GROWTH OF MALAYSIAN PARAGONIMUS WESTERMANI IN MAMMALS AND THE MODE OF TRANSMISSION OF THE FLUKE AMONG MAMMALS

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ABSTRACT: The host susceptibility of Malaysian Paragonimus westermani was observed in cats, dogs and rats, infected with metacercariae. In rats, worms were harboured in the muscles and the flukes were morphologically similar to the excysted metacercariae except for their slightly larger body size. In cats, about a half number of the flukes were recovered from muscles and 40% from cysts found in the lungs. Majority of the flukes from these cysts were mature. In dogs, few mature flukes were obtained from cysts in the lungs and about 90% of flukes were recovered from muscles. The flukes from the muscles of cats and dogs were of the same juvenile stage as those from rats. The juvenile flukes recovered from muscles of the animals were orally given to dogs and cats. Majority of the flukes were found in cysts in the lungs and most of them were fully mature. However, some juvenile flukes still remained in the muscles of cats and dogs. Therefore, the Malaysian P. westermani has a higher final host susceptibility than those from other localities. The present study suggests that many species of animals living in Malaysian jungle serve as paratenic hosts and may play an important role in the completion of the life cycle of P. westermani in Malaysia.

INTRODUCTION

Japanese Paragonimus westermani (Kerbert, 1878) usually remains in the muscles of rat, mouse, rabbit, pig and wild boar and for long period without development, and such animals could play a role as paratenic hosts of the fluke (Habe, 1978, 1983; Miyazaki and Habe, 1976; Shibahara and Nishida, 1986). Ingestion of raw wild boar meat is an important source of human infection of P. westermani in Japan (Miyazaki et al., 1978; Norimatu et al. 1975; Tokudome et al., 1977). In contrast P. westermani in Philippines does not remain in the muscles of mammals as a juvenile fluke (Miyazaki and Habe, 1979; Yokogawa et al., 1979). The study of lung flukes in mammals provide knowledge on the life cycle and these information would be useful for prevention and control of paragonimiasis. In Malaysia, only one species of lung fluke, P. westermani has been recorded from various animals belonging to the family Felidae and from the crab-eating monkey, and a few experimental infections of Malaysian P. westermani in cats have been done only to get adult worms specifically for identification. The growth of Malaysian P. westermani was not clear in the mammalian hosts. The present paper reports the sites and development of Malaysian P. westermani in cat, dog and rat and discusses the role of mammals as paratenic hosts, refering to the presumptive life cycle of this fluke.

MATERIALS AND METHODS

1) Experimental Animals and P. westermani Metacercariae

Seven adult dogs and 11 cats were used for investigation of site and growth of Malaysian P. westermani in mammalian hosts. Before experimental infection, the dogs and cats were shown to be free from lung fluke and intestinal parasites by stool examination. Thirty-two female albino rats, Rattus norvegicus, SD strain about 9 weeks old were also used. Malaysian P. westermani metacercariae were recovered from fresh water crabs, Parathelphusa maculata and

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Parathelphusa malaysiana which were collected from Kampong Langkap near Kuala Pilah and Sungai Wa at Taman Negara, Peninsular Malaysia, respectively. They were inoculated into dogs, cats and rats. The metacercariae from P. maculata collected at Ulu Langat near Kuala Lumpur were inoculated into cats.

2) Inoculation of Metacercariae

The experimental animals were infected with 25 to 150 metacercariae (Tables 1-3). Five cats and a dog were orally infected using a pipette and 29 rats were also orally infected with metacercariae in a little water using a syringe connected to a slender tube inserted into the stomach. Other animals, 6 cats, 6 dogs and 3 rats, were injected with the metacercariae into the peritoneal cavity with a little Ringer’s solution using a syringe connected to a slender vinyl tube.

