper respiratory tract and paranasal sinuses of chickens.
 - Facial swelling is a characteristic finding.
 - A copious, tenacious exudate may be evident at postmortem in the infraorbital sinuses and tracheitis, bronchitis and airsacculitis may be present.

TAYLORELLA

- Short, non-motile Gram-negative rods
- Fastidious, optimal growth on chocolate agar
- Microaerophilic, 5-10% CO2 required
- Positive oxidase, catalase and phosphatase tests but otherwise unreactive
- Causes **contagious equine metritis**
 - In stallions, *T. equigenitalis* is harboured in the urethral fossa and the pathogen localizes in the clitoral fossa of infected mares.
 - Transmission of the bacterium usually occurs during coitus although infection may also be introduced by contaminated instruments.
 - Foals born to infected dams may acquire infection in utero or during parturition.
 - A copious, mucopurulent vulval discharge 2 to 7 days after service may indicate the presence of CEM.

ENTEROBACTERIACEAE

- Gram-negative rods
- Growth on non-enriched media
- Oxidase-negative
- Facultative anaerobes, catalase-positive
- Most are motile by peritrichous flagella
- Ferment glucose, reduce nitrate to nitrite
- Enteric bacteria which tolerate bile salts in MacConkey agar
- Major enteric and systemic pathogens:
 - *Escherichia coli*
 - *Salmonella* serotypes
 - *Yersinia* species

- Opportunistic pathogens:
 - *Proteus* species
 - *Enterobacter* species
 - *Klebsiella* species
- A number of media, commonly including **brilliant green (BG) agar** and **xylose-lysine-deoxycholate (XLD) agar** are used to differentiate salmonellae from other enteropathogens.
 - On BG agar, salmonella colonies and the surrounding medium show a red alkaline reaction.
 - On XLD medium the colonies of most salmonella serotypes are red (alkaline reaction) with black centres due to hydrogen sulphide (H2S) production.
- **Eosin-methylene blue (EMB) agar** is used for identifying *E. coli*.
 - The colonies of some isolates have a **metallic sheen**, a feature unique to *E. coli*.
- *Proteus* species produce characteristic **swarming** on non-inhibitory media, such as blood agar.
- *Serratia marcescens* is unique among the opportunistic pathogens in its ability to produce red pigment.
- The **IMViC** (indole production, methyl red test, Voges-Proskauer test, citrate utilization) tests are a group of biochemical reactions used to differentiate *E. coli* from other lactose fermenters.

	<i>E. coli</i>	<i>Salmonella</i>	<i>Yersinia</i>	<i>Proteus</i>	<i>Enterobacter</i>	<i>Klebsiella</i>
				+: <i>P. vulgaris</i> ; -: <i>P. mirabilis</i>		
Indole prod'n	+	-	V		-	-
Methyl red test	+	+	+	+	-	-
VP test	-	-	-	V	+	+
Citrate utilization	-	+	-	V	+	+
Lactose fermentation	+	-	-	-	+	+
H2S prod'n in TSI	-	+	-	+	-	-



- *E. coli*
 - Somatic (O), flagellar (H) and sometimes capsular (K) antigens are used for serotyping *E. coli*

