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Opening doors: a review of the Protozoa and Insecta taxa published under Wellcome Trust funding at Instituto Evandro Chagas, Belém, Pará State, Brazil

Abrindo portas: uma revisão dos táxons de Protozoa e Insecta publicados, sob o financiamento da Welcome Trust, no Instituto Evandro Chagas, Belém, Pará, Brasil

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ABSTRACT

Wellcome Trust and Instituto Evandro Chagas (IEC) joined research efforts during more than 40 years, and many publications have been made about the scientific contributions with the content of this partnership. The aim of the present historical article is to list the new species of Protozoa and Insecta that were named during the presence of Welcome Trust funding at IEC and to briefly mention how their discovery influenced future research and to show how they relate to present trends in the different areas. The result was a total of 119 new species named in conjunction with their hosts and authors, and five that were transferred (*comb. nov.*); Ralph Lainson authored/co-authored 108, Jeffrey Shaw 60 new species, 56 by Lainson and Shaw, and seven by other colleague authors. Most of the species were discovered in Brazil. The description of these new species has provided a clearer understanding of the taxonomic groups to which they belong and how some are transmitted to man with their resultant pathologies and treatments. And many scientific doors were opened showing the variety of protozoal parasites in Amazonian vertebrates.

Keywords: Protozoa; Parasites; Insecta; Parasite-Host Relation; Taxonomy.

RESUMO

A Wellcome Trust e o Instituto Evandro Chagas (IEC) aliaram esforços pela pesquisa durante mais de 40 anos, e muitas publicações foram feitas sobre as contribuições científicas resultantes dessa parceria. O objetivo deste artigo histórico é listar as novas espécies de Protozoa e Insecta que foram nomeadas durante a presença do financiamento da Wellcome Trust no IEC, e mencionar resumidamente como a descoberta das mesmas influenciou futuras pesquisas e mostrar como se relacionam com as atuais tendências nas diferentes áreas. O resultado foram 119 novas espécies nomeadas juntamente com seus autores e hospedeiros e cinco que foram transferidas (*comb. nov.*); Ralph Lainson foi autor/coautor de 108, Jeffrey Shaw, de 60, Lainson e Shaw, de 56, e outros autores colegas, de sete. A maioria das espécies foram descobertas no Brasil. A descrição dessas novas espécies proporcionou uma compreensão mais clara dos grupos taxonômicos aos quais elas pertencem e como algumas são transmitidas ao homem com suas patologias e tratamentos resultantes. E muitas portas científicas foram abertas, mostrando a variedade de parasitas protozoários nos vertebrados da Amazônia.

Palavras-chave: Protozoa; Parasitos; Insecta; Interações Hospedeiro-Parasita; Taxonomia.

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INTRODUCTION

An article[1] on Wellcome Trust funded research at Instituto Evandro Chagas, in Pará State, Brazil, did not give details of the new organisms that were discovered. A total of 119 new species were named and, due to taxonomic revisions, five species named previously by other authors were transferred (*comb. nov.*) to newly created genera. These taxa are listed in table 1 together with their hosts and authors. The aim of the present article is to briefly mention how their discovery influenced future research and to show how they relate to present trends in the different areas.

Ralph Lainson was supported for the longest period and his contributions were dominant, being an author/co-author of 108 new species and five new combinations. Jeffrey Shaw authored/co-authored 60 new species and two new combinations. One hundred and one of these new species were discovered in Brazil and two names were given to *Leishmania* found in Panama. The descriptions of 13 published individually by Ralph Lainson (10) and Jeffrey Shaw (three) were of material that they had collected while respectively working in Belize and Central America.

SPECIES OF PROTOZOA

PROTOZOA: EUCOCCIDIIDA & MICROSPORIDIA

The taxonomic ranks (family, genus, and subgenus) that were created for some of the species are not listed in table 1 and are as follows: the haemosporidian genus *Saurocytozoon* Lainson & Shaw, 1969[2] ; the haemosporidian family Garnidae Lainson, Landau & Shaw, 1971[3] containing the genera *Garnia* Lainson, Landau & Shaw, 1971, *Fallisia* Lainson, Landau & Shaw, 1974[4], and *Progarnia* Lainson, 1995[5]; two hemogregarine genera *Cyrilia* Lainson, 1981[6] and *Hemolivia* Petit, Landau, Baccam & Lainson, 1990[7]; and the microsporidian genus *Alloglugea* Paperna & Lainson, 1995[8]. A simple question is why were they found? All are from cold-blooded vertebrates and the majority is from lizards. While searching for lizard *Leishmania* that to this date have never been found in the Americas, a wealth of parasites was discovered in different blood cells, opening new research areas. However, besides this, it was obvious that an enormous number of parasites was waiting to be discovered. Thus, any available animal was examined for parasites, irrespective of it being a potential reservoir of a human disease.

