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GLOBAL IMPORTANCE OF PIROPLASMOSIS

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ABSTRACT

Since the first description of an intracellular blood parasite, *Haematococcus bovis,* later to be included in the genus *Babesia*, a number of piroplasms belonging to the genus *Theileria* and *Babesia* have been described. They infect a wide range of domestic and wild animals, several bird species and even man. Of all the piroplasmoses, theileriosis of cattle in Africa, particularly *Theileria parva*, had a greater impact on the development of beef and dairy cattle industries, on veterinary research and infrastructure as well as legislation and policies than any other livestock disease complex.

Piroplasmosis is still today one of the greatest obstacles to the development of the livestock industries in tropical and sub-tropical countries of the world. Cattle and horses seems to be affected the most with approximately one billion cattle and one hundred million equids worldwide at risk of contracting piroplasmosis. The real cost of tick-borne diseases, including piroplasmoses, is extremely difficult to estimate. However, despite the lack of reliable data, the costs are generally accepted to be substantial. Piroplasmoses result in direct losses as a result of poor growth, poor milk production, poor performance and mortality in infected animals and indirectly contribute enormously to the high costs involved in controlling the tick vectors and in limiting the exportation of many animals. Eradication of either the tick vector or the disease would at first appear to be the ideal approach to control piroplasmosis,

however, there have been relatively few attempts with limited success over the years. Today, eradication of piroplasmosis is no longer considered economically justifiable and other means of control such as regular acaricide application, often in combination with vaccination and chemoprophylaxis, are used. Despite extensive research efforts, no molecularly engineered vaccine is as yet available for either cattle or horse piroplasmosis and in many countries live attenuated organisms are still being used for the immunization of cattle.

INTRODUCTION

One of the great challenges facing the world at the dawn of the 21st century is to produce sufficient food to satisfy the needs of the growing human population. The global human population is expected to grow from the current 6 billion to 8 billion in the year 2020 (UN 2000). Consequently, it is expected that the total meat consumption will increase from 180 million tonnes (1993) to 275-310 million tonnes (2020), and milk from 400 to 770 million tonnes over the same period (Delgado et al. 1999).

Domestic animals only meet about 30% of human needs for food and agriculture in the form of meat, milk, milk products, eggs, fibre, fertilizer for crops and draught power. To meet the requirements for meat and milk products, governments have attempted to intensifiy their livestock enterprises, and in recent years there has been an increasing trend towards importation of cattle from temperate to tropical environments to increase production of meat and milk. This has led all to frequently to serious losses of these imported cattle most commonly due to tick-borne diseases of which babesiosis is the most wide-spread.

It is impossible to define in exact terms the importance of piroplasmosis on animal production as it is determined by many factors some of which (such as mortailities, production losses, and quarantine cost), are easy to identify and therefore quantify, others, though real and maybe more important than these easily identifiable losses, are very difficult or impossible to quantify, including lost opportunities and lost markets.

This paper will be looking at the role that a group of organisms, the piroplasms, belonging to two genera, *Babesia* and *Theileria*, play in livestock development.

Babesia

Members of the genus *Babesia* are generally divided into what is commonly referred to as large and small babesias. These parasites have been recorded from many different hosts; most domestic animals, birds and even man. To date, vectors for only a few species have been identified - in all cases ticks are the biological vectors transmitting the infection transovarially and transstadially, while mechanical transmission, by insects, does not occur. All the *Babesia* propagate exclusively in red blood cells.

History

Magureanu in 1884 was probably the first person to discover a piroplasm species, when he detected the parasite in sheep in Romania (cited by Euzeby 1990), but it was only much later officially described as *Babesia ovis* (Starcovici 1893). The first recorded description of the piroplasms and *Babesia* in particular, date back to the late 19th century when, in response to a persistent cattle disease, the Romanian government in 1887 established a commission headed by Dr Victor Babes to investigate the problem (Babes 1888). As a result of these studies Babes concluded that the cause of the disease, termed enzootic haemoglobinuria, was a small intra-erythrocytic organism which he called *Haematococcus bovis* (Babes 1888). Later, Starcovici, a member of Babes' research team, renamed the etiological agent *Babesia bovis* (1893).