Diseases caused by <i>Escherichia coli</i>		
Animals involved	Disease	Clinical signs and pathogenesis
Pigs		
Piglets less than one week old	Neonatal diarrhoea (colibacillosis) Colisepticaemia	Profuse watery diarrhoea and severe dehydration, mortality 90–100%. Enterotoxins involved (STa, STb and LT)
	Piglet meningitis	Occasionally septicaemia with invasive strains and death of a piglet within 48 hours of birth
Pigs about two weeks after weaning	Weanling enteritis (colibacillosis)	Diarrhoea, anorexia and fever. Mortality lower than in neonatal pigs. Enterotoxins involved (STa, STb and LT) Acute meningitis and fibrinous polyserositis in piglets has been reported
Weaned pigs	Oedema disease	Often sudden death. Oedema of forehead, eyelids, stomach wall and larynx (hoarse squeal). Nervous signs such as ataxia, convulsions and paralysis may be seen. Shiga toxin (Stx2e) involved often associated with <i>E. coli</i> O139 and O 141
Sows after farrowing	Coliform mastitis	One or more mammary glands affected
Gilts after farrowing	Mastitis-metritis-agalactia (MMA) syndrome	Complex syndrome involving stress, hormonal imbalance and coliform infection (often <i>E. coli</i>)
Cattle		
Calves less than one week old	'White scours' (colibacillosis)	The appetite is normal at first but decreases as the faeces become more fluid. White pasty faeces around rectum. Dehydration and emaciation occur. Death usually within four to five days if untreated. Enterotoxins involved (STa)
Calves less than one week old	Colisepticaemia	Sudden death due to endotoxic shock. May be signs of diarrhoea, depression, respiratory distress followed by death. Endotoxin is the principal toxin involved although other toxins such as cytotoxic necrotizing factor and cytolethal distending toxin also produced
Calves surviving septicaemia/ bacteraemia	Joint ill	<i>E. coli</i> localized in joints and/or kidneys ('white spot'). Entry can be via the umbilicus
Dairy cows soon after parturition	Coliform mastitis	Classically a peracute disease: fever, anorexia, depression and sunken eyes. Death due to endotoxic shock. Less severe form of disease becoming more common. Most frequent in housed cows
Sheep		
Neonatal lambs	Colibacillosis and colisepticaemia	Syndromes similar to those that occur in calves but less common. Enterotoxigenic and enteropathogenic strains involved in colibacillosis
Neonatal lambs	'Watery mouth'	The lamb is dull and anorectic, saliva drools over the muzzle and there is abdominal tympany. There are splashing sounds within the abomasum and death within six to 24 hours. Associated with <i>E. coli</i> endotoxaemia
Ewes	Coliform mastitis	Peracute and similar to the condition in cows. Most commonly seen in ewes housed during lambing
Dogs (cats)		
Neonatal pups	Colisepticaemia	Septicaemia, often fatal
Bitches	Pyometra	Associated with the progesterone-stimulated endometrium. A vaginal discharge may occur four to eight weeks after oestrus. In a closed-cervix pyometra the bitch is toxæmic and ill Endotoxin involved
Adult dogs	Urinary tract infection	Cystitis (often of bitches) is most common but <i>E. coli</i> can ascend higher in the urinary tract. A bacteriuria occurs with greater than 10 ⁵ <i>E. coli</i> /mL urine
Poultry		
Young chicks	Omphalitis	Infection of the vestigial yolk sac. The contents are dark, fluid and evil-smelling. Common name is 'mushy-yolk disease'
All ages	Colisepticaemia	Primary or secondary infection via the intestines or respiratory tract. Many body organs are affected with air-sacculitis, peritonitis and ovarian infection
All ages	Coligranuloma	Chronic condition, possibly following a colisepticaemia. There are nodular lesions in the liver and intestines
Other animals		
Neonatal animals such as foals and rabbits	Colibacillosis and colisepticaemia	Diarrhoea and septicaemia. Less common than in calves and piglets

- There are currently more than 2500 serotypes of *Salmonella*.
 - Serotyping is based on the **Kaufmann and White schema** in which somatic (O) and flagellar (H) antigens are identified.
- **Pullorum disease or bacillary white diarrhoea**
 - *Salmonella Pullorum* infects young chicks and turkey poults up to 2 to 3 weeks of age.
 - Affected birds huddle under a heat source and are anorexic, depressed and have whitish faecal pasting around their vents.
 - Characteristic lesions include whitish nodes throughout the lungs and focal necrosis of liver and spleen.
- **Fowl typhoid**
 - *Salmonella Gallinarum* can produce lesions in young chicks and poults similar to those of pullorum disease.
 - However, in countries where it is endemic, a septicaemic disease of adult birds occurs, often resulting in sudden deaths.
 - Characteristic findings include an enlarged, friable, bile-stained liver and enlarged spleen.
- **Paratyphoid**
 - Infections of poultry by non-host-adapted salmonellae such as *Salmonella Enteritidis* and *Salmonella Typhimurium*.
 - Often subclinical in laying birds.
- ***Yersinia***
 - Only *Y. pestis*, *Y. enterocolitica* and *Y. pseudotuberculosis* are pathogenic for animals and man.
 - *Y. ruckeri* is a pathogen of fish.
 - Infection by the enteropathogens *Y. pseudotuberculosis* and *Y. enterocolitica* occurs by ingestion.
 - The intestinal tract of wild and domestic animals appears to be the reservoir for *Y. enterocolitica* but, as with *Y. pseudotuberculosis*, this species of *Yersinia* can replicate in the environment.
 - Pigs, in particular, are carriers of *Y. enterocolitica* strains that are pathogenic for humans.
 - A cold-enrichment procedure may be necessary for the isolation of both *Y. enterocolitica* and *Y. pseudotuberculosis* from faecal specimens.
- **Feline Plague (bubonic plague in man)**
 - Cats usually acquire infection with *Y. pestis* by ingestion of infected rodents.
 - Three clinical forms of the disease are recognized: **bubonic, septicaemic and pneumonic**.
 - The most common form of the disease is characterized by enlarged lymph nodes (**buboes**) associated with lymphatic drainage from the site of infection.
 - Cats with pneumonic lesions are a potential source of human infection through aerosol generation.
 - Human infection can also be acquired through cat scratches and bites and possibly through the bites of fleas from infected cats.

