Review: One Hundred Years of Veterinary Parasitology in the Land of Israel

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In the present review, an effort was made to describe the progress of veterinary parasitology in the Land of Israel, by following publications that have appeared in the literature, since the establishment of the rule of the mandate given to Britain by the League of Nations at the San Remo Conference in 1920 (1).

Livestock was one of the pillars of the ancient economy. The sources of ancient Judaism and especially the Bible and the Talmud contain an extensive list of animal names and many discussions on animal medicine, hygiene, poisoning and means of prevention and cure of diseases. Enormous veterinary medical material is found in "Shulchan Aruch" written by Rabbi Yosef Caro in 1565. This information includes the rules necessary for testing kosher for the approval of food from animal origin for eating. The Mishnah mentions anatomic-pathological defects for the disqualification of slaughtered animals for human consumption, which in contemporary veterinary medicine are still considered a serious threat to the public health and are contrary to the rules of hygiene (2).

With the establishment of the State of Israel in May 1948, Dr. Yitzhak Tzur-Tchernomorets was appointed the first director of the department in the government Veterinary Institute and served in that position until his untimely death in 1965. He published in 1959 the list of "blood parasites in Israeli livestock" (3).These parasites manifested themselves more powerfully in the early 1930s with the beginning of the improvement of the local breed of cattle. It is no coincidence that parasites from this group were used as a topic for final theses to obtain a doctorate in veterinary medicine by Israelis who studied in veterinary schools abroad (4, 5). In 1952, Professor Shaul Adler wrote in the OIE (World Organization for Animal Health) bulletin that "piroplasmosis" (synonymous with tick fever) was the most important group of diseases of the dairy herd (6).

The presence of *Anaplasma marginale* in cattle in Israel was first documented in 1924 by The Central Laboratories of the British Mandatory Government by examination of blood smears of a cow that had been brought from Beirut to the Jewish settlement of Yama (now Yavniel) (7). Tsur conducted experiments to vaccinate cattle against *A. marginale* by inoculation of *Anaplasma* parasites of sheep and goats (*A. ovis*) (8, 9). In summarizing the results of the experiments, he reported that the *Anaplasma* of sheep and goats were specific to these animals, does not infect cattle and does not prevent infection with cattle *Anaplasma*, an opinion that is accepted to this day. In 1952, the natural mutation *A. centrale* was brought to Israel from South Africa and is still used to produce a vaccine against anaplasmosis of cattle. This vaccine was restricted to an age of about six months (10) and created a state of carrier throughout the life of the cattle (11).

In a series of studies in cooperation with American scientists, the major surface proteins of *A. marginale* (12, 13) that play a crucial role in the interaction between the parasite and the host cells in the formation of an immune response that impairs the parasite's proliferation in cattle was illuminated. However, despite the formation of specific antibodies it elicited the immunity to the recombinant vaccine against *A. marginale* parasites common in the field, was lower than required.

During the Ottoman rule, appeared an anonymous report of jaundice in cattle named "piroplasmosis". In 1924, the veterinarian Yaakov Neria (14) published an article referring to the disease as "Texas fever" caused by the parasite *Babesia bigemina* in cattle.

Dr. Yitzhak Tzur conducted vaccination experiments at the Veterinary Institute against the two types of *Babesia*

(*B. bigemina* and *B. bovis*) that cause disease of bovines in Israel, by using blood from patent and latent carriers (15, 16). Following the study, Tzur prepared a vaccine containing both species of parasites in the same dose and called it a "cocktail." Initial use of the vaccine in farms resulted in acute babesiosis and a significant proportion of the inoculated cattle (about 14%) died from the disease. A possible explanation for the mortality was that the experiments with the vaccine in the laboratory were performed in young cattle, while the vaccination in the farms was carried out also in older cattle, which were more sensitive to infection with *Babesia* parasites. After the death of Yitzhak Tzur, research into the development of vaccines against babesiosis in cattle continued (17). Based on results of experiments performed with both parasites, *B.bigemina* vaccine was prepared from splenectomized donor calves inoculated with parasites obtained during relapse parasitaemia and the virulence of *B. bovis* parasites had been attenuated by rapid passages in spenectomized calves (18).

Following the success of *in vitro* cultivation of *Babesia* species, experiments were made to replace the source of the parasites in the vaccine from infected cattle blood with culture derived parasites (19). The growth and passages in culture decreased the virulence of *Babesia* parasites, however, the decrease of virulence, also resulted in decrease of immunity that these parasites conferred (20, 21). This finding and the higher cost of a vaccine produced in culture shifted to the restoration of the previous method of vaccination by using infected cattle blood.

Every year, outbreaks occur in Israel caused by *Babesia ovis* in flocks of grazing sheep. Prof. Yeruham studied the epidemiology of sheep babesiosis and in his opinion *Rhipicephalus bursa* was the only vector of *Babesia* parasites in sheep in Israel (22, 23, 24, 25).

In 1922 Mason a pathologist working in Cairo reported a disease in cattle and buffaloes in the Mediterranean area and named it "Egyptian fever" (26). The signs of the disease and the pathological changes described by the author were identical to those caused by *Theileria annulata*. Two years later the Australian veterinarian Gilbert, chief of the veterinary laboratory in Jaffa reported the same symptoms and pathological lesions in a bull in Palestine (27).

Theileriosis, was the disease that caused the most severe damage to cattle in Israel, not only because of the severity of the clinical disease and high mortality rates, but also because the lack of vaccine to prevent it and the lack of a drug to treat the sick cattle. In 1934 Prof. Adler of the Hebrew University in Jerusalem and the veterinarian Dr. Ellenbogen conducted an experiment to vaccinate cattle in Israel with blood from calves infected with an Algerian *T. annulata* strain, which had low natural virulence and was sent to Israel by the French team working in Algeria (28, 29). The Algerian *Theileria* strain conferred only partial immunity against the virulent field strains in Israel and it was decided to strengthen the immunity by a second inoculation of blood containing a virulent Israeli strain of *T. annulata* (30). In 1963, schizonts stages were not detected in smears from liver puncture material of two calves inoculated with the Algerian strain and the result was that the low virulent strain was lost and the vaccination against theileriosis in Israel was discontinued.

In 1945 Tzur grew schizonts of *T. annulata* by the explant culture technique from liver or lymph node of *T. annulata* infected calves (31). In the first week schizonts infected with cells multiplied around the explant, but subsequently the explant degenerated and caused the death of the cells infected with schizonts. Efforts to improve the results over about a decade and a half did not succeed, however it has been shown that *T. annulata* schizonts can reproduce in culture.

It was the imminent virologist Professor Abraham Kimron, head of the Veterinary Institute in Bet Dagan, who obtained for the first time (in an unpublished work) a monolayer culture from trypsinized kidney tissues removed from a calf dying from theileriosis (32). Further observation showed that prolonged cultivation led to loss of virulence of the shizonts and that they conferred protection against homologous wild field isolates of *T. annulata.* By the middle of the 1960's culture derived vaccine was applied against *Theileria* infection in Israel. (33, 34, 35, 36, 37).