Their discoveries stimulated others to look for them around the world. *Garnia* is only known in the Western Hemisphere; *Fallisia* species have been recorded in the Americas, South East Asia, and Australasia; and *Saurocytozoon* occurs in both North and South America and in Asia[9]. Molecular methods are now showing possible evolutionary pathways that reflect the above distributions. The 60 Eimeridae species listed in table 1 were found in either warm or cold blooded vertebrates. A recent paper[10] showed that species of *Cyclospora*, *Eimeria*, and *Isospora* from warm blooded vertebrates form a well-supported clade, but organisms identified as *Eimeria* or *Isospora* species from cold-blooded vertebrates and marsupials do not fall within this group, suggesting that these are polyphyletic genera. For example, based on 18S rRNA sequences[10], two *Eimeria* species, one from a snake and the other from an anuran, were phylogenetically closer to European *Schellackia* species within the family Schellackiidae. These observations clearly indicate that future revisions will be required to resolve the polyphyletic genera.

Six species of *Sarcocystis* were described based on distinctive cyst wall morphology. Except for one, their definitive hosts are unknown. The sexual cycle of *Sarcocystis ameivamastigodryasi* Lainson & Paperna, 2000[11] of the teiid lizard, *Ameiva ameiva* occurs in the intestine of the colubrid snake, *Mastigodryas bifossatus*. The oocysts are like those of *Isospora* species having two sporocysts that contain four sporozoites. In the case of the teiid parasite, the oocyst wall ruptures inside the snake's intestine so mature sporocysts are liberated in the faeces. The cystic stage normally occurs in herbivores and the sexual stage in carnivores ranging from canids, corvid birds to snakes. It is possible that some *Isospora* species could in fact be *Sarcocystis* species.

PROTOZOA: KINETOPLASTIDA

Given the medical importance of *Leishmania* species, it is not surprising that the most well-known taxa and taxonomic rank, established in Belém, Pará State, under Wellcome Trust funding, belong to this genus. The creation of the subgenus *Leishmania* (*Viannia*) Lainson & Shaw, 1987[12] was a fundamental step forward in understanding the disease known as leishmaniasis and its phylogeny. Parasites belonging to this subgenus are only found in the Americas, while those of the subgenus *Leishmania* (*Leishmania*) are found in the Old World and the Americas. Three previously named organisms, *L. braziliensis*, *L. guyanensis*, and *L. peruviana* were assigned to this subgenus and eight other species were described (Table 1). All but two of these belong to the subgenus *L.* (*Viannia*). One of these, *L.* (*L.*) *amazonensis* Lainson & Shaw, 1972[13], grows profusely in culture and readily infects a range of laboratory animals, producing in hamsters a pathology like diffuse cutaneous leishmaniasis. Because of these attributes this parasite is used extensively in immunological and chemotherapeutic studies. Molecular methods[14] have shown that the subgenus *L.* (*Viannia*) separated from the basal stock some 80 MYA while the subgenus *L.* (*Leishmania*) separation was later being around 50 MYA. There are distinct differences between the immunological response and pathology of the two subgenera in man. Somewhere along the evolutionary line, the subgenus *L.* (*Leishmania*) seems to have opted to depress the cell mediated response, while the subgenus *L.* (*Viannia*) opted to stimulate it. Perhaps this was due to the very different mammalian hosts in which the two subgenera evolved, one possible being rodents and the other Xenarthra. Today we see this reflected in the extreme immunological differences between diffuse cutaneous leishmaniasis caused by *L.* (*L.*) *amazonensis* and mucocutaneous by *L.* (*V.*) *braziliensis*[15].