BORDETELLA

- Small Gram-negative rods
- Growth on non-enriched media and on MacConkey agar
- Strict aerobes
- Motile, catalase-positive, oxidase-positive
- Utilize amino acids for energy
- **Haemagglutination**, an attribute uncommon in bacteria, occurs with virulent isolates of both *B. bronchiseptica* and *B. avium*.
- Commensals of on the mucous membranes of the upper respiratory tract
 - The bordetellae are occasional pathogens which have an affinity for ciliated respiratory epithelium.
- Cause respiratory disease in mammals and birds
- **Canine infectious tracheobronchitis**
 - Also known as kennel cough
 - The appropriate specimen for laboratory examination is transtracheal aspiration fluid.

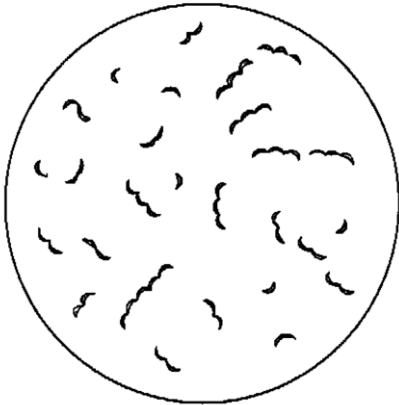
- Microbial pathogens implicated in the disease aside from *Bordetella bronchiseptica*
 - Canine adenovirus 2
 - Canine parainfluenzavirus 2
 - Canine distemper virus
 - Canine adenovirus 1
 - Canine herpesvirus 1
 - Reoviruses 1,2 and 3
 - Mycoplasma species
- The infection with *B. bronchiseptica* in pigs may facilitate colonization by toxigenic *Pasteurella multocida* type D with the subsequent development of severe atrophic rhinitis and distortion of the snout.
- Turkey coryza
 - Caused by *B. avium*
 - A highly contagious upper respiratory tract disease of poults
 - Infection with *B. avium* predisposes to secondary infections with bacteria such as *Escherichia coli*.

MORAXELLA

- Short Gram-negative rods, usually in pairs
- Optimal growth on enriched media
- Aerobic, non-motile
- Usually catalase- and oxidase-positive
- Proteolytic, unreactive with sugar substrates
- Virulent strains are fimbriated and haemolytic
- Susceptible to desiccation
- Found on mucous membranes of carrier cattle
- Causes **infectious bovine keratoconjunctivitis**
 - Sometimes referred to as 'pink-eye' or New Forest disease
 - A highly contagious condition affecting the superficial structures of the eyes, usually in animals under 2 years of age.
 - Initially manifests as blepharospasm, conjunctivitis and lacrimation.
 - Progression of the condition through keratitis to corneal ulceration, opacity and abscessation may occasionally lead to panophthalmitis and permanent blindness
 - Lacrimal secretion is the most suitable specimen for laboratory examination