In 1953 the South African scientist Wilhelm Neitz discovered that treatment of cattle with chlortetracycline during the incubation period of *Theileria parva* tick-borne infection prevented severe disease and mortality and that recovered animals were immune to subsequent infection (38). In Israel, the suitability of this method for vaccination against *T. annulata* theileriosis with parasites derived from ticks was tested in the parasitology laboratory of the Veterinary Institute (39, 40). The immunity of cattle following tick-borne infection was stronger than that acquired following vaccination with a vaccine containing low-virulent culture derived schizonts. On the other hand, the higher cost than a culture derived vaccine, the cumbersome vaccination process and the lower safety of the method did not support the widespread use of a vaccine based on tick derived parasites in Israel. In another experiment, treatment with tetracycline of cattle inoculated with live anti-babesial vaccine mitigated the clinical manifestations and considerably reduced red blood cell destruction (41, 42).

In 1960, *Besnoitia besnoiti* a parasite of the group of the "tissue cyst forming coccidia" was diagnosed for the first time in Israel (43, 44) by Marius Neuman, the head of the helminthology section of the Veterinary Institute. Despite the hint that the final host of this coccidian parasite is in the pasture, the joint study of investigators from South Africa, Germany and Israel was not able to identify it (45). The parasite severely affected the reproductive system of imported bulls and jeopardized the program aimed to improve beef cattle herds in Israel. A number of surveys based on the presence of specific antibodies, conducted in grazing beef cattle herds, revealed a high level of infection increasing with the age of the cattle (46, 47, 48).

Another study (49) showed that inoculating cattle with live tachyzoites or bradizoides of *B. besnoiti* did not result in disease manifestations but, triggered an immune response. Subsequent laboratory and field experiments showed that tachyzoites produced in cell culture confer immunity to natural infection. Based on these results, routine vaccination of bulls was introduced by inoculation of culture-grown tachyzoites. Various anti-parasitic drugs had no effect on *Besnoitia besnoiti* (50).

The economically most important parasite of the above mentioned group is *Neospora caninum* that causes abortion in cattle all over the world including Israel. Canines are the final hosts, in which in the gut a sexual stage occurs and resistant oocysts that contain parasites are excreted with the feces (51). The parasite can rarely cause severe pathological syndromes in dogs (52).

Monica Leskowitz-Mazuz, the present chief of the parasitology laboratory in the Veterinary Institute, conducted a long term study on *N. caninum* infection in dairy herds in Israel. According to the results: cows infected with the parasite had three times as many abortions as uninfected cows, the level of antibodies in the cows did not have a decisive effect on the chance of abortion. Vertical transmission of the infection in the positive cows to the embryos was observed in 61% of the infected cows. In a field trial Lescovitz-Mazuz found that inoculation with live culture derived *N. caninum* tachyzoites into pregnant cows that are already infected with the parasite significantly reduced the percentage of abortions in future pregnancies, but at the same time, did not prevent the transmission of the infection to their offspring (53, 54, 55).

Toxoplasma gondii is another parasite belonging to the above group. Serological surveys based on measuring the level of specific antibodies or isolating parasites, conducted in Israel by Salant in wild and domestic birds and serological surveys conducted by Shkap in farm animals, showed a high infestation rate. According to the annual reports of the parasitology laboratory of the Veterinary Institute, sera of hundreds of sheep and a similar number of goats are found positive each year in testing for specific antibodies to *T. gondii* (56, 57, 58).

Many attempts to vaccinate animals against unicellular parasites by non-viable antigens including experiments performed at the Veterinary institute with *Babesia bovis* (59) and *Theileria annulata* (60) showed that sustainable immunity can only be achieved using vaccines containing live parasites. Prolonged storage of live protozoan parasites was possible only at ultra-low temperatures. The laboratory of parasitology in Beit Dagan was the first to publish the use of frozen vaccines against cattle tick fevers (61, 62, 63, 64, 65). Israel is the only country that vaccinates grazing beef cattle against five diseases caused by unicellular parasites. The Division of Parasitology of the Veterinary Institute has complied standard procedures in the production and quality control stages of viral and bacterial vaccines for use in vaccines against diseases caused by blood and tissue parasites (66).

Trypanosoma evansi appears to be the only pathogenic parasite of this genus that is enzootic in Israel. A report from the Austro-Hungarian and German military medical service from 1917 (67) mentioned the presence of trypanosomes in camels in Israel. In the same year, an article (in German) appeared by Chereidin, Goldberg and Omar (68) on trypanosomiasis in camels in Palestine. The authors reported that in 1915 out of 958 camels of the Turkish army 462 died of trypanosomiasis. In 1923 Steward and Krikorian (69) describe an outbreak of *T. evansi* in camels in the British occupation army in Israel during 1919 and additional infections of trypanosomiasis in horses and mules. Five more publications by Israeli veterinarians described trypanosomiasis in camels and equids (70, 71, 72, 73, 74). Prof. Yaakov Kligler (75) published 25 articles on laboratory experiments with *T.*

evansi in Israel between 1924 and 1940. He investigated the pathological changes in the blood of infected animals, the effect of animal nutrition on susceptibility to trypanosomiasis, the role of the spleen during infections, the antigenicity of the parasites, the immune system's response to trypanosome infections, the drug treatment of the disease and its effect on immunity after recovery.

Two other species of the genus *Trypanosoma* have been documented in Israel: *T. equiperdum* which causes "Dourine" disease in horses and was common in the country during the British Mandate (76). After the establishment of the State of Israel in 1948, the spread of the disease was arrested and since 1952 no infected horses have been diagnosed within the borders of the State. In 1928, Prof. Theodor of the Hebrew University described a non-pathogenic trypanosome in goats, transmitted by *Lipoptena* flies (77).

Infection with *Trichomonas fetus*, another flagellated parasite was diagnosed in Israel for the first time by the veterinarian Ferber (78). The parasite was eradicated by the use of artificial insemination under the guidance of Dr. Natan Ayalon, who was the head of the Department of Animal Reproduction at the Veterinary Institute (79).

Cultivation of *in vitro* parasites that infect blood cells has been the dream and aspiration of many scientists since the beginning of the last century. Following the success in the growth of *T. annulata* by Kimron and the growth of *Babesia bovis* in the United States, the Department of Parasitology in Beit Dagan has specialized in the isolation and growth in cell cultures of seven species of blood and tissue parasites.

In 1910 appeared the first publications in French on the phenomenon of the "oriental sore" in Palestine (80). A decade and a half later, Professor Shaul Adler of the Hebrew University began researching the causes of leishmaniasis and its vectors in nature and published the results of his research in 91 articles between 1925 and 1966.

The establishment of the School of Veterinary Medicine strengthened the research dealing with animal diseases in general and in parasitological research in particular. Today, Professor Gad Baneth's laboratory is one of the recognized international centers for the study of *Leishmania* parasites. In 1996, a new focus of visceral leishmaniasis was documented in dogs in central Israel (81). Visceral leishmaniasis caused by the species *L. infantum* is an important zoonotic disease that can cause death in humans. Another study in collaboration with Prof. Charles Yaffe of the Hadassah Ein Karem School of Medicine revealed that the disease is common among domestic dogs in many communities in central and northern Israel (82, 83).