Investigations in the USA by Smith and Kilborne at approximately the same time led to the demonstration for the first time of a protozoan parasite (*Babesia bigemina*) transmissible to its mammalian host by an arthropod vector *Boophilus annulatus* (1893). Lignieres (1903), while studying babesiosis in cattle in Argentina, recognized that he was dealing with two strains of *B. bigemina*. One form was large, resembling the organism described by Smith and Kilborne, while the other was smaller and often difficult to find in blood smears. He subsequently named the smaller organism *Piroplasma* (later *Babesia*) *argentina* (Lignieres 1910) a term used for many years in Australia and South and Central America and it was only in mid 1970 that parasitologists agreed that *B. bovis* and *Babesia argentina* were the same parasite (Brocklesby 1976).

Some years later M'Fadyean and Stockman (1911) in England encountered another small intraerythrocytic organisms in cattle which they named *Prioplasma* (later *Babesia*) *divergens*. Other European workers observed similar organisms but assumed them to be *B. bovis* and for many years *B. divergens* was thought to be synonymous with *B. bovis*. It was a Yugoslavian team in 1955 (Simic, Petrovic and Rakovic 1955) that pointed out that this was not the case as the tick vectors of the two parasites differed. M'Fadyean and Stockman (1911) also made reference to a large *Babesia* which was probably *B. major*, but this species was only named in 1926 by Sergent.

To date more than 111 species of *Babesia* have been described (Levine 1985). However, the systematic position of many of the so-called "mall" babesias has always been doubtful and has led to many controversies over the years. Recent DNA phylogenetic analyses have shown that at least some of these species belong to different genera. *Babesia equi* for example has recently been reclassified as *Theileria equi* (Mehlhorn and Schein 1998). It was also very recently shown that *Babesia microti* form a group separated from the *Theileria* and *Babesia* and cluster with *B. rodhani* and a recently described small canine piroplasm (*Theileria annae*) (Zahler et al. 2000). This would suggest that there is probably a third taxonomic entity of equal rank besides the Babesiidae and Theileriidae (Zahler, Rinder and Gothe 2000).

Theileria

The members of the genus *Theileria* differ from the members of the genus *Babesia* in a variety of characteristics: The *Theileria* is generally small, pleomorphic (round, ovoid, rod- and comma shaped) parasites usually 1-2 μm in length. Unlike the *Babesia* they reproduce by merogony in lymphocytic cells in addition to their merogony in erythrocytes. Transmission of *Theileria* by ticks is limited to transstadial transmission.

The description of the *Theilerias* only occurred much later and Robert Koch, the famous German bacteriologist working with his assistant Giemsa, was probably the first person to see *Theileria* in eryhthrocytes of cattle in Dar es Salaam (Koch 1898). They described at the time the presence of large and small forms of *Babesia*, but this was probably dual infections of both *Theileria* and *Babesia*. In 1901 Koch had the opportunity to study the first outbreak of what was generally to become known as East Coast fever in southern Africa. He recognized the intra-lymphocytic or schizont stage of *Theileria*, which for a long time was known as Koch's blue body. The parasite causing this disease was described by Stephens and Christopher (1903) as *Pirolasma kochi*, but it was the name that Sir Arnold Theiler gave the parasite, *Piroplasma parvum* the next year (1904) that became entrenched in the literature and which was subsequently renamed to *Theileria parva* by Bettencourt, Franca and Borges (1907). It was Lounsbury (1904), the Government Entomologist in Cape Town, South Africa, that showed *Rhipicephalus appendiculatus* to be the vector of this parasite. In the same year that *T. parva* was described, Dschunkowsky and Luhs (1904) identified another closely related parasite in Georgia (then Caucasia), *Piroplasma annulatum* (= *Theileria annulata*).

In the most recent review Levine lists 34 species of *Theileria* (Levine 1985), but many more probably do exist in nature and are just waiting to be discovered.

IMPORTANT *BABESIA* SPP. IN THE DIFFERENT HOSTS

Bovine

Although several different *Babesia* spp. of cattle have been described, many are probably synonyms and generally only 4 species are considered to be of economic importance, *B. bovis*, *B. bigemina*, *B. divergens* and *B. major*.

