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

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.
INTRODUCTION

An article1 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: EUCCOCCIIDA & 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, 19692; the haemosporidian family Garnidae Lainson, Landau & Shaw, 19713 containing the genera Garnia Lainson, Landau & Shaw, 1971, Fallisia Lainson, Landau & Shaw, 19744; and Pragarnia Lainson, 19955; two hemogregarine genera Cyrilia Lainson, 19816 and Hemolivia Petit, Landau, Baccam & Lainson, 19907; and the microsporidian genus Alloglugea Paperna & Lainson, 19958. 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 Asia9. 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 paper10 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 sequences10, two Eimeria species, one from a snake and the other from an anuran, were phylogenetically closer to European Schellackiidae 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 ameivamastigodyrasi Lainson & Paperna, 200011 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, 198712 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, 197213, 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 methods14 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.) braziliensis15.
### 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 neustici Lainson & Paperna, 1996* | Lizard        |
| *Plasmodium kerthopxy* Lainson, Landau & Paperna, 2001 | Lizard        |
| *Plasmodium carmelina* Lainson, Franco & Matta, 2010 | Lizard        |
| Eucoccidiida: Haemosporida: Leucocytozoidae |               |
| *Saurocytozoan tupinambi* Lainson & Shaw, 1969 | Lizard        |
| *Saurocytozoan mbayui* Lainson, Landau & Shaw, 1974 | Lizard        |
| Eucoccidiida: Haemosporida: Haemoproteidae |               |
| *Polychromophilus deanei* Garnham, Lainson & Shaw, 1971 | Bat           |
| *Haemoproteus peltcephali* Lainson & Naiff, 1998 | Lizard        |
| *Haemoproteus geochelonis* Lainson & Naiff, 1998 | Lizard        |
| Eucoccidiida: Haemosporida: Garniidae |               |
| *Garnia gonatodi* (Telford, 1970) Lainson, Landau & Shaw, 1971, 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 uranoscadani* 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        |
| *Pragaria archosauriae* Lainson, 1995 | Lizard        |
| Eucoccidiida: Adeleina: Haemogregarinidae |               |
| *Cyrilia lignieresi* (Laveran, 1906) Lainson, 1992, comb. nov. | Fish          |
| (Syns Haemogregarina lignieresi Laveran, 1906; H. gomesi Neiva & Pinto, 1926; Cyrilia gomesi Lainson, 1981) | Fish          |
| *Hemolivia stellata* Petit, Landau, Baccam & Lainson, 1990 | Anuran        |
| Eucoccidiida: Eimerinida: Lankesterellidae |               |
| *Lankesterella petitii* Lainson & Paperna, 1995 | Anuran        |
| Eucoccidiida: Eimerinida: Schellackiidae |               |
| *Schellackia landauae* Lainson, Shaw & Ward, 1976 | Lizard        |
| Eucoccidiida: Eimerinida: Eimeridae |               |
| *Tyzzeria booe* Lainson & Paperna, 1994 | Snake         |
| *Cyclospora niniae* Lainson, 1965 | Snake         |
| *Cyclospora schneideri* Lainson, 2005 | Snake         |
| *Caryospora pseudes Lainson, Nascimento & Shaw, 1991* | Snake         |
| *Caryospora micrini Lainson, Nascimento & Shaw, 1991* | Snake         |
| *Caryospora constancia Lainson, Nascimento & Shaw, 1991* | Snake         |
| *Caryospora paraensis* Lainson, Nascimento & Shaw, 1991 | Snake         |
| *Caryospora caramajagenis* 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 luscruiniensis* 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 caci Lainson, 1994                   | Bird          |
| Isospora thraupis Lainson, 1994               | Bird          |
| Isospora caponemaensis Lainson, 2003          | Mammal        |
| Isospora rodiguesae Lainson, Da Silva, Franco & De Souza, 2008 | Chelonia |
| Eimeria orthogeomyos Lainson, 1968            | Mammal        |
| Eimeria tamanandae Lainson, 1968              | Mammal        |
| Eimeria rhynchonycteridis Lainson, 1968       | Mammal        |
| Eimeria pseudemydis Lainson, 1968             | Turtle        |
| Eimeria bathrops 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 cholaepi Lainson & Shaw, 1982         | Mammal        |
| Eimeria tricheci 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 marajoenensis Lainson & Shaw, 1991    | Mammal        |
| Eimeria porphyrae 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 bragancoensis Lainson & Naiff, 2000   | Bat           |
| Eimeria carmelinae Lainson, 2002              | Lizard        |
| Eimeria damnosa Lainson, Brigida & Silveira, 2005 | Mammal        |
| Eimeria lepidoisrenis 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 cniobaphora (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 amphisboenae Lainson, 2003      | Lizard        |

Eucoccidiida: Eimeriina: Sarcocystidae

| Sarcocystis kinasteni Lainson & Shaw, 1972 | Mammal |
| Sarcocystis azevedai Shaw & Lainson, 1969  | Mammal |
| Sarcocystis mammacae Shaw & Lainson, 1969  | Mammal |
| Sarcocystis oryzomyos Shaw & Lainson, 1969 | Mammal |
| Sarcocystis proechimyos Shaw & Lainson 1969 | Mammal |
| Sarcocystis ameivamastigodyasi 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 monterogei* 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 plicae* Lainson, Shaw & Landau, 1975 | Mammal                |
| *Trypanosoma cecili* Lainson, 1977            | Lizard                |
| *Trypanosoma (Megatrypanum) saloboense* Lainson, Da Silva & Franco, 2008 | Mammal                |

| Insecta                                       |                       |
|-----------------------------------------------|-----------------------|
| Diptera: Psychodidae: Phlebotominae           |                       |
| *Brumptomyia orlandoi* Fraiha, Shaw & Lainson, 1970 |                       |
| *Psychodapygus wellcomei* Fraiha, Shaw & Lainson, 1971* |                       |
| *Psychodapygus laisani* Fraiha & Ward, 1974   |                       |
| *Nyssomyia umbratilis* (Ward & Fraiha, 1977) Galati, 2003|                       |
| *Psychodapygus llanosmartinsi* Fraiha & Ward, 1980* |                       |
| *Nyssomyia shawi* (Fraiha, Ward & Ready, 1981) Galati, 2003|                       |
| *Nyssomyia richardwari* (Ready & Fraiha, 1981) Galati, 2003 |                       |
| *Trichopygomyia ratcliffei* Arias, Ready & Freitas, 1983) Galati, 2003 |                       |
| *Psychodapygus 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.

Leishmania hertigi deanei Lainson & Shaw 197716, later raised to specific status by Lainson and Shaw12 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 201617 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 *Psychodapygus wellcomei* Fraiha, Shaw & Lainson 197119 was the first indication of the vectorial importance of this genus for *L. (Viannia)* species in Amazonia. Six *Psychodapygus* species are associated with *L. (V.)* *braziliensis* and five with *L. (V.)* naiffi20. 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 *Psychodapygus*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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