CAMPYLOBACTER

- Slender, curved Gram-negative rods in gullwinged shapes and spiral forms



- Motile, microaerophilic
- Most species grow on MacConkey agar
- Enhanced growth on enriched media
- Non-fermentative, oxidase-positive with variable catalase reactions
- Commensals of the intestinal tract and sometimes of the reproductive tract
- The principal disease conditions associated with infection are either intestinal, presenting as diarrhoea, or genital, causing infertility or abortion.
- Three species, namely *C. fetus subspecies venerealis*, *C. fetus subspecies fetus* and *C. jejuni subspecies jejuni* are recognized pathogens of veterinary importance.
- **Bovine genital campylobacteriosis**
 - The principal cause is *Campylobacter fetus subspecies venerealis*
 - Transmitted during coitus to susceptible cows by asymptomatic carrier bulls.
 - The disease is characterized by temporary infertility associated with early embryonic death, return to oestrus at irregular periods and, occasionally, by sporadic abortion.
 - Dihydrostreptomycin, administered either systemically or topically into the prepuce, is used for treating bulls.
 - Intrauterine administration of dihydrostreptomycin can be used therapeutically.
- **Intestinal campylobacteriosis in humans**
 - The main cause is *Campylobacter jejuni*.
 - Campylobacter infection is the most frequent cause of food poisoning in many countries.
 - *Campylobacter coli* and *C. lari* are sometimes implicated.

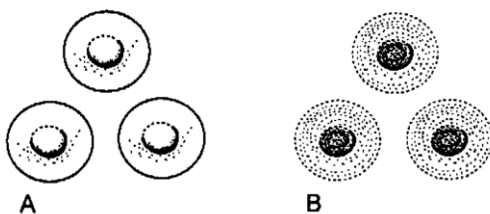
- Poultry meat is a major source of human infection.
- **Ovine genital campylobacteriosis**
 - May be caused by either *C. fetus subspecies fetus* or *C. jejuni*.
 - Round, necrotic lesions up to 2 cm in diameter with pale raised rims and dark depressed centres evident on the liver surface in some aborted lambs are pathognomonic.

LAWSONIA

- Curved, Gram-negative rods
- Obligate intracellular pathogens
- Microaerophilic
- No growth on inert media
- Growth in tissue culture prepared from enterocytes
- Implicated in **porcine proliferative enteropathy**
 - *Lawsonia intracellularis* has an affinity for porcine enterocytes, its site of replication.
 - Infection induces enterocyte proliferation with the development of adenomatous and inflammatory lesions in the terminal ileum, caecum and colon.

MYCOPLASMA

- Smallest free-living prokaryotic microorganisms
- Possess triple-layered limiting membranes but lack cell walls
- Do not stain by the Gram method
- Highly pleomorphic, filterable plastic forms
- Mycoplasmas are susceptible to desiccation, heat, detergents and disinfectants. However, they are resistant to antibiotics such as penicillin which interfere with the synthesis of bacterial cell walls.
- Microcolonies have a 'fried-egg' appearance



- Most are facultative anaerobes
- Do not replicate in the environment
- Most are host-specific
- Mycoplasma and Ureaplasma contain species of veterinary importance
- Organisms in the genera *Haemobartonella* and *Eperythrozoon*, which were previously

grouped with the rickettsial organisms, have been reclassified as members of the *Mycoplasma* genus.

- These organisms parasitize red blood cells and are known as the haemotropic mycoplasmas or are sometimes referred to by the trivial name 'haemoplasmas'.
- Mycoplasma species cause a wide range of diseases in animals
 - **Enzootic pneumonia of pigs**
 - Caused by *M. hyopneumoniae*
 - Poor ventilation, overcrowding and temperature fluctuations may precipitate an outbreak.
 - Pigs of all ages are susceptible.
 - The condition is characterized by coughing, poor growth rates and, in some cases, respiratory distress.
 - At postmortem, pulmonary consolidation is confined to the apical and cardiac lobes with clear demarcation from normal lung tissue.
 - **Contagious bovine pleuropneumonia (CBPP)**
 - A severe contagious disease of cattle
 - Caused by *M. mycoides subspecies mycoides* (small colony type)
 - The main method of transmission is by aerosols.
 - At postmortem, the pneumonic lungs have a marbled appearance. Grey and red consolidated lobules alternate irregularly with pink emphysematous lobules and the interlobular septa are distended and oedematous.
 - **Contagious caprine pleuropneumonia (CCPP)**
 - Caused by *M. capricolum subspecies capripneumoniae* (formerly *Mycoplasma strain F38*)
 - Characterized by pneumonia, fibrinous pleurisy, profuse pleural exudate and a marbled appearance on the cut surface of affected lungs.



- Pleuropneumonia in goats can occasionally be caused by *M. mycoides subspecies capri* or *M. mycoides subspecies mycoides* (large colony type).