B. bovis and *B. bigemina*, respectively a small and large species, are transmitted by *Boophilus* ticks. They usually occur together and have a worldwide distribution corresponding to their *Boophilus* vectors i.e. in countries between 32°S and about 40°N (McCosker 1981), but *B. bovis* is generally regarded as the more important cause of disease. These 2 parasites probably have had a major impact on the development of livestock industries in North & South America, Australia and southern Africa where they have been and still are among the most important causes of mortality in cattle. In most of these countries the disease is under control, either as a result of a successful eradication program as in the USA or an effective immunization program as in Australia and South Africa (McCosker 1981). However, in Latin America and the rest of the southern African region, serious losses continue to occur. Outbreaks are associated with the movement of cattle from vector-free to endemic areas, as well as where seasonal climatological factors favour a temporary increase in the tick population, or where exotic *Bos taurus* cattle are introduced to upgrade indigenous breeds. Pure bred *Bos taurus* or their crosses are more susceptible to ticks and babesiosis than are *Bos indicus* and in most Asian countries, where *Bos indicus* cattle predominate, the effect of babesiosis is relatively insignificant (McCosker 1981).

In east Africa, babesiosis is second in importance to another tick-borne disease, East Coast fever, caused by *T. parva* - the control measure (intensive dipping) for this disease also controlling the tick vectors for *Babesia*. In many other parts of Africa, other diseases of cattle such as runderpest, CBBP and trypanosomosis have seriously impacted on development. However, as these diseases come under effective control, tick-borne diseases, including babesiosis, become more important. *B. major* occurring in Europe and the middle east is transmitted by *Haemaphysalis punctata* and is usually less pathogenic than the other bovine *Babesia* spp.

B. divergens occurs in western and central Europe, including Scotland and western England. It is transmitted by *Ixodes ricinus* and does cause significant mortality. Annual losses in England and Scotland, based on a 1974 estimate, was in the region of about 450,000 US$ (Barnett 1974).

There are at least 3 newly identified large *Babesia* spp. in cattle, that have vectors other than *Boophilus* and are usually not pathogenic (or very mildly pathogenic) to cattle. One of these is *B. ovata* that is widely distributed in Japan and appears different from *B. bigemina* and *B. bovis* (Minami and Ishihara 1980). It is transmitted by *Haemaphylsalis longicornis*. In 1981 a *Babesia* was isolated from *Hyalomma marginatum rufipes* and subsequently transmitted to cattle in SA - this parasite was named *Babesia occultans* (Gray and De Vos 1981). It is probably widely distributed in southern Africa and its relationship with *Babesia beliceri*, described in Russia, also transmitted by a *Hyalomma* spp., is unclear.

Sheep and Goats

It appears that tick-borne diseases of sheep and goats and particularly babesiosis are among the least recognized problems in veterinary science. The lack of research in this field accounts for remarkable gaps in our knowledge. Three species have been described, *Babesia ovis*, *Babesia crassa* and *Babesia motasi*.

B. ovis is probably the most important disease agent in sheep but rarely in goats (Friedhoff 1997). The principal vector is *Rhipicephalus bursa*, but *Rhipicephalus turanicus* and *Hyalomma anatolicum excavatum* have also been shown experimentally to transmit the parasite (Beermann 1987). *B. ovis* is considered to be highly pathogenic, mortality rates, despite parasitaemias being relatively low (0.2-3%), in susceptible sheep ranging from 30-50%, The pathogenic mechanisms are in some aspects similar to those of *B. bovis* although severe haemoglobinuria are frequently encountered (Friedhoff 1997). The exact geographical distribution of *B. ovis* is still unknown but it appears to be widespread in eastern Europe, southern Ukraine, Spain, Portugal, southern Italy, Greece, Turkey, Syria, Israel, Jordan, Iraq, Iran, and the central Asian states of the former USSR. *B. ovis* is also widespread in northern Africa, but south of the Sahara *B. ovis* has only been reported from Nigeria, Ghana and Somalia. *B. ovis* has been reported from Central and South America and Cuba, however, the geographical distribution and prevalence of *B. ovis* in South and East Asia (including China and Japan) is unknown.

All large *Babesia* spp. of sheep or goats, besides *B. crassa*, have been described as *B. motasi*. Whether this is the only valid species, or a complex of subspecies, is still unknown. It is reported that strains in western and northern Europe are far less pathogenic than the Mediteranean strains and there are serological and even slight morphological differences between the two. Some strains are also infective for sheep and goats while others are only infective for sheep (Friedhoff 1997). It appears to be more widely spread than *B. ovis* and has been reported from northen, eastern and southern Europe, northern and tropical Africa, the Near and Middle East, central Asia and India. *B. motassi* is reported to be the only pathogenic species of sheep and goats in Latin America. Reported vectors are *Haemaphylsalis punctata*, perhaps *Ixodes ricinus* and *Dermacentor* spp. (but not *R. bursa*) (Friedhoff 1997). The disease is not as severe as that caused by *B ovis*, however, the parasitaemia is much higher with anaemia being the main clinical sign.