Later in Baneth's laboratory, new molecular diagnostic methods and a non-invasive diagnostic method were developed by sampling the conjunctiva with an applicator (84). In addition, a number of relatively rare cases on a global scale of infection in dogs have been found by species of Leishmania that cause human skin disease (*L. tropica, L. major*) (85). Infections of *L. tropica* have also been documented in jackals and foxes in Israel. Allopurinol, a derivative of pyrazole and pyrimidine, suppresses *Leishmania* culture has helped reduce symptoms caused by *L. infantum* in dogs. Dr. Yasur- Landau and collaborators found that sometimes the treatment with this preparation led to the resistance of *Leishmania* parasites and to the "reactivation" of the clinical disease. In addition, they identified the enzymatic and genetic mechanism for the formation of resistance, a phenomenon that had not previously been reported in the scientific literature (86). Based on recent investigations Baneth reported the prevalence of cutaneous leishmaniasis in Israel was caused by two species - *L. tropica* that occurs along the Judean Desert east of Jerusalem and the Galilee region with a natural reservoir located in the rock hyrax and *L. major* common in the Jericho area in the southern part of the Jordan Valley and the Arava region with a natural reservoir the sand rat and in the western Negev with a reservoir the wild gerbils and desert gerbils. *L. infantum*, which infects dogs and humans and is spreading from the north to all other parts of Israel.

The genera of *Coccidia* and *Cryptosporidium* are parasites that mainly multiply in the intestines of mammals and birds and cause inflammatory symptoms, especially in young animals.

Cryptosporidiosis in cattle affects young calves during the first month after birth (87). A survey of calves up to the age of three weeks in 44 dairy farms in Israel found that in 40 of them secrete cryptosporidium oocysts (88). Cryptosporidiosis is a transient disease even without drug treatment and subsequent mortality is extremely rare. In a field trial (89), it was found that giving 100 mg / kg of paromomycin sulfate for 10 consecutive days, starting from 36 hours after birth, suppresed multiplication of the parasites. Based on these results, it should be considered to examine whether the economic damage caused by the disease is greater than the cost of the treatment.

Researchers from Israel and Turkey (90) analyzed the genotypes of the *Cryptosporidium* parasites in both countries. The number of different genotypes was higher in Turkey than in Israel. According to the researchers, genetically different populations of parasites can appear in animals in a short period of time. They referred to differences in the conditions in Israel that restrict the transmission of parasites from farm to farm compared to Turkey where this type of cattle grazes and the trade of calves between herds is very common. In the last two decades, a considerable number of fecal sample that came to the parasitology unit at the Veterinary Institute have been found to be positive for *Cryptosporidium* parasites.

Preliminary results of a study currently being conducted by Dr. Daniel Yasur-Landau at the Veterinary Institute show that in many cases animals (calves, lambs and goats) are infected in a relatively large number of different species when at least some of them may also infect humans.

Compared to cryptosporidiosis, intestinal coccidiosis is a serious disease in farm animals and in the absence of drug treatment can cause mortality in significant percentages of the infected animals. In a survey to detect coccidiosis in cattle, carried out by Markovics (91) oocysts were diagnosed in 28 dairy farms out of 31 farms tested. In an effort to minimize the use of synthetic drugs and following the shepherds' attempt to treat diarrhea of goats during the weaning period with the mastic tree (*Pistacia lentiscus*), experiments were performed with goats naturally infected with *Coccidia*. The goats fed with the mastic tree secreted smaller amounts of oocysts, when tannin appears to be the active ingredient in the plant that mitigates the diarrhea (92).

Among the first publications concerning coccidiosis in poultry is the Prof. Melech's pamphlet "The Inner Parasites of Poultry" (93). Prof. Shimon Bornstein, a graduate of veterinary medicine in Texas, was a pioneer on the subject of poultry health in Israel and between the years 1955-1957 he published half a dozen articles on coccidiosis. He listed eight species of *Coccidia* that infect birds but in his opinion only three of them cause actual disease (94, 95). Ten years after the publications of Bornstein an article by the poultry veterinarian Dr. Arie Bickeles was published describing the problem of coccidiosis in poultry in the 1960's of the previous millennium (96). The poultry veterinarians Drs. Weissman and Meroz reported an outbreak of coccidiosis in battery-held chickens and referred to the ways in which coccidiosis is wide spread by tools (97).

In 1995, an innovative concept was published in Israel based on a different strategy for vaccinating chicks against coccidiosis. The method was based on vaccinating breeding adult chickens with antigens of the sexual phase of *E. maxima*. Antibodies formed in the hens were passed into the yolk of the eggs laid by them and from the yolk to the chicks that hatched from the eggs (98).

Prior to the establishment of the School of Veterinary Medicine in Israel, diseases of pets that were in constant proximity to humans and wildlife diseases did not receive the required attention from institutions engaged in parasitological research in Israel.

Prof. Gad Baneth in collaboration with Dr. Michael Samish, described in detail the life cycle of *Hepatozoon canis* in the dog and in the brown dog tick *Rhipicephalus sanguineus* (99) and the *Hepatozoon* species in the cat with possible trans-placental transmission (100). In another investigation a new species of *Babesia* parasite –*B. vulpes* was described in canids by Baneth and collaborators (101). In addition they found that the bacterium *Borrelia persica* transmitted by the soft tick *Ornithodorus tholozani* also infects domestic and wild animals which are its natural reservoir (102).

Prof. Shimon Harrus of the School of Veterinary Medicine in cooperation with Drs. Avi Keysary and Dr. Trevor Waner from the Israel Biological Institute have been involved for the past three decades in the characterization and research of rickettsia which are transmitted by arthropods and harm animals and humans (103, 104). They demonstrated that in the process of the disease caused by *Ehrlichia canis* autoantibodies develop against platelets and as a result, the function of the platelet is impaired (105, 106) and that the disease agent can survive in the spleen of dogs for years (107). They have been able to attenuate the virulence of an *E. canis* strain by passages in cultures to a degree that it could serve as a basis for a future vaccine against canine ehrlichiosis (108). Professor Harrus identified several *Rickettssia* species that were not known to exist in Israel (109).

For the past two decades, Harrus has been studying *Bartonella*, a bacterium transmitted in nature by arthropods. He identified new species of *Bartonella* common in the Negev (110) and studied the ecology and the relationship between the hosts of the bacteria and its vectors. He demonstrated that there is transmission by fleas, including transmission to flea offspring's that have been fed by regurgitations of infected adult fleas. In Prof. Harrus's laboratory, exotic parasites that are usually not found in the geographical niche that characterizes Israel were first diagnosed, such as the first case of the African parasite *Trypanosoma congolense* (which also affects cattle) in dogs imported to Israel (111) and a rare case of canine neoplasia in dogs (112).

The parasite *Nuttalia danii* (113), which multiply in the red blood cells of a field rodent was found in Israel. This is of great theoretical and practical importance for understanding the evolutionary development of blood parasites and the interactions between blood parasites and their hosts. This parasite was first classified as *Nuttalia*, a subspecies of the genus *Babesia* similar to the blood parasite of horses named formerly *Nuttalia equi*. In 1981 the German researcher Schein discovered a process of asexual multiplication in the white blood cells (schizogonia) of the horse parasite and in 1998 it was transferred from the *Babesia* group to the genus *Theileria*. In contrast to the pathogenic *Theileria* parasites of cattle, the pathogenesis of theileriosis in horses is caused by the parasites inside red blood cells and not inside the white blood cells. Twenty-eight years earlier, Yitzhak Tzur (113) announced the discovery of the schizogonia process in the jird parasite. This rodent parasite can be used as a cheap and convenient model to develop a vaccine against this type of parasites which will in the future be implemented to *Theileria equi* in horses.