BRUCELLA

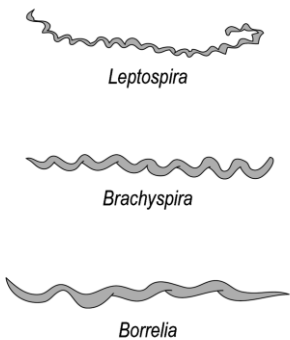
- Small Gram-negative coccobacilli
- Stain red using the modified Ziehl-Neelsen method
- Aerobic and capnophilic
- Non-motile, catalase-positive
- Most isolates are oxidase-positive
- Urease-positive
- Intracellular pathogens
- As a general rule, brucellae have a predilection for both female and male reproductive organs in sexually mature animals
 - Erythritol, a polyhydric alcohol which acts as a growth factor for brucellae, is present in high concentrations in the placenta of cattle, sheep, goats and pigs. This growth factor is also found in other organs such as the mammary gland and epididymis, which are targets for brucellae.

- Each *Brucella* species tends to infect a particular animal species.
 - Bovine brucellosis caused by *B. abortus*
 - Caprine and ovine brucellosis caused by *B. melitensis*
 - Ovine epididymitis caused by *B. ovis*
 - Porcine brucellosis caused by *B. suis*
 - Canine brucellosis caused by *B. canis*
- Some species cause undulant fever in humans
 - *B. abortus*, *B. suis*, *B. melitensis* and, rarely, with *B. canis*.
- Brucellin, an extract of *B. abortus*, has been used for intradermal testing

SPIROCHETES

- Spiral motile bacteria with endoflagella
- Labile in the environment and sensitive to desiccation
- Although Gram-negative, many stain poorly using conventional methods
- Some grow only in liquid media; most require specialized media
- Many produce zoonotic infections

Serological test	Principal immunoglobulin class identified	Remarks
<i>Brucella</i> milk ring test	IgM, IgG1, IgA	Conducted on bulk milk from a herd. If positive, sera are taken from individual cows in the herd and subjected to one or more of the other tests
Milk ELISA*	IgG	Extremely sensitive test
Plate agglutination tests: Rose-Bengal plate test* and the Card test	IgG1, IgM	Useful screening tests. Antigens buffered to pH 3.65–4.0 and this allows IgG1 to cause agglutination
<i>Brucella</i> serum agglutination test (SAT) (tube agglutination)	IgM, IgG2, (IgG1)	Widely used test but often IgG1 antibodies fail to agglutinate, so false negatives may occur. Not suitable for international trade
<i>Brucella</i> complement fixation test (CFT)*	IgG1, IgM	Specific but cumbersome to perform and more modern assays such as ELISA or FPA now give comparable or better results
Enzyme-linked immunosorbent assay (ELISA)*	Has capacity to detect all immunoglobulins. OIE approved version tests for IgG	Reliable, easily automated. Both indirect and competitive ELISAs are described
Fluoresence polarization assay (FPA)*	Has capacity to detect all immunoglobulins	Extremely rapid test with results available within minutes. The FPA can be performed in glass tubes or a 96-well plate format
Supplementary tests		
Coombs antiglobulin test	IgM, IgG2, IgG1	Very sensitive test, will detect ‘incomplete antibodies’ that do not react in the <i>Brucella</i> SAT
Heat inactivation	IgG	
Rivanol precipitation	IgG	These are designed to differentiate the ‘non-specific’ reactions by destroying IgM, the antibody most commonly produced by adult vaccination
Mercaptoethanol treatment	IgG	
*Prescribed tests for international trade		



Borrelia species

- Transmission by arthropod vectors
- The species of particular veterinary importance are *B. burgdorferi* sensu lato, the cause of Lyme disease in animals and humans, and *B. anserina* which causes avian borreliosis.
- Avian spirochaetosis
 - Acute disease of birds
 - Chickens, turkeys, pheasants, ducks and geese are susceptible to infection. Soft ticks of the genus *Argas* frequently transmit the disease.
- Lyme Disease
 - Adult ticks feed preferentially on large mammals such as deer and sheep, which are maintenance hosts for the tick population but are unsuitable reservoirs for *B. burgdorferi* sensu lato.
 - The most common tick vector in Europe is *Ixodes ricinus*; in central and eastern USA it is *I. scapularis*; on the west coast of the USA, it is *I. pacificus*, and in Eurasia it is *I.*

- Clinical signs are most often observed in dogs.
- Signs include fever, lethargy, arthritis and evidence of cardiac, renal or neurological disturbance.