Table 1 – Taxa described under funding of the Wellcome Trust by Ralph Lainson, Jeffrey Shaw and their colleagues while working at the Instituto Evandro Chagas, Belém, Pará, Brazil

Protozoa	**Host**
Eucoccidiida: Haemosporida: Plasmodiidae	
Plasmodium vacuolatum Lainson, Shaw & Landau, 1975	Lizard
Plasmodium neusticuri Lainson & Paperna, 1996	Lizard
Plasmodium kentropyxi Lainson, Landau & Paperna, 2001	Lizard
Plasmodium carmelinoi Lainson, Franco & Matta, 2010	Lizard
Eucoccidiida: Haemosporida: Leucocytozoidae	
Saurocytozoan tupinambi Lainson & Shaw, 1969	Lizard
Saurocytozoan mabuyi Lainson, Landau & Shaw, 1974	Lizard
Eucoccidiida: Haemosporida: Haemoproteidae	
Polychromophilus deanei Garnham, Lainson & Shaw, 1971	Bat
Haemoproteus peltocephali Lainson & Naiff, 1998	Lizard
Haemoproteus geochelonis Lainson & Naiff, 1998	Lizard
Eucoccidiida: Haemosporida: Garniidae	
Garnia gonatodi (Telford, 1970) Lainson, Landau & Shaw, 197l, comb. nov.	Lizard
Garnia telfordi Lainson, Landau & Shaw, 1971	Lizard
Garnia utingensis Lainson, Landau & Shaw, 1971	Lizard
Garnia multiformis Lainson, Shaw & Landau, 1975	Lizard
Garnia uranoscodoni Lainson, Shaw & Landau, 1975	Lizard
Garnia morula (Telford, 1970) Lainson, Landau & Shaw, 1971, comb. nov.	Lizard
Garnia karyolytica Lainson & Naiff, 1999	Lizard
Fallisia effusa Lainson, Landau & Shaw, 1974	Lizard
Fallisia modesta Lainson, Landau & Shaw, 1974	Lizard
Fallisia audaciosa Lainson, Shaw & Landau, 1975	Lizard
Fallisia simplex Lainson, Shaw & Landau, 1975	Lizard
Progarnia archosauriae Lainson, 1995	Lizard
Eucoccidiida: Adeleina: Haemogregarinidae	
Cyrilia lignieresi (Laveran, 1906) Lainson, l992, comb. nov. (Syns *Haemogregarina lignieresi* Laveran, 1906; *H. gomesi* Neiva & Pinto, 1926; *Cyrilia gomesi* Lainson, 1981)	Fish
Hemolivia stellata Petit, Landau, Baccam & Lainson, 1990	Anuran
Eucoccidiida: Eimeriina: Lankesterellidae	
Lankesterella petiti Lainson & Paperna, 1995	Anuran
Eucoccidiida: Eimeriina: Schellackiidae	
Schellackia landauae Lainson, Shaw & Ward, 1976	Lizard
Eucoccidiida: Eimeriina: Eimeridae	
Tyzzeria boae Lainson & Paperna, 1994	Snake
Cyclospora niniae Lainson, 1965	Snake
Cyclospora schneideri Lainson, 2005	Snake
Caryospora pseustesi Lainson, Nascimento & Shaw, 1991	Snake
Caryospora micruri Lainson, Nascimento & Shaw, 1991	Snake
Caryospora constanciae Lainson, Nascimento & Shaw, 1991	Snake
Caryospora paraensis Lainson, Nascimento & Shaw, 1991	Snake
Caryospora carajasensis Lainson, Nascimento & Shaw, 1991	Snake
Caryospora epicratesi Lainson, Nascimento & Shaw, 1991	Snake
Isospora albicolis Lainson & Shaw, 1989	Bird
Isospora wilkiei Lainson, 1968	Crocodile
Isospora basilisci Lainson, 1968	Lizard
Isospora tucuruiensis Lainson & Shaw, 1989	Bird

(continued)

Table 1 – Taxa described under funding of the Wellcome Trust by Ralph Lainson, Jeffrey Shaw and their colleagues while working at the Instituto Evandro Chagas, Belém, Pará, Brazil