Equids

Two piroplasms are of importance in equids, i.e. *Babesia caballi* and what is today known as *Theileria equi*. Theiler, working in SA was the first to find a piroplasm in equids (Theiler 1901) which was subsequently named by Laveran (1901) as *Prioplasma equi*. This parasite occurs wide-spread in Zebra which thus potentially creates a natural source of infection for ticks and horses. The pathogenicity of different strains of *T. equi* is variable and mortalities in susceptible horses can be as high as 50%. This was observed among European horses introduced into SA during the Boer war, in Australia horses taken to India and in northern European horses moved to Italy during World War I.

The exact taxonomic position of *Babesia equi* remained controversial and it has been moved back and forth between different genera, but was eventually placed in the genus *Babesia* by Levine (1985). However, when the lymphocytic stages of the parasite had been described, the reclassification as a *Theileria* became inevitable. With the development of DNA technology and phylogentic analysis, it was also possible to show that this organism was clearly distinct from the classical *Babesia* spp. and, in fact, that it formed a paraphyletic group with *B. rodhani* and *Cytauxzoon felis* (Allsopp et al. 1994). *B. microti* has also been shown to have a exo-erythrocytic stage in its life cycle (Mehlhorn et al. 1986). *B. equi* was formally reclassified as *T. equi* in 1998 (Mehlhorn and Schein 1998).

T. equi is transmitted biologically by ticks, but only stage-to-stage (as is the case with the other *Theileria* spp), within the genera *Rhipicephalus, Dermacentor* and *Hyalomma*. The intraerythocytic forms frequently seen in a maltese cross formation helps to distinguish it from *B. caballi*. *B. caballi*, on the other hand, is a true large *Babesia* and is biologically transmitted by ticks of the same genera as *T. equi*, but transmission is transovarially in most of them (Friedhoff 1988). Although ticks are the only biological vectors of the piroplasms of horses transmission of *T. equi* from dam to foetus prenatally has been reported quite commonly. In a recent survey in South Africa approximately 11 % of all reproductive failures in Thoroughbred mares were due to *T. equi* infection of the foetus (De Waal, Horn and Josemans 1999). Iatrogenic spread of *T. equi* has also been reported. In Australia in 1976, after the importation of infected horse from Spain (Churchill and Best 1976; Callow 1984) and also in the UK in a herd of experimental horses where 61 of the 66 horses, bled regularly for hormone concentration assays, were serologically positive for *T. equi*, while 19 animals kept in close physical contact with the seropositive horses, but not bled regularly, tested negative. The proposed source of infection was a mare imported in 1989 from North Africa (Gerstenberg, Allen and Phipps 1999).

B. caballi and *T. equi* generally have the same distribution patterns. Both are widespread, occurring on every continent, being recorded in most tropical and subtropical areas of the world and, in some instances, extending into temperate climatic zones. It has been estimated that more then 90% of the total equid population (118 million) occur in endemic areas (Schein 1988). In Europe, is endemic in France, the Iberian peninsula, Italy, the Balkans and large areas of the former USSR with *B caballi* extending as far as 58°N latitude. It is apparently absent from the British Isles and northern Europe. Africa, Madagascar and western Asia. Central and South America are endemic. The status of the Far East is uncertain, however, Japan is considered free as are Australia and the USA. The USA was considered free of equine piroplasmosis till 1961, when *B. caballi* was introduced into southern Florida, probably by 30 horses imported from Cuba in 1958. Within a year after it was first recognized, *B. caballi* was found throughout Florida, and the tropical horse tick *Dermacentor nitens* was shown to be the vector. Control measures, including tick control, serological testing, treatment and quarantine have contributed to its confinement to Florida. The first field case of *T. equi* was diagnosed in Florida in 1965. This has led to regulations requiring a negative *T. equi* and *B. caballi* complement fixation test (CFT) on all horses imported into the USA, which has probably contributed to the continued piroplasmosis-free status of horses in other areas of the USA.

There is some evidence that horses subjected to heavy training, poor nutrition or other stress factors may develop relapsing episodes, after having previously acquired a non-clinical infection (Hailat et al. 1997). Control through the measures described above can be successful, but eradication from areas where the infection has established has not been achieved.