In 1923, in his article “On Ticks and Other Pests,” Pochatsevsky (114) described the enclosure of a Jewish farm infested with various parasitic arthropods and recommended smearing the animals with olive oil as the best treatment against tick infestation. He also noted that free-ranging domestic birds in the enclosures played a crucial role in the destruction of ticks. One year later Dr. Yaakov Neria (14) described the life cycle of the one host tick *Boophilus annulatus* (known as the cattle tick) and the process of the transmission of *Babesia bigemina* to cattle.

Prior to the establishment of the Entomology Unit at the Veterinary Institute in 1957, most of the research on parasitic arthropods in Israel was conducted by scientists of the Hebrew University of Jerusalem. Among all those who studied ticks during this period, stands out the contribution of Prof. Bruria Feldman-Muhsam, who identified most of the ticks in the Land of Israel and studied their biology and morphology (115). The results of her research led to the conclusion that in addition to the two species of *Rhipicephalus* ticks: the dog tick (*R. sanguineus*) and the common tick in the sheep flocks in Israel (*R. bursa*), there was another species *R. secundus* that differed in morphological characteristics, mainly in stages before the adult tick stage and in its preference for hosts. *R. sanguineus* was found mainly on dogs and *R. secundus* mainly on cattle and sheep (115). In parallel with research on morphological characteristics, she investigated the ability of ticks to survive in different temperature and humidity conditions. Laboratory experiments with the most common tick in Israel *Hyalomma savignyi* (synonymous with *H. excavatum*) showed that larvae are the most important stage for tick survival and the adult stage of this tick can survive in laboratory conditions for about 250 days (116). In an in-depth morphological study Feldman-Muhsam made an order in the classification of the genus *Hyalomma* and concluded that the species *H. savignyi* is in fact *H. excavatum* (117).

In 1957 Yitzak Tsur-Tchernmorez invited the veterinarian Dr. Arieh Hadani to establish an entomology unit in the department of parasitology of the Veterinary institute. Rachel Cwilich, a Holocaust survivor who studied in Switzerland joined Hadani. The establishment of the unit characterized the beginning of the period of direct service of the veterinary entomology to the animal breeders in Israel. Growing of parasite-free ticks under laboratory conditions is the first and necessary step to study their ability to transmit diseases. Hadani and Cwilich (118) published in 1969 methods for laboratory growing of several species of ticks occurring in Israel. Subsequently, various stages in the life cycle of laboratory-grown ticks have been used in studies of the transmission of tick-borne disease agents, testing the susceptibility of the ticks to pesticides and evaluating the effectiveness of anti-parasitic vaccines in cattle and sheep.

Beef cattle grazing on pastures are constantly exposed to blood suckling arthropods. In 1960 Hadani and Tsur-Tchernmorez (119) published the results obtained from a two year follow-up study in a commercial herd including the level of infestation with six species of ticks and the effect of pesticide treatment against them.

In 1964, Hadani and Cwilich (120) reported for first time the presence in Israel of the tick *Boophilus kohlsi* in sheep and goats, which occurs in arid areas of the Middle East. Cattle infested with *B. annulatus* were found in the same area but, not with *B. kohlsi*. This species of tick was first described in 1960 by Hoogstraal & Kaiser (121) in Jordan as a fourth species in the genus Boophilus which, unlike other species, infects sheep and goats instead of cattle. In Israel few ticks of the genus *Amblyomma* were found along the Jordan Valley (122), in a path used by migratory birds on their way to and from Africa. Ticks of this type transmit deadly disease agents to animals in Africa, but they are not an integral part of the tick population in Israel and their presence is the result of a random migration of birds.

In 1981/82 a comprehensive study was conducted by Maria Robina, Hadani and Meir Ziv on the life cycle of the tick *H. excavatum* under natural field conditions. This tick is found on farm animals almost all year round in the adult stage only. The larval and nymph stages parasitize rodents and rabbits and the tick completes an entire life cycle in one to two years (123). The study found that *H. excavatum* ticks could be divided into two groups: ticks that drop in the April-September period (summer period) and those that drop in the remaining months (winter period). The development of the ticks was significantly different between the two groups.

In three consecutive articles, Hadani and his scientific partners (124, 125, 126) published results from studies on tick-host relationship based on the circadian rhythm - an internal biological clock that depends on physiological processes that occur in the various developmental stages of the tick *H. excavatum.* The results of the study showed that ticks adapt to conditions that will allow them to significantly increase the chance of finding a host and surviving. Hadani *et al.* (127) found that adult ticks of the three-host tick *H. excavatum* were able to transmit *T. annulata* when nymphs are fed on an infected bovine. However, although this tick was capable of transmitting *T. annulata* in the laboratory, it did not play the role of a natural vector of theileriosis in the field because nymphs do not feed on cattle.

In the process of identifying ticks collected from animals in the field, Cwilich and Hadani (128), found ticks with morphological markers characteristic of two species of the genus *Hyalomma* - *H. excavatum* and *H. marginatum*. In a controlled laboratory experiment the researchers (129) demonstrated that there was a possibility of hybridization between the two species of ticks. This finding had implications for the value of morphological criteria in defining tick species. The molecular method for defining the species introduced in that period seemed to be more accurate than a method based on morphological characteristics.

In 1968 both researchers published a laboratory method for studying the efficacy of anti-tick pesticides in the laboratory by using *H. excavatum* nymphs (130). This method was proposed for initial testing of pesticides, before making a final decision based on the results of treating tick-infected animals. The above researchers tested the depletion of the active pesticide in a cattle spray race (131). They found that the active ingredient of the pesticide was absorbed in the hairs of the cattle and as a result its concentration in the liquid drained from the cattle and returned to the container decreased during the spraying. Although the chemical tested is not in use today, it is advisable to check the changes in concentration in the spraying process of the new preparations that have been introduced recently.

In 1973, Dr. Michael Samish, a tick and mite researcher, joined the parasitology unit at the Veterinary Institute. Together with Pipano (132) they reported that nymphs of *H. excavatum* transmit *T. annulata* provided that the larval stage feeds on cattle infected with the parasite. Adult *H. excavatum* ticks infected in the larval stage do not transmit the *Theleria* parasites if in the nymph stage they feed on hosts that are not susceptible to theileriosis. They also found that female adult ticks carry a considerable larger load of *T. annulata* parasites compared to male adult ticks (133) which should be taken into consideration during preparation of suspension of infected ticks (134). Hadani, Samish and collaborators (135, 136) investigated the development of *T. annulata* parasites in the salivary glands of the adult stage of the two host tick *H. detritum* which transmited the infection to cattle in the field in Israel. They concluded that blood nutrition and activation of the ticks does not appear to be the sole cause of development of sporosoites in the salivary glands of the tick.

Cwilich and Hadani (137) described a method for growing *Ixodes ricinus* in the laboratory which was a rare tick in Israel. Ticks of this genus were involved in paralysis and toxicosis in animals (138) and humans (139) in Israel. *I. ricinus* was found also on cattle by Oren Erster (140).

In northern Israel, during the winter season, black goats were infested with reddish parasites on the eyelids and the neck. This phenomenon is popularly known as chiggers. The parasites were identified by Cwilich and Hadani (141) as larvae belonging to the family *Trombiculidae* that are also a threat humans and may transmit pathogens. It should be noted that 35 years earlier an article was published by a French researcher describing the presence in Israel of larvae of the genus *Trombicula* on lizards (142).