- Grow slowly in specialized culture media at 30-35°C, in microaerophilic conditions
- Culture of borreliae from infected animal is confirmatory

Brachyspira/Serpulina species

- Five genospecies of intestinal spirochaetes have been isolated from pigs namely *Brachyspira hyodysenteriae*, *B. pilosicoli*, *B. innocens*, *Serpulina intermedia* and *S. murdochii*.
- Infection with *B. hyodysenteriae* causes dysentery which is most often encountered in weaned pigs from six to twelve weeks of age.
- Can be demonstrated in stained faecal smears or in silver-stained histopathological sections
- Diagnosis confirmed by culture on selective blood agar anaerobically at 42°C

Leptospira species

- Found in aquatic environments
- Produce systemic infections in many species
- Shed in urine of affected species
- Cultured in liquid media aerobically at 30°C
- Dark-field microscopy, silver staining and immunofluorescence used for recognition

Leptospirosis in domestic animals	
Host	Disease syndrome
Cattle	- Subclinical with or without leptospiuria - Milk-drop syndrome, with or without any other clinical signs (often Hardjo) - Abortion and neonatal mortality: abortion ‘storms’ (Pomona) and sporadic abortions (Hardjo) - Haemoglobinuria, jaundice and fever in calves, and less commonly, in young adults. Serovars commonly involved are Pomona, Grippotyphosa and Icterohaemorrhagiae. Occasionally, some animals show signs of meningitis
Pigs	- Subclinical, often with leptospiuria (especially Pomona) - Fever and focal non-suppurative mastitis and leptospiuria - Infertility, abortions and stillbirths (Canicola, Pomona, Icterohaemorrhagiae or Bratislava) - Fever, anorexia, jaundice, haemoglobinuria and high mortality in young pigs (often Icterohaemorrhagiae)
Dogs	- Subclinical with leptospiuria (often Canicola) - Acute haemorrhagic disease: high fever, vomiting, prostration and often early death (usually Icterohaemorrhagiae) - Acute renal failure (many serovars including Canicola, Icterohaemorrhagiae, Grippotyphosa and Bratislava) - Infertility, abortions and stillbirths (Bratislava)
Horses	- Recurrent iridocyclitis (‘periodic ophthalmia’ or ‘moon blindness’) which can result in blindness - Occasionally abortion with foetuses of six months to term - Rarely fever, anorexia, depression and icterus
Sheep	- Mainly subclinical infections with leptospiuria (serovars such as Hardjo) - Occasionally, acute leptospirosis with depression, dyspnoea, haemoglobinuria, anaemia and high mortality in lambs (often Pomona)



CHLAMYDIA/CHLAMYDOPHILA

- Spherical intracellular bacteria with unique developmental cycle
- Infectious extracellular forms, called elementary bodies (EBs) are small, metabolically inert and osmotically stable
- Appropriate staining procedures include the modified Ziehl-Neelsen and Giemsa methods
- Unable to synthesize ATP and replicate only in living cells
- Cell walls lack peptidoglycan but contain genus-specific lipopolysaccharide
- Species vary in virulence for particular hosts; some strains are associated with specific diseases in domestic animals
- Produce respiratory, enteric, plural and reproductive tract diseases in animals and humans
 - **Sporadic bovine encephalomyelitis**
 - Neurological disease caused by *C. pecorum*
 - Affected animals, which are usually under 3 years of age, develop a high fever and exhibit incoordination, depression, excessive salivation and diarrhoea. Terminally, animals may become recumbent and can develop opisthotonos.
 - **Feline chlamydiosis**
 - *Chlamydophila felis* (formerly known as feline strains of *C. psittaci*) is associated with conjunctivitis and less commonly rhinitis.
 - If secondary infection with organisms such as *Mycoplasma felis* and *Staphylococcus* species occurs, the ocular discharge may become mucopurulent.
 - **Enzootic abortion in ewes**
 - Caused by *C. abortus* (formerly known as ovine strains of *C. psittaci*)
 - Characterized by abortion during late pregnancy or by the birth of premature weak lambs.
 - confirmation of a diagnosis of EAE is most easily accomplished by microscopic examination of stained smears from affected cotyledons or chorion for evidence of chlamydial EBs.
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- **Avian chlamydiosis**
 - Clinical signs vary in nature and severity, depending on the strain of *C. psittaci*. and the species and age of the affected birds.
 - Infection is usually acquired by inhalation or by ingestion.
 - The most frequent post-mortem findings are hepatosplenomegaly, airsacculitis and peritonitis.