3) Recovery of the Flukes

Dogs, cats and rats were bled to death under anesthesia on days 208 - 258, 155 - 249 and 10 - 150 after infections, respectively, and flukes were recovered. Postmortem examinations were carried out on each animal immediately. Gross lesions which might be attributable to parasitic invasion were recorded. Visceral organs and cavities were examined for lung fluke infection and worms were recovered. Subsequently, the lungs, liver and muscles of the whole body were cut into slices, 3 to 4 mm thick, and kept in Ringer’s solution at 36 - 38 °C for 6 - 8 hours to release flukes from the tissues. The sediment was poured into a petri dish and examined for flukes under a stereomicroscope. Most of the juvenile flukes recovered were inoculated into dogs and cats again. The remaining worms were used for morphological observations; they were pressed between two slide glasses in 70% alcohol and mounted with Canada balsam after staining with carmine.

4) Transfer of Juvenile P. westermani to Cats and Dogs

Most of the juvenile worms recovered from the muscles of cats, dogs and rats were fed again to 5 cats and 2 dogs. Numbers and ages of the juvenile flukes and animals used are shown in Table 4. The animals were autopsied at 161-212 days after inoculation. The same procedures mentioned above for fluke recovery and examination were employed.

<table>
<thead>
<tr>
<th>Cat No.</th>
<th>Body weight at necropsy (kg)</th>
<th>Sex</th>
<th>No. of Metc. given</th>
<th>Method of infection</th>
<th>Autopsy days after infection</th>
<th>No. of worms recovered (%)</th>
<th>No. of worms recovered from lungs</th>
<th>Peritoneal cavity</th>
<th>Muscles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0</td>
<td>F</td>
<td>30</td>
<td>oral infection</td>
<td>220</td>
<td>14 (46.7)</td>
<td>10*</td>
<td>0</td>
<td>3†</td>
</tr>
<tr>
<td>2</td>
<td>2.9</td>
<td>F</td>
<td>30</td>
<td>oral infection</td>
<td>229</td>
<td>3 (10.0)</td>
<td>2*</td>
<td>0</td>
<td>0†</td>
</tr>
<tr>
<td>3</td>
<td>2.6</td>
<td>F</td>
<td>30</td>
<td>oral infection</td>
<td>234</td>
<td>5 (16.7)</td>
<td>4*</td>
<td>0</td>
<td>0†</td>
</tr>
<tr>
<td>4</td>
<td>2.0</td>
<td>M</td>
<td>30</td>
<td>oral infection</td>
<td>242</td>
<td>4 (13.3)</td>
<td>2*</td>
<td>0</td>
<td>1†</td>
</tr>
<tr>
<td>5</td>
<td>2.7</td>
<td>M</td>
<td>30</td>
<td>oral infection</td>
<td>249</td>
<td>5 (16.7)</td>
<td>4*</td>
<td>0</td>
<td>0†</td>
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<tr>
<td>6</td>
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<td>F</td>
<td>50</td>
<td>peritoneal inoculation</td>
<td>155</td>
<td>26 (52.0)</td>
<td>4*</td>
<td>14†</td>
<td>0†</td>
</tr>
<tr>
<td>7</td>
<td>3.7</td>
<td>M</td>
<td>50</td>
<td>peritoneal inoculation</td>
<td>192</td>
<td>32 (64.0)</td>
<td>18*</td>
<td>0</td>
<td>1†</td>
</tr>
<tr>
<td>8</td>
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<td>50</td>
<td>peritoneal inoculation</td>
<td>192</td>
<td>37 (74.0)</td>
<td>16*</td>
<td>0</td>
<td>2†</td>
</tr>
<tr>
<td>9</td>
<td>2.9</td>
<td>M</td>
<td>40</td>
<td>peritoneal inoculation</td>
<td>208</td>
<td>26 (65.0)</td>
<td>14*</td>
<td>0</td>
<td>0†</td>
</tr>
<tr>
<td>10</td>
<td>2.9</td>
<td>F</td>
<td>47</td>
<td>peritoneal inoculation</td>
<td>237</td>
<td>30 (63.8)</td>
<td>10* × 2†</td>
<td>0</td>
<td>2†</td>
</tr>
<tr>
<td>11</td>
<td>3.2</td>
<td>M</td>
<td>30</td>
<td>peritoneal inoculation</td>
<td>242</td>
<td>25 (83.3)</td>
<td>12*</td>
<td>0</td>
<td>1†</td>
</tr>
</tbody>
</table>