Protozoa	**Host**
Isospora saimiri Lainson & Shaw, 1989	Mammal
Isospora cacici Lainson, 1994	Bird
Isospora thraupis Lainson, 1994	Bird
Isospora capanemaensis Lainson, 2003	Mammal
Isospora rodriguesae Lainson, Da Silva, Franco & De Souza, 2008	Chelonia
Eimeria orthogeomyos Lainson, 1968	Mammal
Eimeria tamanduae Lainson, 1968	Mammal
Eimeria rhynchonycteridis Lainson, 1968	Mammal
Eimeria pseudemydis Lainson, 1968	Turtle
Eimeria bothrops Lainson, 1968	Snake
Eimeria ameivae Lainson, 1968	Lizard
Eimeria crocodyli Lainson, 1968	Crocodile
Eimeria poti Lainson, 1968	Mammal
Eimeria micruri Lainson & Shaw, 1973	Snake
Eimeria liophi Lainson & Shaw, 1973	Snake
Eimeria leimadophi Lainson & Shaw, 1973	Snake
Eimeria cyclopei Lainson & Shaw, 1982	Mammal
Eimeria choloepi Lainson & Shaw, 1982	Mammal
Eimeria trichechi Lainson, Naiff, Best & Shaw, 1983	Mammal
Eimeria philanderi Lainson & Shaw, 1989	Mammal
Eimeria caluromydis Lainson & Shaw, 1989	Mammal
Eimeria vitellini Lainson, Costa & Shaw, 1990	Bird
Eimeria corticulata Lainson & Shaw, 1990	Mammal
Eimeria zygodontomyis Lainson & Shaw, 1990	Mammal
Eimeria lagunculata Lainson, Costa & Shaw, 1990	Chelonia
Eimeria mammiformis Lainson, Costa & Shaw, 1990	Chelonia
Eimeria podocnemis Lainson, Costa & Shaw, 1990	Chelonia
Eimeria carinii Lainson, Costa & Shaw, 1990	Chelonia
Eimeria marajoensis Lainson & Shaw, 1991	Mammal
Eimeria porphyrulae Lainson, 1994	Bird
Eimeria crypturelli Lainson, 1994	Bird
Eimeria bufomarini Paperna & Lainson, 1995	Anuran
Eimeria peltocephali Lainson & Naiff, 1998	Turtle
Eimeria molossi Lainson & Naiff, 1998	Bat
Eimeria bragancaensis Lainson & Naiff, 2000	Bat
Eimeria carmelinoi Lainson, 2002	Lizard
Eimeria damnosa Lainson, Brigido & Silveira, 2005	Mammal
Eimeria lepidosirenis Lainson & Ribeiro, 2006	Fish
Eimeria amazonensis Lainson, Da Silva, Franco & De Souza, 2008	Chelonia
Eimeria carbonaria Lainson, Da Silva, Franco, & De Souza, 2008	Chelonia
Eimeria carajasensis Lainson, Da Silva, Franco & De Souza, 2008	Chelonia
Eimeria wellcomei Lainson, Da Silva, Franco & De Souza, 2008	Chelonia
Acroeimeria paraensis Lainson, 2002	Lizard
Acroeimeria cnemidophori (Carini, 1941) Lainson, 2002, comb. nov.	Mammal
Choleoeimeria rochalima (Carini & Pinto, 1926) Lainson & Paperna, 1999, comb. nov.	Lizard
Choleoeimeria carinii Lainson & Paperna, 1999	Lizard
Choleoeimeria amphisbaenae Lainson, 2003	Lizard
Eucoccidiida: Eimeriina: Sarcocystidae	
Sarcocystis kinosterni Lainson & Shaw, 1972	Mammal
Sarcocystis azevedoi Shaw & Lainson, 1969	Mammal
Sarcocystis marmosae Shaw & Lainson, 1969	Mammal
Sarcocystis oryzomyos Shaw & Lainson, 1969	Mammal
Sarcocystis proechimyos Shaw & Lainson 1969	Mammal
Sarcocystis ameivamastigodryasi Lainson & Paperna, 2000	Lizard/Snake

(continued)

Table 1 – Taxa described under funding of the Wellcome Trust by Ralph Lainson, Jeffrey Shaw and their colleagues while working at the Instituto Evandro Chagas, Belém, Pará, Brazil