In the past it was not clear whether the one-host tick *Rhipicephalus* (*Boophilus*) *annulatus* had a involvement in transmitting *Anaplasma marginale* since this parasite does not pass from the mature female tick through the eggs to the next generation. Samish *et al.* (143) demonstrated under experimental barn conditions that this tick was indeed capable of transmitting *Anaplasma* parasites provided that despite being a one host tick its developmental stages may move from an infected animal to an uninfected one. In addition Samish (144) was able to grow *A. marginale* in culture on cells of the tick *Dermacentor variabilis.*

Following the desire to minimize the use of chemical pesticides, Samish investigated various biological measures to harm disease vectors (145). He first discovered that entomopathogenic nematodes (very small nematodes that attack insects) are capable of killing ticks. The effectiveness of nematodes as a pesticide has been demonstrated in limited field trials. In addition, he examined the effect of fungi that damage arthropods. He found that a strain of the genus *Metridium* attacked several species of ticks with great efficiency. Experiments with commercial broiler coops showed that spraying the spores of the fungi the day before the introduction of the chicks greatly reduces the population of *Alphitobius diaperinus* (146).

By far the most common disease caused by mites is the mange caused by *Sarcoptes scabies*. Infection of camels (147) and sheep (148) was documented as early as the British Mandate. Sarcoptic mange has been diagnosed in almost all farm animals, pets and wildlife in Israel (149). The veterinarian Dr. Israel Yeruham in parallel with his work of treating sick farm animals, proved in his publications to be a skilled field entomologist. He raised the suspicion that hedgehogs infected with *Sarcoptes* may be the source of infection for farm animals and wildlife (150). Another mite that settles inside the host's tissue is the follicle mite of the genus *Demodex*, which forms colonies within the skin. The various species are characterized by a high specificity for their hosts. Yeruham and collaborators conducted a survey of 120 cattle herds and found 83% of them infected with *Demodex bovis* (151). However in contrast to the severe disease caused in dogs, infection with the follicle mites in farm animals was not accompanied by visible disorders. Psoroptic mange and successful treatment with the systemic drug Ivermectin was reported (152, 153) by Yeruham and collaborators. They surveyed for chorioptic mange 109 herds of dairy cattle and 94 flocks of sheep. On their opinion all specimens collected from cattle belonged to *Chorioptes texanus* and those collected from sheep, goats and deer to *C. bovis*. In another publication they described *Psoroptes ovis* and *P. cuniculi* in domestic and wild ruminants in Israel (154, 155, 156).

Yehuda Braverman was another entomologist who left footprints in the Israeli parasitology, thanks to his research on the biting midges He studied parasitic insects of many species (157), but most of his efforts have been concentrated in research on the genus *Culicoides.* In a comprehensive study conducted by him using modern techniques he identified 58 species responsible for transmitting animal diseases in Israel (158). Subsequently, he investigated the efficacy and potential of transmission of viruses by the major vectors (159), the seasonal prevalence (160) and the activity of each of them throughout each of the hours of the day, the length of time during which the midges survived (161), the number of generations established, their habitats, and their geographical distribution. The preferred farm animals by the midges were determined for each of the species by blood tests of the saturated females (162) and conclusions were drawn as to which species prefer to sting mammals and which prefer to sting birds. Apart from transmitting diseases, several species of midges cause by biting a recurring summer urticaria in horses, cattle, sheep and donkeys. Infrared thermography has been found to allow the early detection of sensitive horses (163).

The possibility that arthropods transmitting viruses are carried by air currents from other parts of the Middle East, especially from the "fertile crescent", has been investigated (164). The altitude of the above-ground flight was also examined for the species of midges that are attracted to bovines and it was found that the *C. imicola* preferred a light trap placed about 26 meters above the one placed 1.4 meters above the ground, in a flight path that makes them suitable for long-distance transportation (165). The continuation of the study in this sort of flies, which is of great importance to the animal health, is being carried out today by Drs. Adi Bechar and Asael Roth from the Entomology Laboratory in the Division of Parasitology at the Veterinary Institute. Bechar led a study to monitor the causes of arbo-viral diseases (diseases caused by viruses transmitted by arthropods) in order to better understand the epidemiology and ways in which this viruses spread in Israel (166, 167, 168).

Significant reinforcement for the study of arthropods that harm animals came with the establishment of the laboratory of Professor Yuval Gottlieb, of The Koret School of Veterinary Medicine, at the Hebrew University. In the last decade, the laboratory has studied the biology and ecology of arthropods of veterinary importance and blood-sucking arthropods that have the potential to transmit diseases to animals and humans (169) among them, flies, which transmit diseases to cattle, such as lumpy skin disease (170). The research focused mainly on the connection between different arthropods, the symbiotic bacteria they carry and the disease factors they transmit. The dog tick was found to contain an essential bacterium which provided it with B vitamins that are not found in the blood meal and a high incidence of symbiont bacteria was found in the larvae, which are probably essential for the survival of the larval stage of the arthropods under field conditions. In collaboration with Prof. Eyal Klement, Professor Gottlieb is investigating the ecology of disease-carrying flies (171, 172, 173).

Myiasis (development of fly maggots in the tissues of live animals) has attracted the attention of veterinarians in Israel since the beginning of the last century. In 1923 Joseph Dauel (174) warned of the approach of the season of *Hypoderma* flies, described their life cycle and recommended actions to reduce the damage caused by the maggots. Thirty-six years later, Tsur, Hadani and Bar Moshe (175) reported that "the problem of myiasis arose as a result of the development of the beef cattle industry in Israel, even though the phenomenon was already known in the local cattle before."

At a conference of the Association for the Advancement of Science, Aryeh Hadani, Rachel Cwilich and Yehuda Mindel (176) referred to a number of cases of myiasis caused by pre-adult stages of flies of the genera *Wohlfahrtia*, *Chrysomya*, *Lucillia* and *Calliphora*. In the same year, a report was published (177) on a myiasis outbreak caused by larvae of the fly *Wohlfarhtia magnifica* in sheep flocks in the Golan Heights. Skin defects were observed on all parts of the body but, especially in the auricle of the ear. Eighteen years later Hadani *et al.* (178) reported in 1989 myiasis in camels in Sinai caused by *Wohlfahrtia* maggots.

Yeruham *et al.* (179) conducted a three years survey of in 187 herds of dairy cattle and found lice infestations in 145 of them (78%). Among blood-sucking lice, the most common species was the tail louse (*Haematopinus quadripertussus*) and was found in 83% of infected cattle. This louse parasitizes mainly the perineum and around the eyelids throughout the year. The little bleu cattle louse (*Solenopotes capillatus*) was found in 22% of the infected herds, the long-nosed louse (*Linognathus vituli*) – in 3% and the biting louse *Damalinia bovis* was observed mainly in winter in 45% of the infected herds. The short nosed cattle louse (*Haematopinus eurysternus*) was not found in the survey.

In the flea life cycle, only the adult stage was on the host and feeds on its blood. Of all the existing species, the cat flea (*Ctenocephalides felis*) is the most common and infects a large number of mammalian species, including pets, farm animals and humans. Yeruham *et al.* (180) reported mortality caused by severe flea infestation in calves, lambs and goats. According to results of laboratory tests and post-mortem examination death was caused by severe anemia due to blood suction by a large number of fleas.