F: female, M: male, * Adult worm (with eggs in uterus), † Immature worm (without eggs in uterus), ‡ Juvenile worm (similar to excysted metacercariae).
Cat Nos. 2, 4, 5, 7 and 8 were infected with metacercariae from Kuala Pilah.
Cat Nos. 1, 3, 6 and 9 from Sungai Wa and Cat Nos. 10 and 11 from Ulu Langat.
RESULTS
Experimental Infection of Cats with Metacercariae
Distribution of flukes:
The results of the experimental infection in cats with the metacercariae are shown in Table 1. The average recovery rate of five cats (Nos. 1-5), orally infected with metacercariae, was 20.7% ranging from 10.0 to 46.7%. Out of 31 flukes recovered, 22 were found in cysts in the lungs, 5 in the muscles and 4 in the pleural cavity. A total of 176 worms was recovered from the cats (Nos. 6 - 11) inoculated with metacercariae intraperitoneally and the average recovery rate of worms was 57.0% (52.0 - 83.3%). Eighty-two worms were recovered in the muscles and 88 in lungs or cysts in the lungs and a small number of flukes were found in the pleural cavity.

Postmortem examinations:
On gross examination of the infected cats, in which 1 to 9 cyst formations were recognized in the pulmonary parenchyma, membraneous rust colored fibrinous exudate was present in the cavity, and adhesions between the lung lobes were present. In the cats, in which migrating flukes were found in the pleural cavity or lungs, collections of stagnant thoracic fluid were present and small number of hemorrhagic spots, 4 - 6 mm in diameter, were recognized in the lungs. In cat No.6, a large amount of stagnant thoracic fluid with blood cells was present, and about 30 hemorrhagic spots or nodules, 1 - 16 mm in diameter, were present in the lungs.

Development of the flukes:
In cat No. 6, autopsied 155 days after infection, fourteen flukes recovered from nodules of the lungs were immature, while four flukes from cysts in the lungs were mature (Table 1). The sizes of the mature flukes were variable, 5.8 - 7.4 mm long and 3.1 - 4.8 mm wide, with a few eggs in the uteri. In cats autopsied 192 days later, all flukes recovered from cysts in the lungs were fully mature. The sizes were 8.2 - 9.1 mm in length and 5.1 - 6.0 mm in width and the worms had numerous eggs in the uteri. Flukes recovered from muscles were morphologically similar to excysted metacercariae except for their slightly larger body size (0.7 - 1.4 mm in length and 0.4 - 0.7 mm in width). The worms had numerous granules in their excretory bladder. The flukes from the pleural cavity were immature and their sizes were about 3.5 mm in length and 2.1 - 3.2 mm in width. Their ovary and testes were divided into 5 or 6 lobes but vitelline glands were less developed. No remarkable differences were observed in the development of the flukes from the three different localities in Malaysia.

Experimental Infection of Dogs with Metacercariae
Distribution of flukes:
Table 2 shows the results of experimental infection of 7 dogs with metacercariae from Kuala Pilah and Sungai Wa. In dog No.1, orally infected with 150 metacercariae and necropsied 234 days after infection, only 3 (2%) worms were recovered from muscles. The remaining six dogs were infected intraperitoneally with 80 or 100 metacercariae and were necropsied 208 to 258 days after infection. Only 3 (2%) worms were recovered from muscles. The remaining six dogs were infected intraperitoneally with 80 or 100 metacercariae and were necropsied 208 to 258 days after infection.