Dogs

Dogs are generally infected with two *Babesia* spp., *Babesia canis* and *Babesia gibsoni*. However, recent studies on the vector specificity, enzymatic patterns, cross immunity, serology, pathology and molecular biological analysis suggested that *B. canis* actually consist of 3 sub-species; *Babesia canis canis* transmitted by *Dermacentor reticulatus* in Europe, *Babesia canis vogeli* transmitted by *Rhipicephalus sanguineus* in tropical and subtropical countries, and *Babesia canis rossi* transmitted by *Haemaphysalis leachi* in South(ern) Africa (Uilenberg et al. 1989). It has even been suggested that these subspecies might be considered as true species (Carret et al. 1999). *B. canis*-group has also been isolated from a variety of wild Canidae, but the epidemiological significance of these as potential reservoirs is not yet fully known. With the greater movement of dogs and the presence of competent tick vectors in the temperate climatic zones, reports indicate that the disease is becoming widespread throughout the world.

B. gibsoni has strong superficial similarities to *T. equi*, since the forms most frequently seen in erythrocytes are more or less round, but the occasional maltese cross forms seen in some isolates, mainly from America [but appear to be absent in parasites described from Asia]. 18S rRNA sequences from 4 isolates of *B. gibsoni*, originating from Japan, Malaysia and Sri Lanka were compared with an isolate from California, USA, showing almost identical genotypes between the small canine *Babesia* from Asia, but a distant genetic relationship to that from the USA. The American isolate segregates together with *T. equi* while the Asian isolate showed close relationship with *B. divergens* and *Babesia odecoilei* (Zahler et al. 2000). These authors concluded that the American parasite should be attributed to the genus *Theileria*. Recently Zahler et al. (2000) described, what appears to be, a different small prioplasms of dogs, being more closely related to *B. micrtoti*, *B. rodhani* and *T. equi* for which they proposed the name *Theileria annae*.

B. gibsoni has a limited distribution being recorded in north Africa, India, Sri Lanka, Malaysia, USA and the Far East (including Japan). Transmission is by *R. sanguineus* and *Haemaphysalis bispinosa*. This parasite is also somewhat more tolerant to the usual babesiacides. Contrary to the pattern observed in cattle, where the young are relatively resistant, young dogs and pups appear highly susceptible, with death often occurring in the absence of treatment.

Pigs

The babesias associated with pigs, *Babesia trautmanni* (large) and *Babesia peroncitoi* (small) occur at lower prevalence rates than the babesias of grazing animals. The warthog and bush pig apprear to be natural reservoirs of *B. trautmanni* (De Waal, Lopez-Rebollar and Potgieter 1992). The vectors have only recently being confirmed, being *Rhipicephaulus simus* and *Rhipicephalus turanicus* - in both instances transmission is transovarially by the tick (De Waal, Lopez-Rebollar, & Potgieter 1992; Lopez-Rebollar and De Waal 1994).

B. trautmanni has been reported from the former USSR, southern Europe and Africa. *B. peroncitoi* has a very limited distribution and has been reported from Italy, North Africa, Senegal and Nigeria. The vector of this parasite is still unknown.

Avian

A number of *Babesia* parasites have been described from birds, many in error, being confused with rickettsia-like organisms, immature stages of other blood parasites (*Haemoproteus* spp or *Plasmodium* spp) (Pierce 2000). To date 13 *Babesia* species had been recognized in birds, most of these appeared to be host specific, at least to the family level (Pierce 2000). They usually appear as ring forms, fan shaped or cruciform tetrad schizonts presenting the characteristic Maltese cross formation. It has been speculated that they are probably also not true *Babesia's* and in all likelihood related to the *B. mictroti* type (Allsopp at al. 1994). Only one of the 13 described species of *Babesia* in birds, *Babesia shortti*, is known to be pathogenic and parasitaemias as high as 65% have been observed and infect birds in the Falconidae and Accipitridae families. It has been suggested that Argasid ticks (the soft ticks) are are the vectors, but to date the vectors are still unknown (Pierce 2000).

