The intestinal trichostrongyloid nematode of mice, Heligmosomoides polygyrus bakeri, is often referred to as Nematospiroides dubius. Here, Jerzy Behnke, Anne Keymer and John Lewis ask the question: which is correct?

To most biologists the use of Latin names to distinguish animals has a clear and very obvious purpose: the elimination of any possible ambiguities arising from the use of common names. However, the choice of Latin names is dependent on taxonomic criteria which, for the most part, are still based on morphological distinguishing features and which may change when new information becomes available. Occasionally taxonomic controversies touch parasitic species of widespread interest, causing confusion in the associated literature as two or more names are used to describe the same organism. Already for those of us who teach the immunochemistry of filarial worm infections, the taxonomic revision of Dipetalonema viteae to Acanthocheilonema viteae causes headaches we could have done without.

A debate of more serious proportions concerns the intestinal trichostrongyloid nematode of mice, Heligmosomoides polygyrus (or Nematospiroides dubius?). Even in the past year papers have been published which refer to the parasite by one of the two names without recognition of the alternative. The confusion has been exacerbated by the identification of D. viteae from Apodemus sylvaticus; Microtus agrestis (which is now known not to be susceptible to the species/strain derived from Apodemus sylvaticus) and it is thus possible that the two Heligmosomoides polygyrus were originally coined for quite different species of worm to that parasitizing Apodemus sylvaticus; Microtus spp. in Europe are affected by many species of Heligmosomoides and Heligmosomoides, all of which are superficially similar and can only be distinguished by detailed morphometric analysis.

Indeed, Durette-Desset considered Bouleguer's parasite (Strongylus laeviceae from Microtus agrestis) to be equivalent to Heligmosomoides laeviceae, since revised to Heligmosomoides laeviceae. In 1926 Baylis reported a parasite recovered from Apodemus sylvaticus in Oxford. He believed this worm to differ from that described by Bouleguer and, because of the incomplete earlier descriptions, he named his parasite Nematospiroides dubius to avoid any further confusion! However, the story is further complicated by the description of a very similar worm from Apodemus sylvaticus and Mus musculus in the USSR by Schulz 12, which he named Heligmosomoides skrjabini. Baylis corresponded with Schulz and, after examining his specimens, published an article confirming that the two were indeed the same parasite, admitting that its features were consistent with those of the genus Heligmosomoides but insisting that Nematospiroides dubius had priority because his paper was published on the first day of November and Schulz's not until later the same month.

In the following four decades the parasite changed names several times and considerable confusion was generated as to whether there was just one species common to field mice, house mice and voles, or whether several closely related species infected overlapping ranges of hosts. Moreover, the names Heligmosomoides, Nematospiroides and Heligmosomum (Railliet et Henry 1909) were abolished and reinstated in turn.

In 1968 the genus Heligmosomoides was re-established by Durette-Desset who distinguished Heligmosomoides from Heligmosomum on the basis that only the latter had oblique cuticular ridges on the dorsal side. In 1972 Durette-Desset and co-workers discussed Heligmosomoides polygyrus (synonym: Nematospiroides dubius?) as the principal parasite of Apodemus sylvaticus. More recently Asakawa published a comprehensive review of the genus Heligmosomoides and Heligmosomum. In the meantime British authors continued to use Nematospiroides dubius to describe the parasite infecting Apodemus sylvaticus in the UK.

Subspecies of Heligmosomoides polygyrus

The controversy would probably have disappeared in the scientific archives were it not for the isolation and successful maintenance in laboratory mice of a parasite conforming to the description of Heligmosomoides polygyrus. The life cycle is readily maintained in the laboratory and adult worms are long lived (eight months so that frequent passage is not necessary. Moreover, since the infective larvae can be kept in aqueous suspension at 4°C for many months, a single culture can provide thousands of larvae for months of subsequent research. All these attributes have led to the parasite being adopted as a popular laboratory model of intestinal trichostrongyloid infection and a vast literature has grown around the worm. Unfortunately, laboratory workers confused by the continuing taxonomic revisions of the wild parasites have continued to use Nematospiroides dubius, Heligmosomoides polygyrus or both.