<table>
<thead>
<tr>
<th>Dog No.</th>
<th>Body weight at necropsy (kg)</th>
<th>Sex</th>
<th>Method of infection</th>
<th>Autopsy days after infection</th>
<th>No. of worms recovered (%)</th>
<th>No. of worms recovered from</th>
<th>Cyst in lungs</th>
<th>Lungs</th>
<th>Pleural cavity</th>
<th>Peritoneal cavity</th>
<th>Muscles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17.7</td>
<td>F</td>
<td>oral infection</td>
<td>234</td>
<td>3 (2.0)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3†</td>
</tr>
<tr>
<td>2</td>
<td>14.7</td>
<td>F</td>
<td>peritoneal inoculation</td>
<td>208</td>
<td>52 (65.0)</td>
<td>2†</td>
<td>0</td>
<td>1†</td>
<td>0</td>
<td>49†</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>12.0</td>
<td>F</td>
<td>peritoneal inoculation</td>
<td>227</td>
<td>29 (29.0)</td>
<td>0</td>
<td>2†</td>
<td>1†</td>
<td>0</td>
<td>26 (236)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>12.2</td>
<td>F</td>
<td>peritoneal inoculation</td>
<td>240</td>
<td>9 (9.0)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9†</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10.3</td>
<td>M</td>
<td>peritoneal inoculation</td>
<td>245</td>
<td>35 (35.0)</td>
<td>4 (2†)</td>
<td>0</td>
<td>0</td>
<td>1†</td>
<td>30†</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>11.2</td>
<td>M</td>
<td>peritoneal inoculation</td>
<td>252</td>
<td>23 (28.8)</td>
<td>0</td>
<td>0</td>
<td>2†</td>
<td>0</td>
<td>21†</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>15.6</td>
<td>F</td>
<td>peritoneal inoculation</td>
<td>258</td>
<td>23 (28.8)</td>
<td>2† (1†)</td>
<td>0</td>
<td>2†</td>
<td>0</td>
<td>19†</td>
<td></td>
</tr>
</tbody>
</table>

F: female, M: male, †, ††: Cf. the foot in Table 1,
Dog Nos. 1, 3 and 4 were infected with metacercariae from Kuala Pilah.
Dog Nos. 2, 5, 6 and 7 were infected with metacercariae from Sungai Wa.
The average recovery rates of worms was 32.6% (9.0 - 65.0%) and a total of 171 worms were recovered. Majority of the flukes (154 out of 171; 90.1%) were recovered from muscles and 6 and 8 flukes were found in cavities and cysts in lungs, respectively.

Postmortem examinations:

On gross examination, no abnormality was observed in any organs of 2 infected dogs (Nos. 1 and 4), from which flukes were only recovered from muscles. In the other dogs, some haemorrhagic lesions, 1 - 10 mm in diameter, were present in the lungs and flukes were found in the pleural cavity or in the lungs. In these dogs, stagnant haemorrhagic exudates were present in the pleural cavity, and adhesions of the lungs to the thoracic wall and between lung lobes were also observed. One or 2 typical worm-cysts were present in the lungs of dogs Nos. 2, 5 and 7; and 2 flukes were found in each cyst.

Development of flukes:

A total of 157 flukes were recovered from muscles of the dogs. Three of them measured 1.9 - 3.1 mm in length, and primordial cells of ovary, testis and uterus were recognized. The remaining 154 flukes were very stunted and they had granules in the excretory bladder, and a small stylet was still visible on the oral sucker. Their sizes ranged from 0.7 to 1.2 mm in length and 0.4 to 0.6 mm in width. Five out of 8 flukes recovered from cysts of lung were 4.5 - 6.7 mm in length and 2.8 - 3.4 mm in width, and eggs were present in their uteri. Three other flukes from cysts in lungs and all the flukes from cavities and lungs were immature. Their sizes were 1.9 - 4.2 mm in length and 1.4 - 3.3 mm in width, though their ovary and testes were developed slightly.

Experimental Infection of Rats with Metacercariae

Table 3 shows the results of oral infection of 29 albino rats with metacercariae from Kuala Pilah. The average recovery rate of flukes from the rats was 42.8%. Almost all of the worms, 307 out of 310, were recovered from the muscles and only a few worms were found in the lungs or abdominal cavity. The 3 intraperitoneally inoculated rats with 50 metacercariae each from Taman Negara were necropsied 100 days after infection. The recovery rate of the flukes from these rats was 48.7% (46.0 - 52.0%) and all of them were recovered from muscles.

Postmortem examination:

On the gross examination of the infected rats, no pathological changes were generally observed except those examined 10 to 20 days after infection. In these rats, haemorrhagic tracks were found in the muscles of abdominal walls and legs, presumably due to migration of juvenile flukes.