Human

Although human babesiosis was only first reported in the 1950's, drawings of Wilson and Chowning (1904) from patients with spotted fever illustrated what appear to be *Babesia* organisms in the erythrocytes. With the improvement of diagnostic techniques in recent years it has become evident that babesiosis of man occurs in a significant number of instances where man inadvertently interrupts the vector host cycle of *Babesia* of other mammals. Human babesiois in the New World has so far been diagnosed as caused by the rodent *Babesia, B. microti* transmitted by *Ixodes dammini*, and in the Old World by infection with the cattle *Babesia, B. divergens*, transmitted by *Ixodes ricinus* (Healy and Ristic 1988). Human babesiosis is no longer considered a medical rarety and infection among the general population is significant. The clinical presentation of babesiosis in splenectomised and immunosuppresed individuals is often severe, with possible fatal consequences, but in most non-splenectomized patients, the infection can be controlled by drugs (Telford et al. 1993).

IMPORTANT *THEILERIA* SPP. IN THE DIFFERENT HOSTS

Cattle

A number of *Theileria* spp. occur in cattle, the most important of which are *T. annulata* and *T. parva*. A number of other, less pathogenic, species have also been recorded.

Theileria annulata - this parasite is reported to infect cattle and Asiatic buffalo (*Bubalus bubalis*). It is highly pathogenic for cattle and is transmitted by *Hyalomma* ticks of which *Hyalomma a. anatolicum* is probably the main vector. It has a limited distribution in southern Europe, Asia and north Africa. The distribution in Africa is confined to the countries north of the Sahara desert, but it extends on through Egypt into Sudan to south of Khartoum. The extent of its distribution in the Far East is not yet clearly delimited.

Theileria parva - is a parasite of the Cape buffalo (*Syncerus caffer*) and is also infective to cattle and Asiatic buffalo. It is highly pathogenic to cattle and causes what is commonly known as East Coast fever, Corridor disease and January disease (Norval, Perry and Young 1992). Previously regarded as 3 sub-species, molecular DNA studies have shown these sub-species to be indistinguishable from each other on a molecular level, although the disease syndromes they cause are quite distinct (Norval, Perry and Young 1992). *T. parva* is widely distributed in eastern, central and southern Africa. The main vectors are *Rhipicephalus appendiculatus* and *R. zambeziensis* (Norval, Perry and Young 1992).

Theileria mutans - was probably first partly described in 1906 by Theiler. It is also a parasite of the Cape buffalo that is infective to cattle. It is usually of low pathogenicity in cattle and only occasionally causes fatal infections. It is transmitted by *Amblyomma* ticks and its distribution covers virtually all of sub-Saharan Africa and the Carribean.

Theileria taurotragi - described from an Eland (*Taurotragus oryx*) (Brocklesby 1962) has been shown to infect cattle, sheep and goats (Norval, Perry and Young 1992). In cattle variable clinical reactions occur and most are mild and subclinical. It has been recorded from cattle in Eastern, central and southern Africa.

Theileria sergenti/orientalis/buffeli-complex - It has been found that *Theileria* parasites of low pathogenicity, previously considered to be *T. mutans* were widespread throughout the world and now generally referred to as the *Theileria sergenti/orientalis/buffeli*-complex. These parasites are distributed mainly in Japan, Australia, Asia and Africa. *Haemaphysalis* spp. ticks are reported to be vectors. However, the name *T. sergenti* is invalid (Morel and Uilenberg 1981) and some controvesy still exists whether only one, two or even more benign *Theileria* spp. of cattle exists (Stewart, Uilenberg and de Vos 1996; Kawazu et al. 1999; Chae et al. 1999).

Sheep and goats

The only pathogenic *Theileria* spp of sheep and goats appears to be *Theileria lestoquardi*. *Theileria separata*, known to infect sheep and sometimes goats do not cause economically important disease. *T. lestoquardi* is transmitted by *Hyalomma anatolicum anatolicum* and has been recorded in south-eastern Europe, northern Africa, and the Near and Middle east and parts of China. Malignant theileriosis of sheep and goats is widespread in some important sheep breeding regions (like Iran, Iraq and India), where it causes high morbidity and mortality in mainly exotic but also local breeds. The disease resembles that of *T. annulata* of cattle (Friedhoff 1997).

Recent studies on a *Theileria* spp. causing fatal disease in sheep and goats in the northwestern part of China, believed to be *T. lestoquardi*, have shown that some characteristics of this parasite are not in accordance with attributes ascribed to *T. lestiquardi* (Schnittger et al. 2000). SrRNA sequence comparison revealed that the Chinese parasite was more closely related to *T. buffeli* and clearly divergent from *T. lestoquardi*, suggesting that this is an as yet undescribed *Theileria* spp. (Schnittger et al. 2000).