BACTERIOLOGY

RICKETTSIALES

- Minute, non-motile Gram-negative bacteria
- Obligate intracellular pathogens, replicating only in cells
- Demonstrated in blood smears by Romanowsky stains
- Host specificity and tropism for particular cell types evident
- Extracellular survival brief for most members apart from *Coxiella burnetii*
- Cause systemic diseases, mainly arthropodborne, in humans and animals
 - **Rickettsiaceae**
 - Cell walls often contain peptidoglycan
 - Cultured in specific cell lines or in fertile eggs
 - Tropism for vascular endothelium or leukocytes
 - **Anaplasmataceae**
 - Lack cell walls, possess cell membranes
 - Have not been cultured in vitro
 - Tropism for erythrocytes

Family	Genus	Principal cells parasitized in the host
Rickettsiaceae	Rickettsia	Vascular endothelium
Anaplasmataceae	Anaplasma	Erythrocytes, platelets and leukocytes
	Aegyptianella	Erythrocytes
	Ehrlichia	Leukocytes
	Neorickettsia	Leukocytes

- **Q (query) fever**
 - Caused by *Coxiella burnetii*
 - Most infections are acquired by inhalation of aerosols originating from parturient sheep, goats or cattle.
 - *Coxiella burnetii* localizes and replicates in the female



genital tract and mammary glands of ruminants with intermittent or continuous shedding of organisms in uterine discharges, foetal fluids and milk.

Pathogen	Host	Vector	Geographical distribution	Disease
<i>Rickettsia rickettsii</i>	Humans, dogs	Ticks (principally <i>Dermacentor</i> species)	Western hemisphere	Rocky Mountain spotted fever
<i>Anaplasma marginale</i>	Ruminants	Hard ticks	Tropical and subtropical regions	Anaplasmosis (gall sickness)
<i>A. ovis</i>	Small ruminants	Hard ticks	Tropical and subtropical regions	Anaplasmosis
<i>A. phagocytophilum</i>	Ruminants, horses, humans	<i>Ixodes</i> species of tick	Worldwide	Tick-borne fever, equine and human granulocytic ehrlichiosis
<i>A. bovis</i>	Cattle	Ticks (<i>Hyalomma</i> species)	Africa, South America, Middle East, Asia	Bovine ehrlichiosis
<i>A. platys</i>	Dogs	Ticks suspected	Americas, Mediterranean, Middle East	Infectious cyclic thrombocytopenia
<i>Ehrlichia canis</i>	Dogs	Ticks (<i>Rhipicephalus</i> species)	Tropical and subtropical regions	Canine monocytic ehrlichiosis
<i>E. ewingii</i>	Dogs, humans	Ticks (<i>Amblyomma</i> species)	USA	Canine granulocytic ehrlichiosis
<i>E. ruminantium</i>	Ruminants	Ticks (<i>Amblyomma</i> species)	Sub-Saharan Africa, Caribbean	Heartwater
' <i>E. ovina</i> '	Sheep	Ticks	Africa, Asia, Middle East	Ovine ehrlichiosis
' <i>E. ondiri</i> '	Cattle	Ticks suspected	Highlands of East Africa	Bovine petechial fever
<i>Neorickettsia helminthoeca</i>	<i>Canidae</i> , bears	Ingestion of salmonid fish infested with the infected metacercariae of the fluke <i>Nanophyetus salmincola</i>	West coast of North America	Salmon poisoning disease
' <i>N. elokominica</i> '	<i>Canidae</i> , bears, racoons	As for <i>N. helminthoeca</i>	As for <i>N. helminthoeca</i>	Salmon fever
<i>N. risticii</i>	Horses	Complex infection cycle involving an intermediate snail reservoir and a trematode vector. Transmission to horses believed to occur following ingestion of aquatic insects infested with infected metacercariae	USA, Europe	Potomac horse fever
<i>Aegyptianella pullorum</i>	Birds	Ticks (<i>Argus</i> species)	Africa, Asia, Mediterranean	Aegyptianellosis