Development of flukes in rats:

All the flukes recovered from rats were juvenile and morphologically similar to the excysted metacercariae with the exception that they were slightly larger in size. They were 0.7 - 0.9 mm in length and 0.3 to 0.5 mm in width.

Transfer of Juvenile P. westermani to Cats and Dogs

The results of oral infection in cats and dogs with juvenile worms recovered from muscles of cats, dogs and rats of the previous experiments are shown in Table 4. The average recovery rate of worms in five infected cats was 68.2%, ranging from 48.0 to 84.0%. Out of 99 flukes obtained, 77, 4, 11 and 7 flukes were recovered from cysts in the lungs, tissues of lungs, pleural cavity and muscles, respectively. Sixty-four out of 77 flukes recovered from cysts in the lungs were mature while 1 out of 11 from pleural cavity and five out of 7 flukes from muscles were still juvenile worms with granules in the excretory bladder.

In dog No. 8, 2 and 3 flukes were recovered from the pleural cavity and muscles, respectively. The recovery

<p>| Days after | No. of | No. of | No. of worms recovered from |</p>
<table>
<thead>
<tr>
<th>infection</th>
<th>rats used</th>
<th>worms*</th>
<th>lungs</th>
<th>peritoneal cavity</th>
<th>muscles</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>5</td>
<td>48</td>
<td>0</td>
<td>0</td>
<td>48</td>
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<td>20</td>
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<td>53</td>
</tr>
<tr>
<td>30</td>
<td>5</td>
<td>55</td>
<td>0</td>
<td>0</td>
<td>55</td>
</tr>
<tr>
<td>60</td>
<td>5</td>
<td>62</td>
<td>0</td>
<td>1</td>
<td>61</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
<td>57</td>
<td>1</td>
<td>0</td>
<td>56</td>
</tr>
<tr>
<td>150</td>
<td>5</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>34</td>
</tr>
</tbody>
</table>

* All worms recovered were juvenile.
Table 4  Results of experimental infection of dogs and cats with juvenile *Paragonimus westermani*
recovered from some paratenic host animals

<table>
<thead>
<tr>
<th>Host animal</th>
<th>Body weight at autopsy (kg)</th>
<th>Sex</th>
<th>Juvenile worms recovered from (days after postinfection)</th>
<th>No. of juvenile worms fed</th>
<th>Autopsy days after infection</th>
<th>No. of worms recovered (%)</th>
<th>cyst in lungs</th>
<th>lungs</th>
<th>pleural cavity</th>
<th>muscles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dog No.8</td>
<td>14.5</td>
<td>F</td>
<td>Rat (150)</td>
<td>40</td>
<td>185</td>
<td>5 (12.5)</td>
<td>0</td>
<td>0</td>
<td>2†</td>
<td>3†</td>
</tr>
<tr>
<td>Dog No.9</td>
<td>16.4</td>
<td>F</td>
<td>Rat (100)</td>
<td>35</td>
<td>209</td>
<td>10 (28.6)</td>
<td>8*</td>
<td>0</td>
<td>2†</td>
<td>not examined</td>
</tr>
<tr>
<td>Cat No.12</td>
<td>2.8</td>
<td>F</td>
<td>Cat (192)</td>
<td>25</td>
<td>200</td>
<td>12 (48.0)</td>
<td>4*</td>
<td>0</td>
<td>5†</td>
<td>3†</td>
</tr>
<tr>
<td>Cat No.13</td>
<td>4.3</td>
<td>M</td>
<td>Cat (237, 242)</td>
<td>23 (12.1)</td>
<td>166, 161</td>
<td>19 (82.6)</td>
<td>16 (11*)</td>
<td>5†</td>
<td>2†</td>
<td>1†</td>
</tr>
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<td>Cat No.14</td>
<td>3.6</td>
<td>M</td>
<td>Dog (227)</td>
<td>17</td>
<td>172</td>
<td>12 (70.6)</td>
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<td>M</td>
<td>Dog (245, 252)</td>
<td>50 (30, 20)</td>
<td>195, 202</td>
<td>42 (84.0)</td>
<td>33 (25*)</td>
<td>4†</td>
<td>2†</td>
<td>3†</td>
</tr>
<tr>
<td>Cat No.16</td>
<td>3.9</td>
<td>M</td>
<td>Rat (100)</td>
<td>25</td>
<td>212</td>
<td>14 (56.0)</td>
<td>12*</td>
<td>0</td>
<td>2†</td>
<td>0</td>
</tr>
</tbody>
</table>