The first reported laboratory study was by Spurlock who used larvae raised from wild Mus musculus caught on the Conway Ranch near Woodland, California. However, the present widely employed laboratory strain was originally isolated by Ehrenford in 1950 from Peromyscus maniculatus caught near Woodland. Forrester later called this isolate strain 50 (Refs 23,24). Spurlock provided larvae of this strain for various laboratories including the Wellcome Foundation in London, from where the parasite was distributed further. Interestingly, Ehrenford referred to this para-
perornyscus maniculatus

apparent from subsequent work that

whole body irradiation or transplanted
gyrus bakeri

from five localities in northern California
host for the parasite in question.

similar to the other subspecies in most
adult worms 24 although susceptibil~ was
enhanced following treatment with
from the strain normally infecting Mus

Forrester 23 examined 231 ~ndividuals

laboratory infe~on, even when given

d). Scale bars = 20μm (a and b) and 100μm (c and d).

Fig. 1. Scanning electron micrographs comparing the anterior (a and b) and the midbody cuticle (c and d) of Heligmosomoides polygyrus polygyrus (a and c) and Heligmosomoides polygyrus bakeri (b and d). H. p. polygyrus (c) has fewer cuticular ridges than does H. p. bakeri (d) but the cephalic ridges are more prominent (a versus b). Scale bars = 20μm (a and b) and 100μm (c and d).

site as Nematospirodes dubius. It became
apparent from subsequent work that
Peromyscus maniculatus is an incidental
host for the parasite in question. Forrester 23
examined 231 individuals from five localities in northern California
and found no worms. In addition, Pero-
myrus maniculatus was refractory to
laboratory infection, even when given
whole body irradiation or transplanted
adult worms; 24 although susceptibility was
enhanced following treatment with
prednisolone. 25 It is thus very likely that
Ehrenford established the most widely
used strain of the parasite from an ab-
normal host and that the parasite was from
the strain normally infecting Mus
musculus in the USA. This strain (Strain 50)
has been named Heligmosomoides poly-
gyrus bakeri (Fig. 1 and Ref. 14).

American voles Phenacomys inter-
medius and Phenacomys ungava are also
infected by a very similar parasite, now
called Heligmosomoides polygyrus ame-
ricanus 14 which can be distinguished from
Heligmosomoides polygyrus bakeri by the
difference in the arrangement of the
dorsal ray and in the number of cuticular
ridges and longer spicules. 14 Although
similar to the other subspecies in most
other morphological respects, Heligmoso-
omoides polygyrus americanus was con-
sidered by Rausch and Rausch 26 to be a
different species because it infects Pheno-
comys intermedius throughout the geo-
ographical range of this host, even host
populations which have been isolated for
some time. Heligmosomoides polygyrus
americanus is therefore unlikely to
have adapted to Phenacomys intermedius
in recent historic times as suggested by
Durette-Desset and colleagues 14. Asakawa 11
considers Heligmosomoides polygyrus
americanus to be a distant rela-
tive, more closely related to Heligmo-
smoides johnsoni and Heligmosomoides
hudsoni, which parasitizes the American
rodents Phenacomys and Dicrostonyx,
respectively. Two other subspecies of
Heligmosomoides polygyrus have also been
recognized. The name Heligmosomoides
polygyrus polygyrus has been ascribed to
the normal parasite of Apodemus sylvaticus
in Europe and Heligmosomoides polygyrus
corsicus to similar worms from Mus
domesticus in Corsica 8. In this classifi-
cation, Heligmosomoides polygyrus poly-
gyrus is the original parasite described by
Bailis 7 as Nematospirodes dubius. 7

British Species and Their Hosts

In the UK, the field mouse, Apodemus
sylvaticus, is almost invariably parasitized by
Heligmosomoides polygyrus polygyrus
and, in some surveys, all of the animals
studied have been reported to carry
worms. 6 The parasite is still variously
referred to as Nematospirodes
dubius, 15, 16, 19, 28 or Heligmosomoides poly-
gyrus, 27, 29 but British authors have given
little attention to the possibility of there
being other closely related species in the
UK, particularly in voles. 15, 17, 28 Recently,
Quinell and colleagues 7 tried to infect
both Clethrionomys glareolus and Microtus
ogrestis with the laboratory mouse main-
tained strain (Heligmosomoides polygyrus
bakeri) and with recent isolates of Helig-
mosomoides polygyrus polygyrus from
Apodemus sylvaticus. No adult worms
were recovered from any of the voles and
eggs were detected in the faeces on only
one occasion when the voles had been
with the immunosuppressive
agent cortisone. Even in this case faecal
examinations were negative from day 14
onwards. Therefore, it appears likely that
reports of Heligmosomoides polygyrus
from voles in the UK may be misidentifi-
cations. 15, 17 Through the most promising can-
didate is Heligmosomoides glareoli, originally
described by Baylis 10 from Cleithro-
omys glareolus in Oxford. Heligmosomoides
glareoli has been recorded from Cleth-
ronomys glareolus in France 11 but European
voles are affected additionally by species
whose taxonomy is still not totally re-
olved 15, 17, 29 and which also need to be
considered.