IMPORTANCE OF PIROPLASMOSIS

Mortality due to babesiosis in imported susceptible cattle is frequently high - a mortality rate in excess of 50% is not uncommon. This is particularly so in some Latin American countries, Africa and Asia. Such losses frequently escalate as a result of stress associated with transport, changer in nutrition, pregnancy, etc. Immunization may reduce such losses to negligible proportions. Production losses, though temporary, are of considerable importance to the individual importer. Such losses include decreased milk and meat production in animals recovering from acute piroplasmosis, abortions, temporary infertility, delays in reaching maturity and decreased draught power.

COST OF INTRODUCTION INTO A REGION

As a result of the Rinderpest pandemic of 1896 and the effects of the war, the cattle population in the northern territories of South Africa were dramatically reduced and cattle numbers were inadequate to meet the needs of the population. Cattle were subsequently imported from various parts of the world, including Africa. Veterinary authorities failed to realize that ECF was being introduced from cattle imported from East Africa, until it was too late and the disease came well established in the region (southern Africa). East Coast fever was thus first introduced into southern Africa in 1902 from cattle being imported from German East Africa (Tanzania) and Zanzibar and rapidly spread throughout the region (Norval, Perry and Young 1992). Mortality exceeded 90% and the effects were devastating for the already diminished cattle population in the region. Thousands of animals died and transport (oxen used in those days for transport) came to a standstill (Norval, Perry and Young 1992). It is estimated that a total of 400,000 deaths occurred in the period 1904-1910 in SA. With a total death toll of 1.4 mill at the end of the eradication campaign by 1960 (Norval, Perry and Young 1992).

COST OF PREVENTION

The cost of control policies to prevent the introduction of the disease can be astronomical as illustrated by the management safeguards imposed by the Georgia and USA Departments of Agriculture, to prevent the introduction of equine piroplasmosis into the United States of America, by horses competing in the Summer Olympic games of 1996 in Atlanta (Brooks 1999). Only 4 horses finally received import permits and the control programme cost 500,000 US$ or 125,000 US$ per equine piroplasmosis positive horse (Brooks 1999). In contrast, the Australians for the 2000 Olympic games have regarded the risk of introduction of equine piroplasmosis into Australia as negligible and, most importantly, that the introduction of foreign ticks should be prevented. Iatrogenic spread should also be prevented by use of clean instruments on all horses (Martin 1999).

COST OF ERRADICATION

Probably the most successful single programme for the control of babesiosis was conducted in the USA from 1907 to 1940 when *Boophilus* ticks were essentially eradicated from a 1,8 mil km2 area (Bram and Gray 1983). Eradication was accomplished by dipping all cattle every 2 weeks. Another factor contributing to the success of the programme was that large areas, which were environmentally marginally suitable for *Boophilus*, also had a substantial winter tick kill. In addition, very low numbers of wild ruminants were present in these areas, which allowed eradication to occur by removing cattle for extensive periods from pasture during which time the ticks could die. Another significant factor contributing to its success was overwhelming support by cattle producers. In 1906 it was estimated that the annual losses associated with ticks and babesiosis was 130 million US$ - in today's terms, probably in excess of 1 billion dollars. The end result was the elimination of babesiosis in the USA. There have been only few reports of serious or significant outbreaks of babesiosis in the USA (bordering on Mexico) since tick eradication. Similar eradication programmes have been attempted in several countries such as Australia, Argentina, Mexico, Uruguay, etc. (FAO 1989). These have not been successful (mainly due to acaricide resistance developing), and today it is not considered economically justifiable and other means of control are deemed necessary, viz. immunization.

As a result of the continual spread of ECF and the failure of the immunization technique of Koch to control the disease it was decided in 1904 to eradicate ECF from southern Africa. The method implemeted were quarantine of infected areas and control of all cattle movement by permit. A programme of fencing infected farms/locations was introduced to control the spread. It was not until 1909 that a dipping strategy to control the brown ear tick (*R. appendiculatus*) was introduced A 5-7 day dipping interval was recommended with 3 day dipping where there was a threat of infection. This reduced cattle mortality, so that the population increased steadily throughout the region, but it failed to eradicate the infection. Further measures were implemented in 1929, consisting of quarantine and slaughter or removal of all cattle from infected farms, leaving the area free of cattle for at least 15 months. The first success came only in 1946 when the then Transvaal Province of SA achieved complete eradication. The disease was finally eradicated from SA in 1954 (Norval, Perry and Young 1992).