F: female,  M: male,  *†, ‡: Cf. the foot in Table 1.

rate was 12.5%. All of the flukes recovered from the dog were immature, especially a single fluke from muscle having the same characteristics of the metacercarial stage. In dog No.9, typical cyst formation was recognized in the lungs, 8 fully matured flukes which measured 7.9 - 8.5 mm long by 3.8 - 4.4 mm wide were recovered. Two immature flukes were recovered from pleural cavity but the muscles of this dog were not examined.

**DISCUSSION**

It is well known that the distribution and development of *P. westermani* in favorable definitive hosts, like cats and dogs and in unfavorable hosts, such as rodents are quite different. In the former hosts, worms are found in cysts in the lungs and are mature, but in the latter hosts, majority of worms remain in the muscle with little development. In dogs and cats infected with *P. westermani* from Japan, the triploid fluke takes about 2 months to reach maturity, and the diploid fluke takes almost two and a half months (Takizawa, 1964; Habe, 1978; Shibahara, 1983). *P. westermani* from Korea, China and the Philippine also shows similar growth in dogs and cats (Fan, 1966; Miyazaki and Habe, 1979; Unpublish data, S. Habe). In general the worm recovery rates in cats and dogs infected with metacercariae from these countries were about 60 to 80% by oral inoculation and 90% more by peritoneal inoculation.

In our present study the average worm recovery rates of cats and dogs, orally infected with Malaysian *P. westermani*, were 20.7% and 2%, respectively. Kim (1969) infected six cats with 109 metacercariae from freshwater crabs, *Parathelphusa maculata* and *Johora johorensis*, and recovered 31 worms from 61 to 108 days after infection. These rates are very low compared to those of *P. westermani* from other localities. The results of experimental intraperitoneal inoculation also shows a similar tendency. The Malaysian *P. westermani* has a lower infectivity to mammalian hosts than those from other localities. Furthermore, in spite of keeping the infections for 5 or more months after feeding with metacercariae, about 50% and 90% of the flukes were still recovered from the muscles of the cats and dogs respectively. The worms were very stunted and morphologically similar to the excysted metacercariae with the exception that their body sizes were slightly larger. The rates of mature flukes out of total worms recovered were only 40% from infected cats and 3% from infected dogs.

All the flukes recovered from albino rats were juvenile just like those that parasitized the muscles of dogs and cats. Such stagnated worms have been collected from other animals, such as pig, wild boar, mouse, hamster, guinea pig, rabbit, monkey and hen infected with *P. westermani* from Japan (Habe, 1978, 1982, 1983; Shibahara and Nishida, 1986; Takizawa, 1964). This is the first report where juvenile worms were recovered from cats and dogs infected with *P. westermani*. The development and distribution of Malaysian *P. westermani* in cat and dog are very different from the flukes of other countries but no significant differences are recognized in rat. However, Philippine *P. westermani* does not remain in the muscle of rats and migrates into the lungs and then mature in relatively high rate. This suggests that Malaysian *P. westermani* has a higher
Figs. 1-3. Living juvenile worms. Bar=0.2mm.
1. Worm recovered from muscle of rat 150 days after infection with metacercariae.
2. Worm recovered from muscle of dog 240 days after infection with metacercariae.
3. Worm recovered from muscle of cat 237 days after infection with metacercariae.

Fig. 4 Lungs of dog; 209 days after inoculation with 35 juvenile worms from muscles of rat. Bar=3cm.

Fig. 5 Mounted adult worm from worm cyst in lungs of cat; 172 days after inoculation with juvenile worms from muscles of dog. Bar=2mm.