In 1922, the agriculture instructor Lipshitz referred in an article in the leaflet "The field" (181) to the "external parasites in domestic birds" and noted that the common red tick (probably *Dermanyssus* mite) was the most harmful. A tick that penetrates under the scales of the legs (*Knemidocoptes*), lice, bugs and fleas were also among the parasites that endangered the health of the birds. Two years later the poultry breeding instructor Friedman (182) wrote in the same leaflet "The first condition for success in raising poultry is to keep away from them the insects that attack the birds and suck their blood." Both articles suggested treatments that were available at the time.

Poultry spirochetosis appears to have caused significant damage to poultry farming in the 1920s and has attracted the attention of those involved in this industry. Dan Uri (183) in an article in "The field" discussed the drug treatment of the infection with derivative of Arsenic. He also recommended a treatment for destroying ticks transmitting the spirochetes (probably *Argas persicus*) consisting of a mixture containing three quarters of olive oil and a quarter of petroleum. Fifty nine years later, spirochetosis was also diagnosed in ducks in Israel by Zamberg and Perlstein (184).

Six years after the discovery of *Aegyptianella pullorum* by Carpano, Komarov (185) (who later changed his name to Kimron) isolated the parasite from the soft ticks *Argas persicus* collected in coops in Israel, and thirty-four years later, Hadani and Dinur (186) succeeded in a controlled laboratory experiment to transmit *A. pullorum* from bird to bird using the tick *A. persicus*.

Rosen and Hadani (187) diagnosed infestation with the feather mite of the genus *Ornithonyssus* in the cattle egrets and two years later (188) they reported that the house sparrow was a source of infection of poultry by the northern feather mite (*Ornithonyssus sylviarum*) and the tropical feather mite (*O. bursa*). In 1985 they conducted a survey on mites in 609 wild birds from seven species captured near poultry farms (189) and they found that 39.4% were infested with external parasites. The researchers identified 16 species of *Sarcoptiforme* and six species of *Mesostigmate* including *O. sylviarum* and *O. bursa*. This study demonstrated the central role that wild birds have in the spread of external parasites in poultry.

In 1986, Rosen *et al.* (190, 191) classified the bed bug as a new external parasite of poultry in Israel, based on severe infestations in breeding flocks, mainly in laying nests and cooks. Bugs were also found in the people's homes of the infected farms. This finding showed that 64 years after Lipshitz reported poultry infections with bugs (181) the problem still exists.

The father of the Israeli helminthology Prof.Gideon Witenberg was born in 1895 in Poland. After graduating in veterinary medicine in Russia he specialized for three years in study of parasitic worms with Prof. Konstantin Skryabin who is considered one of the greatest helminthologists of all time. In 1926, Witenberg accepted Prof. Shaul Adler's invitation to move to the Hebrew University of Jerusalem in order to establish a unit for the study of worms in humans and animals. Prof. Wittenberg identified and published for the first time the presence in Israel of a large number of parasitic worm species. In 1934 he published an article entitled "Parasitic Worms of Dogs and Cats in Palestine" (192) with a list of worms he found in dogs and cats. Results of the survey he conducted revealed that one hundred percent of the dogs and ninety percent of the cats examined by him, using fecal samples or post-mortem examinations, were infected with worms. Wittenberg noted that despite the phylogenetic difference between dogs and cats there are a significant number of worms that infect dogs and cats alike. In his opinion, out of 169 species of worms described in the world in these animals at that time, 40 species were found in the Land of Israel, a high figure published in the literature at the time.

In The Hebrew University Prof. Witenberg was followed by Prof. Joseph Hamburger. The contribution from the Tel Aviv University to the veterinary helminthology in Israel came from Professors Jacob Lengi and Daniel Gold and from the Soroka Medical Center - Beer Sheva from the Director of the Parasitology Laboratory, Prof. Joseph El On.

After the establishment of the Department of Parasitology in the Veterinary Institute, Dr. Marius Noiman gained the position of helminthologist in 1951 and was engaged in the diagnosis and research of parasitic worms in animals. After his retirement he was replaced by Dr. Alex Markovics who served until 2016. Currently the position is held by Dr. Daniel Yasur-Landau, a graduate of the Israeli School of Veterinary Medicine who earned a Ph.D. degree in parasitology and degrees of specialist in Tropical Veterinary Medicine and in Veterinary Parasitology.

Intestinal nematodes in sheep and goats, characterized by diarrhea and mortality, which occurred mainly in the autumn months, were recorded already in the first years of the Mandatory rule in the country. The Animal Diseases Ordinance published in 1926, included "Gastric worm disease" in sheep and goats known by the Arab name Jiam (2). Eventually there was a change in the name of the disease and it was called, according to the ordinance from 1945, "gastritis and intestinal worms in the flock" (193). The disease was investigated by Prof. Shimshoni (194) during his activity as a veterinarian for sheep diseases. According to his conclusions, in countries where the winter is cold and the summer is rainy, there is an increase in the secretion of parasitic eggs by the sheep in the spring, known as "spring rise". On the other hand in Israel where the winter is rainy and the summer is hot and dry, which impairs the survival of larvae of worms in the pasture, there is an increase in egg secretions in the fall. The increase originates in fourth degree larvae that were dormant in the gastric and intestinal mucosa during the summer, have completed their development before the rainy season and became mature worms that lay eggs. Inflammation of the stomach and intestines caused by worms in cattle was reported by Savir *et al.* (195) in 1964, in a herd grazing on pasture.

Recently, a number of research studies have been carried out on the effectiveness of medication with tannin-rich browse in goats infected with gastrointestinal nematodes (196).

Lungworms are of significant economic importance for grazing sheep and goats. Most of these worms are dependent on snails as an intermediate host to complete the life cycle and therefore environmental conditions necessary for the survival of the intermediate hosts regulate the amount of larval stages of worms on the pasture. In 1949 Gerichter (197) described three species of lungworms in cats in Israel and three years later he published the development of larvae of sheep lungworms in snails (198). The present Head of the Helminthology laboratory at the Veterinary Institute, Yasur–Landau, and his collaborators (199) from The Veterinary School of the Hebrew University published the first molecular identification of the main lungworm that infects cats and causes severe respiratory disease.

Among the first publications on parasitic worms in this area was an article by Dr. John Wortabet (200) that appeared in the "The Lancet" medical journal in 1881. The author described an outbreak of trichinosis in 257 people in the village El-Khiam. The villagers ate meat of a wild boar and about two weeks later swelling of the face and severe pain in the muscles appeared. Residents who did not eat pork showed no sign of illness. About two and a half years later, another outbreak of trichinosis in the village of Ein Kinia (Golan Heights) was reported by the same author (201) and he noted that he learned from the residents that around the year 1868, a similar outbreak occurred. In 1933 Prof. Witenberg (202) reported in an article in German on the spread of *Trichinella* and *Echinococcus* in Israel and two years later he was followed by Dr. Heiman Morrison (203) who reported trichinosis among Jewish patients admitted to his hospital. Another reference to the *Trichinella* parasites in Israel is found in a thesis for the degree of "Doctor of Medicine" in 1975 by Dr. Margyah (204) in which he described an outbreak of trichinosis in the village of Eilabun in which part of the population was Christian Arabs. In 1984, Blondheim *et al.* (205) reported on six patients from southern Lebanon who came to Israel for treatment after eating meat from a domestic pig farm. Among the other signs of the disease, miscarriages were observed in pregnant women.