Eradication of the disease by eradicating the tick vector is generally not advisable under endemic situations. The best method for controlling babesiosis in endemic areas is not to control ticks at all. However, where *Bos taurus* cattle are concerned, it is necessary to limit the number of ticks to prevent tick-worry. The reliance on tick control for the prevention of babesiosis historically has proven highly effective, but complete reliance on one system may impose circumstances that prove hazardous. Of interest in this respect are the reports from Zimbabwe of significant cattle losses (nearly 1 million head of cattle in the period 1973-1979) occurring in the period of political unrest, during which time the previously well established dipping program broke down, with the subsequent rapid increase in, amongst other, Boophilus ticks. This was rapidly followed by an increase in the major tick-borne diseases, including babesiosis.

PREVENTATIVE VACCINATION

Immunization against piroplasmosis is only practised in cattle on a large scale. In Australia, South Africa and in certain Latin American countries wide scale immunization using live attenuated strains of *B bigemina* and *B bovis* are used and the immunization of susceptible exotic cattle being imported into an endemic area is the most important requirement as well as immunization of cattle in endemically unstable areas - the latter necessitate a good knowledge of the epidemiology of the parasite in the country (or region). In some parts of Africa the immunization and treatment method is used to vaccinate cattle against ECF using tick derived sprotozoite stabilate (Musisi 1999) and in some Medittiranean countries a tissue culture schizont is used to vaccinate cattle against *T. annulata* infection (Pipano 1992).

Despite many years of intensive research at the expense of enormous resources, no "sub-unit" or molecular vaccine is available for any of the *Babesia* or *Theileria* infections. There is, however, some encouraging progress being made, which will be highlighted during the conference.

CONCLUSION

Approximately 80% of the 1,338 billion cattle are at risk of contracting babesiosis; the impact of this disease on development and its economic impact are insufficiently documented to allow an exact estimate but it has been estimated that global losses amounting to 13,9-18,7 billion US$ (in 1997) occur annually (De Castro 1997). Therefore, piroplasmosis is one of the greatest obstacles to the development of livestock industries in many tropical and subtropical countries of the world.

Recently Ross McLeod (McLeod and Kristjanson 1999), using a spreadsheet model based on various presumptions estimated the annual cost of tick and tick-borne diseases in selected countries in Africa and Asia - with the cost being the highest in India. It has by far the largest cattle herd of the countries included in the study and about 5% of the total cattle herd in India was comprised of European and cross-bred cattle. Theileria annulata seems to be the major disease, resulting in 114 million US$ loss due to mortalities and a further 125 million US$ in lost milk production. The annual cost per herd was highest in the African countries as cattle producers in these countries employ high intensity tick control methods to offset production losses associated with tick-borne diseases. It must also be remembered that ECF is endemic in much of this region. The impact of equine piroplasmosis in SA and probably elsewhere in the world is economically mostly centered in the Thoroughbred industry where reproductive failures and losses in revenue as a result of horses not competing in races, etc result in considerable losses (2.5 million US$ /annum) (Guthrie A. unpublished data).

Disease control technologies for livestock diseases are often inadequately or incorrectly applied because of poor understanding of the epidemiology of these diseases under different conditions and the relative merits of different control options in terms of efficacy and impact. It is often more economically attractive to protect only the more intensive production units in proximity to markets. The collapse of cattle dipping infrastructures for tick control in Eastern and Southern Africa and the disappearance of significant mosquito and tsetse control programmes may serve as examples. The dilemma is that the pastoral and rural societies that are most in need of assistance have virtually no opportunity to translate assistance into the self-supporting sustainable systems that would improve their livelihood. A further contributing factor to the resurgence of disease is environmental concerns that may preclude or restrict application of insecticide-based control methods. Losses of markets for life-grade or pedigree cattle are another real factor though difficult to quantify in assessing the importance of piroplasmosis. For the developing country or producer in the endemic area, this is realized when restrictions are placed on the movement of animals for fattening or slaughter, from endemic area to tick-free areas, or when cattle from endemic areas attain lower prices on the open market. Such restrictions may affect movement of animals within countries or between countries and most frequently reduces accessibility to lucrative markets for producers in endemic areas.

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