The final host susceptibility than the Japanese, Chinese and Korean flukes while the Philippine P. westermani has the lowest.

The final host of P. westermani is widely distributed among mammals, especially of the families Felidae and Canidae. In Malaysia, only one species of lung fluke, P. westermani has been recorded from tiger, Felis tigris, domestic cat, Felis domestica, clouded leopard, Neofelis nebulosa diardithe, wild cats, Felis bengalensis, F. planiceps and F. temminckii, black panther, Felis pardus, and crab-eating monkey, Macaca irus irus (Groves et al., 1967; Lee and Miyazaki, 1965; Lim and Betterton, 1977; Rohde, 1963, 1967; Miyazaki and Kwo, 1969). Most of the natural final hosts belong to Felidae. In spite of the juvenile worms recovered from muscles of experimental cats in the present study, and it is without doubt
that the animals of Felidae are the most important and suitable final hosts for Malaysian \textit{P. westermani}. However, our results showed Canidae to be unsuitable hosts for Malaysian \textit{P. westermani}.

It was experimentally proved that juvenile flukes remaining in the muscles of dogs, cats and albino rats were able to reinfect other carnivores. In the case of cat infections, the recovery rate of flukes was 68.2\% on the average, while in dogs, it was 20.7\%. In the animals inoculated with juvenile flukes, the worm recovery and maturity rate were also higher than those infected with the metacercariae. Carnivorous animals are more readily infected by the Malaysian \textit{P. westermani} via feeding of juvenile worms from paratenic hosts than metacercaiae from crabs. Therefore, the present study suggests that many wild mammals living in jungle must serve as paratenic hosts and they play a very important role in the completion of the life cycle of the flukes in Malaysia and its neighborhood. In experiments the same mode of infection has been shown in the triploid and diploid types of \textit{P. westermani}, \textit{P. miyazakii} Kamo et al., \textit{P. mexicanus} Miyazaki et Ishii and \textit{P. heterotremus} Chen et Hsia (Fan and Khaw, 1964; Fan and Hsu, 1965; Habe, 1978, 1983; Miyazaki and Habe, 1976; Shibahara and Nishida, 1966; Sugiyama et al., 1990). For example, it was proven that the wild boar, \textit{Sus scrofa leucomystax}, plays an important role as the paratenic host for human paragonimiasis westermani (triploid type) in the southern part of Kyushu, Japan (Norimatsu et al., 1975; Miyazaki et al., 1978; Tokudome et al., 1977). Kwo and Miyazaki (1968) reported heavy infections of \textit{P. westermani}, \textit{P. miyazakii} Kamo et al., \textit{P. mexicanus} Miyazaki et Ishii and \textit{P. heterotremus} Chen et Hsia (Fan and Khaw, 1964; Fan and Hsu, 1965; Habe, 1978, 1983; Miyazaki and Habe, 1976; Shibahara and Nishida, 1966; Sugiyama et al., 1990). For example, it was proven that the wild boar, \textit{Sus scrofa leucomystax}, plays an important role as the paratenic host for human paragonimiasis westermani (triploid type) in the southern part of Kyushu, Japan (Norimatsu et al., 1975; Miyazaki et al., 1978; Tokudome et al., 1977). Kwo and Miyazaki (1968) reported heavy infections of \textit{P. westermani} in all the tigers examined in North Sumatra, Indonesia, and Miyazaki and Habe (1976) postulated that those tigers might have been infected due to feeding on animals harboring immature worms and serving as paratenic hosts. Lim and Betterton (1977) reported that civet cats have the potential of being paratenic hosts from feeding experiments and suggested that wild boar and a number of small mammals were also potential paratenic hosts. Although locally acquired paragonimiasis has not been observed in man in Malaysia, \textit{P. westermani} has been found in a number of animals and freshwater crabs. Lim and Betterton (1977) gave the reason that freshwater crab is not generally used as a source of food and wild boar meat is infrequently eaten. In addition to that, the development of \textit{P. westermani} in man could be considered to be similar to that seen in the present experiments where mature worms may not be found.

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