According to Dr. Alex Markovics (206) about 1,000 hunted wild boars are tested in Israel every year, with an average *Trichinella* infestation of about 4%, and a higher infestation of 8-10% in the Upper Galilee and the Golan Heights. In addition surveys conducted among foxes and jackals in the Golan Heights and the Upper Galilee showed infestations of about 30% (207).

The esophageal worm *Spirocerca lupi* has at least two hosts: the adult worm residing in dogs and other canines and the larval stages in manure beetles. Although this worm was reported in Israel by Prof. Witenberg (192) in 1934 it attracted little attention until the late 1980s, when it was diagnosed as the cause of several dog deaths. The spreading disease has attracted the attention of a long list of scientists among them Dr. Alex Markovics from the Veterinary Institute, Drs. Gad Baneth, Shimon Harrus, Itamar Aroch, Yuval Gottlieb from The Veterinary School, Prof. Alon Harmelin from the Weizmann Institute of Science and Dr. Eran Dvir from the Tel Hai Academic College. In one of the first publications Harmelin *et al.* (208) described the life cycle of the parasite in nature, from the excretion of eggs in the feces of infected dogs, ingestion and development in manure beetles, ingestion of infected beetles by dogs to worm migration from the dog's stomach through the aorta to the esophageal wall.

Markovics and Medinsky (209) proposed an improved method for detecting *Spirocerca* eggs in the feces of infected dogs. In most cases the worm travels in the walls of the aorta to the walls of the esophagus (thus allowing the secretion of eggs through the dog's digestive tract) but, there may also be an aberration in the migration when the parasite settles in the heart or subcutaneous tissue or reaches the spine (210, 211). In a comprehensive article on spirocercosis, a group of ten researchers from the Hebrew University Veterinary Hospital and the Koret School of Veterinary Medicine referred to the increase in the number of *Spirocerca* infected dogs which attended the hospital each year as well as the disease signs, diagnostic and treatment methods (212).

The head of the Veterinary School Hospital's diagnostic laboratory, Prof. Aroch, and collaborators (213) retrospectively examined *Spirocerca* infections that were diagnosed during five years at the university hospital or were detected in fecal examinations in the parasitology laboratory at the Kimron Veterinary Institute. In their opinion, the signs of the disease were the result of a migratory path of the worm in the dog's body. In the context of the treatment and prevention of spirocercosis, it has been found that periodic injections of the derivatives of the group of macrocyclic lactones (doramectin, ivermectin) did not always prevent worm infection. The results of studies currently underway at the School of Veterinary Medicine and Tel Hai Academic College indicate that *Spirocerca* infection has become endemic in Israel and in addition to the serious disease it causes in dogs it is also involved in cancerous transformation of esophageal defects that turn into osteosarcoma, chondrosarcoma and fibro-sarcoma that have the potential to metastasize (214).

Researchers at the School of Veterinary Medicine have discovered with the help of molecular tests that *Spirocerca* parasites from different geographical areas are not genetically identical. In addition, they compared *Spirocerca* worms of dogs and foxes and found that they were morphologically and genetically different, the worm of foxes belonging to a separate species - *Spirocerca vulpes* (215) that was first defined by them.

The major intermediate host of the *Spirocerca* parasite in Israel was first studied by Yuval Gottlieb and collaborators. A practical recommendation from the study was that this beetle lives mainly on soil with high humidity as a result of frequent watering, while in dry places the chance of infection decreases (216).

Dirofilaria repens a thin worm about 10-15 cm long is located in the subcutaneous tissue of carnivores and humans while pre-adult stages are transmitted by mosquitoes. This worm was found in dogs in a survey conducted by Witenberg in 1934 and 65 years later diagnosed again by Harrus and collaborators (217). As the authors noted in the period between the two diagnoses in dogs, a number of cases of this parasite in humans have been reported in the medical literature in Israel, a fact that proves that there are conditions for its existence in this country. Another species of *Filaria* - *Dioflaria immitis* was reported in the annual reports of the Division of Parasitology in the Kimron Veterinary Institute.

In 1933, Witenberg (202) reported on the presence of the *Echinococcus granulosus* parasite in Israel. For years, echinococcosis has been mentioned in reports on sheep and goat diseases, detected in slaughterhouses and diagnosed in humans. Dr. Rakover, a physician from the Hadassah Hospital in Jerusalem, has published a number of articles on human echinococcosis in Israel (218). In the early years of the State of Israel, a significant portion of the Jewish population diagnosed with echinococcosis became infected in their country of origin but, their numbers have diminished over time (219). In the late 1970s, there was an increase in the incidence of human disease in the north of the country, especially in the town of Yarka situated in the Western Galilee (220). A survey of infections in dogs in the community found 8% of infections in dogs. Ten percent of the sheep slaughtered at the local slaughterhouse had cyst of *Echinococcus*. An explanation for this phenomenon was given by Goldschmidt *et al.* in their article on the onset of echinococcosis in northern Israel (221). In their opinion, the import of infected sheep into the settlement and domestic slaughter (without veterinary supervision) in which animal parts unfit for consumption were thrown to dogs led to a high level of infection in dogs and consequently in humans.

A serological survey was carried out by El-On *et al.* (222) in Tamra a settlement similar to Yarka. Specific *Echynococcus* antibodies were detected in 0.48% in the adult population and 0.57% in children. According to the authors, antibodies in adults may also indicate infections that had occurred long time before the survey, whereas antibodies in children indicate infection that preceded the survey by several years.

The situation in the Bedouin population of the Negev, some of which were engaged in sheep farming, was not significantly different from that in the north of the country. Following an increase in hospitalizations of *Echinococcus* patients in the hospital of the southern city of Beer Sheva, a serological survey was performed to detect antibodies against the infection. The survey revealed positive responses in 0.68% of samples from the Bedouin population (including children) compared with 0.60% of positive samples in the Jewish population, most of whom aged 60 and over (223). A group of researchers from the Beer Sheva Hospital (Soroka Medical Center) and Ben-Gurion University of the Negev analyzed the data related to the results of the survey and the authors concluded that the disease was endemic in the Bedouin population while in the Jewish population the infection occurred before arriving in Israel (224).

El-On and Hoida (225) analyzed the causes of *Echinococcus* infection in the various populations in Israel and concluded that the main cause for sustaining the infection lies in traditional customs. The authors noted the fact that most of the non-Jewish population lives in land houses surrounded by a courtyard with a small corral for sheep and lambs. Uncontrolled slaughter and close contact with dogs, including feeding those with uncooked sheep viscera containing echinococcal cysts contributed to spreading of the parasite.

Molecular methods introduced in Israel about two decades ago (226) have shown higher sensitivity and specificity than searching for worms and eggs in the feces of dogs after giving a laxative (Arecoline) that paralyzes the worms. In addition to the high ability to detect the presence of *Echinococcus* worms in dogs, molecular methods can be used to identify the geographical origin of the parasites.

Man is the only natural final host of *Taenia saginata* and *Taenia solium* and the only source of eggs of these worms.