Conclusions

These confusions would probably have
gone unnoticed were it not for the fact
that the worm is an extremely popular
laboratory model. It is a continuing source
of irritation that there is still no consensus
as to what the parasite should be called, at
least as adjudged by the reports from
experimental parasitologists. It is clear
from the confusion surrounding the orig-
inal descriptions that it is possible to argue
ad nauseam in favour of any of the names
proposed. It is our view that the seminal
taxonomic position of the other
Heligmosomoides spp still poses unresolved questions. It is likely that a species
complex exists without clear dividing lines
between some of the organisms involved. Durette-Desset and colleagues 14 sug-
gested that the parasites subspecies in recent historic times (see also
Asakawa 11, 12). If this was indeed the case, the whole genus is probably subject to
intensive selection pressure imposed by
the various hosts and their ecology. In view of
the complex taxonomy of this group of nematodes, few of the field reports can be
taken at face value.
As far as British rodents are concerned, the relationships of parasites in voles, field mice and house mice need to be reconsidered in the light of detailed descriptions of American and European species. Although the Heligmosomoides and Heligmosomum species affecting voles in Europe are distinct, there is still work to be completed on the species affecting voles in the UK. It is time that the common species, subspecies and strains were isolated and subjected to isoenzyme and DNA sequence analysis to establish accurately their phylogenetic relationships.

Acknowledgements

We thank the various groups of students who participated in departmental field courses and whose curiosity provided the motivation for the preparation of this article. Rupert Quinney, John Kinella and Donald Forrester revised the manuscript and we are grateful for their suggestions and advice. We also thank Anton Page for help with electron microscopy.

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Critical Stages in the Development of Plasmodium in Mosquitoes

A. Warburg and L.H. Miller

One tool for the control of malaria that may become available to future generations of public health workers is the introduction of genes into the Anopheline vector populations that will render the mosquitoes refractory to Plasmodium. Insights from basic research that could transform this idea into a technical reality are presently lacking. In this review, Alan Warburg and Louis Miller focus on one crucial area of research: the identification of potentially vulnerable points in the developmental cycle of Plasmodium in mosquitoes.

It may be argued that, due to selective pressure, Plasmodium sp. would overcome any barrier genetically engineered into vector mosquitoes. However, the adaptive versatility of malaria parasites is not limitless. For example, mammalian malarias are transmitted by Anopheline mosquitoes, and avian malarias by Culicine mosquitoes. After persistent mutual exposure, why have mammalian malarias transmitted by Anopheline mosquitoes, and avian malarias by Culicine mosquitoes? Recent evidence suggests that P. falciparum, a major human malaria parasite, is phylogenetically closer to avian Plasmodium sp than to other human or primate malarias. It seems likely that an avian malaria parasite, at some point in the past, made the transition from bird to human. Why have Culicine mosquitoes lost their ability to transmit P. falciparum? It would appear that a fundamental difference exists between Anopheline and Culicine mosquitoes that restricts their vectorial capacity to mammalian and avian parasites, respectively (Table 1).

The successful completion of the sporogonic development of malarias in the midgut, haemocoel and salivary glands of the mosquito vectors depends on their ability to overcome a series of barriers. In the midgut, gametocytes transform into gametes that fertilize to produce motile zygotes or ookinetes. Ookinetes then cross the peritrophic membrane, a process probably made possible by specific recognition and penetration mechanisms. Attachment to the midgut epithelium and passage through it may also depend on receptor-mediated recognition and invasion. Survival of oocysts in the mosquito haemocoel is made possible by their ability to evade haemolymph-mediated immune reactions and the availability of essential nutritive factors. Sporozoites released into the haemocoel must locate, recognize and penetrate the salivary glands. They survive within the acinar cells of the glands from where they exit into the salivary duct and are injected with the saliva into the vertebrate host during subsequent feedings.

Development in the Midgut

Gametogenesis is triggered by slightly alkaline conditions (pH ~8.0) and a reduction in temperature from that of the vertebrate host. A mosquito-derived molecule stimulates exflagellation and, at least in some mosquito species, digestive enzyme activity may influence the ability of oocyttes to penetrate the gut wall. Other than that, very little definitive information exists about the possible role of extrinsic factors in the development of gametes and oocyttes in the lumen of the midgut. However, these developmental stages have been the focus of intensive efforts to develop transmission-blocking vaccines. Such vaccines stimulate the production of antibodies that recognize surface antigens on gametes and


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