Protozoa	**Host**
Piroplasmida: Theileriidae	
Theileria electrophori Lainson, 2007	Fish
Microspora: Glugeidae	
Alloglugea bufonis Paperna & Lainson, 1995	Anuran
Kinetoplastida: Trypanosomatidae	
Endotrypanum monterogeii Shaw, 1969	Mammal
Leishmania (Leishmania) amazonensis Lainson & Shaw, 1972	Mammal*
Leishmania (Viannia) panamensis Lainson & Shaw, 1972	Mammal*
Leishmania (Leishmania) aristidesi Lainson & Shaw, 1979	Mammal
Leishmania (Viannia) lainsoni Silveira, Shaw, Braga & Ishikawa, 1987	Mammal*
Leishmania (Viannia) naiffi Lainson & Shaw, 1989	Mammal*
Leishmania (Viannia) shawi Lainson, Braga, de Souza, Póvoa & Ishikawa, 1989	Mammal*
Leishmania (Viannia) lindenbergi Silveira, Ishikawa, de Souza & Lainson, 2002	Mammal*
Leishmania (Viannia) utingensis Braga, Lainson, Ishikawa & Shaw, 2003	Mammal
Porcisia deanei (Lainson & Shaw, 1977) Espinosa et al., 2018	Mammal
Trypanosoma leuwenhoeki Shaw, 1969	Mammal
Trypanosoma preguici Shaw, 1969	Mammal
Trypanosoma plicae Lainson, Shaw & Landau, 1975	Lizard
Trypanosoma cecili Lainson, 1977	Crocodile
Trypanosoma (Megatrypanum) saloboense Lainson, Da Silva & Franco, 2008	Mammal
Insecta	
Diptera: Psychodidae: Phlebotominae	
Bruptomyia orlandoi Fraiha, Shaw & Lainson, 1970	
Psychodopygus wellcomei Fraiha, Shaw & Lainson, 1971†	
Psychodopygus lainsoni Fraiha & Ward, 1974	
Nyssomyia umbratilis (Ward & Fraiha, 1977) Galati, 2003‡	
Psychodopygus llanosmartinsi Fraiha & Ward, 1980†	
Nyssomyia shawi (Fraiha, Ward & Ready, 1981) Galati, 2003†	
Nyssomyia richardwardi (Ready & Fraiha, 1981) Galati, 2003	
Trichopygomyia ratcliffei (Arias, Ready & Freitas, 1983) Galati, 2003	
Psychodopygus leonidasdeanei Fraiha, Ryan, Ward, Lainson & Shaw, 1986	
Evandromyia carmelinoi (Ryan, Fraiha, Lainson & Shaw, 1986) Galati, 2003	
Trichopygomyia readyi (Ryan, 1986) Galati, 2003	

* Infections found in man; † Found infected with *Leishmania* (*Viannia*) *braziliensis*; ‡ Found infected with *Leishmania* (*Viannia*) *guyanensis*. (end)

Leishmania hertigi deanei Lainson & Shaw 1977[16], later raised to specific status by Lainson and Shaw[12] in 1987, is very different from all other *Leishmania*. The amastigotes are very large and do not appear to be intracellular. Latterly studies have shown that it is phylogenetically outside the genus *Leishmania* being closer to *Endotrypanum*. This led to the creation of the genus *Porcisia* Shaw, Camargo & Teixeira 2016[17] to accommodate it and the Panamanian porcupine parasite, *P. hertigi*.

Great advances in our understanding of the taxonomy of *Trypanosoma* (*Schizotrypanum*) *cruzi* were made by Miles et al.[18] while working at the Instituto Evandro Chagas that confirmed three genetically distinct lineages that were denoted as Type I, II & III. In the opinion of the author these represent distinct species but have never been named so they do not appear in table 1. Subsequently these lineages have been shown to be distinct by with different molecular markers.

SPECIES OF INSECTS

INSECTA: DIPTERA: PSYCHODIDAE: PHLEBOTOMINAE

Unravelling the epidemiologies of the different *Leishmania* species inevitable led to the discovery of new phlebotomine species. It also showed how the epidemiological importance of different groups varies in different biomes. The discovery of *Psychodopygus wellcomei* Fraiha, Shaw & Lainson 1971[19] was the first indication of the vectorial importance of this genus for *L.* (*Viannia*) species in Amazonia. Six *Psychodopygus* species are associated with *L.* (*V.*) *braziliensis* and five with *L.* (*V.*) *naiffi*[20]. It is the predominant genus in south of the Amazon River extending to virgin Atlantic rain forest. In north of the river, *L.* (*V.*) *guyanensis,* transmitted by *N. umbratilis*, is the dominant leishmania in man. The number of *Nyssomyia* sand flies is significantly greater in this biome, but there is no significant difference in the variety of species of *Nyssomyia* and *Psychodopygus*[21].

Continuous environmental variations related to global warming and man's activities modulate the sand fly fauna. Understanding and documenting this is the challenge.

CONCLUSION

Unforeseen benefits have resulted from the description of the species that form the subject of this paper. They range from a clearer understanding of the taxonomic groups to which they belong to how some are transmitted to man with resultant contrasting pathologies and treatments. For example, in 1965 it was accepted that *Leishmania braziliensis* was the etiological agent of all forms of cutaneous leishmaniasis in Brazil. Studies of the parasites from wild animals, man and sand flies showed that this was wrong. Many scientific doors were opened, giving just a glimpse to the amazing variety of protozoal parasites that occur in Amazonian vertebrates.

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