According to the annual report of the Israeli Veterinary Services *Cysticercus bovis* is occasionally diagnosed during meat inspection of slaughtered cattle. In 1981, following fecal contamination by outside workers of cattle forage in a commercial feedlot, an outbreak of cysticercosis occurred resulting in significant economic damages (227). The eggs of *T. saginata* do not develop in humans and therefore the parasite does not pass from person to person. On the other hand the eggs of *T. solium* may reach various organs in man and develop to a cysticercus-like form. In a nation-wide study, during a period of 14 years, human cysticecosis was reported in nine Israeli travelers who visited various Asian countries (228).

In 1957 the Chief Veterinarian of sheep diseases, Michael Landau (229) described an outbreak in a flock of sheep ewes caused by *Coenurus cerebralis*, a pre-mature stage of the canine tapeworm *Taenia multiceps*. In October 2006, it was reported in the daily press that a four-year-old girl from southern Israel was hospitalized for a "space occupying lesion" in the skull which after surgery was diagnosed by Prof. El-On as a bladder of *C. cerebralis*.

According to the annual reports of the Division of Parasitology, two species of Cestode worms have been diagnosed in the intestines of herbivores whose larval stage develops in rot mites in Israel. In horses, grazing on pasture, the worm *Anoplocephala perfoliata,* which attaches to the passage between the small and large intestine, and in lambs *Moniezia* spp. tapeworms.

At the beginning of the twentieth century a number of articles have been published in Israel on schistosomiasis in humans, a fact that indicates the presence in nature of intermediate hosts of this genus of parasites. Schistosomiasis exists in Israel also in ruminants and Prof. Yaakov Lengi from the Tel-Aviv University studied the life cycle of *Schistosoma bovis* in the intermediate and final hosts of the parasites. In the first publication (230) which extended over 36 pages the author described the development of pre-mature stages in the snail *Bulinus truncatus*. An important finding is that the stage of hatching from the egg (miracidium) caused after penetration into snails, resulted in a mortality rate of 19 to 43 percent of the mollusks. In the second publication (231), Lengi describes the migration of *S. bovis* in the mammalian body. He concluded that infection of sheep through the skin is more effective than through the mouth. In connection with the taxonomic aspects of the various schistosome species infecting humans or animals, in his opinion *S. bovis* was very similar to *Schistosoma haematobium*.

According to Dr. Alex Markovics (232) since the 1950's outbreaks of schistosomiasis in cattle and sheep were diagnosed every five to seven years, of which two outbreaks in 1984 and 1991 caused heavy damage to the infected herds. The use of a test to detect specific antibodies against *S. bovis* allowed a rapid scan of herds in which the parasite was diagnosed and the removal of the infected animals, an action that contributed to a reduction in the sources of infection.

In a field trial treatment of infected sheep with *S. bovis* with a single dose of 20 mg/kg of Praziquantel, a significant decrease in the count of eggs secreted by the treated animals was achieved (233). On the other hand, this treatment was not economically feasible and it preserved the sources of infection in nature. In the second half of 2020 (234), an outbreak of schistosomiasis occurred in a herd of cattle grazing in the Golan Heights, accompanied by diarrhea, thinness and significant mortality. Fecal tests revealed eggs of *S.bovis* and the diagnosis was confirmed by the polymerase chain reaction (PCR).

At the beginning of 1962, a pathological examination of a bovine belonging to a herd of beef cattle grazing near the city of Hedera revealed a large number of liver worms (*Fasciola hepatica*) (235). Periodic tests performed in the herd for about a year revealed eggs of *F. hepatica* in 75% to 80% of the cattle in the herd and a smaller numbers of eggs from two other types of worms - *Schistosoma and Paramphistomum*.

In Israel, *Fasciola gigantica* was diagnosed by the Department of Pathology of the Veterinary Institute in wild ruminants (water buffalos, Ibexes and gazelles) grazing in a reserve near the town of Hedera (236). In the summer of 1970, a herd of about 20 wild buffaloes was transferred from the Hula Lake Reserve to the reserve near Hedera. A dozen of gazelles and three wild goats (*Capra ibex*) were also brought into the reserve. Shortly afterwards two buffaloes died and a large number of *F. gigantica* was found in their liver. In some part of the reserve there was a muddy ground infested by snails of the genera *Lymnaea* and *Bulinus*. Tests of fecal samples collected from the ground in the reserve revealed eggs of *Fasciola gigantica*. A few months later a number of gazelles and one wild goat died from the above parasite. Until now, the *F. gigantica* liver fluke has not spread among cattle in Israel.

Daniel Gold and Yaakov Lengi (237) conducted a research on snails around water pools. They identified four species, two of them, *Lymnaea truncatula* and *Lymnaea auricularia* were found suitable to serve as hosts for the pre-adult stages of *Fasciola hepatica* and *F. gigantica* flukes, respectively.

The genus *Paragonimus* includes flukes that settle in the lungs of fish eaters including humans. In the pre-adult stages they develop in mollusks, crustaceans and fish. In a publication that came out of Prof. Harrus's laboratory (238) a sudden death of a dog caused by *Paragonimus kellicotti* was presented with no early signs of illness. This is the first case in Israel, and the authors believe it may herald the penetration of the parasite into the Middle East.

Stray dogs and cats are deprived of veterinary care and suffer from external parasites and parasitic worms and potentially are a source of infection for domestic animals and humans. Thirty-five years after Witenberg published the results of the worm survey in dogs and cats (192), Lengi and his partners (239) conducted in 1969 a survey in stray dogs and cats in the Tel Aviv district. They found significantly fewer species of worms than were found in the Witenberg's survey but, along with that they still found dogs infected with *Echinococcus granulosus*.

The emergence of diseases, not previously observed in Israel, caused or transmitted by parasites challenges researchers from the academic and government systems. In 1989, we witnessed the penetration of the "Lumpy skin disease", which was observed for the first time in Israel. This disease with an unclear epidemiology is caused by a virus transmitted by flying insects that feed on blood. Cattle were destroyed in a number of farms in order to prevent its spread in Israel, an action that did not prevent two more outbreaks. In 1988 the coccidian parasite *Neospora caninum* was first identified in the United States and within a year it was found to be a very significant cause of abortions in the dairy farms worldwide, including those in Israel, and as expected, Israeli researchers joined efforts in seeking measures to reduce the damages.

Parasitic diseases were a very significant barrier to the improvement of farm animals in Israel and especially the tick fevers, which were a danger to the very existence of the cattle industry. However practical solutions proposed by researchers in the past enabled the importation of improved stock. The Israeli veterinary parasitology that developed further persisted in this trend, became a leader in the study of parasitic disease agents in animals in the geographical area and acquired an international reputation. In recent years, close cooperation in parasitology research has been created between the academic and the government scientists, which has created a powerful arm to deal with present and future parasitic diseases of animals

ACKNOWLEDGMENT

The author thanks all those who assisted in the process of writing this review and especially Mrs. Leah Fish, a former employee of the Department of Parasitology at the Veterinary Institute, Professor Shimon Harrus for reading the review and expressing his opinion, the former chief of the Veterinary services Prof. Arnon Shimshoni and Dr. Avishai Lublin, Director of the Poultry Diseases Division.

Special thanks to Dr. Zalman Greenberg from the Public Health Laboratory of the Ministry of Health in Jerusalem, who collected and sorted 6,571 publications in the field of veterinary and human parasitology, published by Israeli and foreign researchers, from the period before the British Mandate until the 1980's and 1990's of the previous century.

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