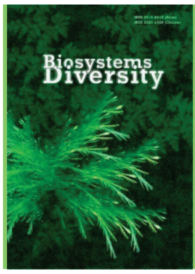

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Larvae of helminths of molluscs and insects in Karakalpakstan

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The work discusses some issues related to the species diversity of helminth larvae developing in the body of freshwater molluscs and insects distributed in the territory of Karakalpakstan, a vast region in Uzbekistan. A total of 42 species of parasites in larval form were identified in the region; 27 species were recorded in aquatic molluscs and 15 species in insects. 29 species were recorded for the first time in Karakalpakstan. We established that the class Gastropoda in the water bodies of Karakalpakstan is represented by 17 species; 9 of them belong to the family Lymnaeidae, 6 species to Planorbidae and 2 to Physidae. 3,477 mollusc individuals of 11 species were infected with larval stages of trematodes. The prevalence of infection in Lymnaeidae (*Radix* and *Lymnaea*) ranged from 1.7% to 25.5%. A similar prevalence was recorded in Planorbidae (1.6–25.4%). *Physa fontinalis* showed a prevalence of infection of 1.3%. 27 species of parasites in cercarial forms were identified in molluscs. The largest number of cercariae of trematode species was found in molluscs from the family Lymnaeidae (14 species). They were followed by representatives of Planorbidae (12 species). The fauna of cercariae identified in molluscs from water bodies in Karakalpakstan was from 12 families of trematodes. The most common were the cercariae of those species of trematodes that complete their life cycle in wetland birds (20 species). Cercariae of 6 species of trematodes turned out to be parasites of mammals, mainly ungulates. 1 species of trematodes in a larval stage was recorded in each of the fish and amphibian groups. The richest species composition in the studied region was shown by trematode cercariae representing Schistosomatidae (6 species), which were followed by Echinostomatidae (4 species). Cercariae of other trematode families were represented by one, two and three species. It was established that the studied molluscs do not play an equal role as intermediate hosts of trematodes. The richest species composition was shown by populations of *Radix auricularia* (14 species), *Planorbis planorbis* (12 species), *Anisus spirorbis* (9 species), and *Lymnaea stagnalis* (5 species). Populations of *L. bactriana*, *Pl. tangitarensis* were infected by only one species. The prevalence recorded in the studied insects infected with helminth larvae ranged widely from 1.1% to 14.4%. The identified larvae turned out to be representatives of Cestoda (3 species), Trematoda (1 species) and Nematoda (11 species). The largest number of species (4) of helminth larvae were found in beetles from the family Scarabaeidae – *Gongylonema pulchrum*, *Spirura rytipleurites*, *Choanataenia infundibulum* and *Echinolepis carioca*, and mosquitoes – *Dirofilaria immitis*, *D. repens*, *Dipetalonema ewansi* and *Setaria labiatopapillosa*. 2 species were recorded in flies – *Stephamofilaria stilesi* and *Parabronema skrjabini*. The recorded species belong to the classes Nematoda and Cestoda. The intensity of infection ranged from single to 11–17 individuals. The work provides original data on the morphology and biology of the larvae of the studied molluscs infected with cercariae of trematodes and insects with metacercariae of trematodes, cysticercoids of cestodes and larvae of nematodes, and presents the structure of communities of larval forms of parasitic worms.

Keywords: helminths; larvae; cercariae; metacercariae; cysticercoids; molluscs; insects; Uzbekistan.

Introduction

Studying the role of freshwater molluscs and insects in the biological cycles of helminths is of great interest for understanding the ways of evolution of helminth life cycles and their distribution patterns, and important for the control of helminthiases of agricultural and commercial animals with the help of the obtained data. The spread of many pathogenic helminths in space depends on the presence or absence of their intermediate hosts. Obviously, the correlation between the distribution of aquatic molluscs and groups of helminths as such Fasciolidae, Schistosomatidae, Schistosomatidae, Gastrothylacidae and other trematodes is one of the main factors determining the pathways of helminth circulation in specific territories. This applies to a certain extent to insects, which participate in the life cycles of a number of parasites from the groups Cestoda, Trematoda, Acanthocephala and Nematoda. On the other hand, parameters such as prevalence and intensity of infection with helminth larvae in molluscs and insects can to a certain extent an indicator of the state of water bodies and pastures with regard to related helminthiases.

Molluscs and insects are undoubtedly the most popular objects of helminthological research for biologists, veterinary scientists and doctors in Karakalpakstan. However, the list of works reflecting the participation of molluscs and insects in the life cycles of helminths in the studied region is relatively small (Arystanov, 1969; Shakarbaev, 2017; Medetov, 2018). Arystanov (1969) considered the molluscs of the Amu Darya delta and the south of the Aral Sea area as intermediate hosts of trematodes. The author reported the discovery of 35 species of trematode cercariae in freshwater molluscs in the studied bodies of water in Karakalpakstan. As of today, these data are significantly outdated and do not reflect the current situation about the infection of molluscs with larval stages of parasitic worms. Regarding insects, there is one report (Medetov, 2018) on the role of some locust species in the circulation of nematodes from the genera *Aprocta* and *Diplotriaena*.

Taking into account the importance of molluscs and insects in the circulation of animal helminths, it is quite relevant to study in detail the species diversity of intermediate hosts (molluscs and insects) and their role in the circulation of infections in connection with the modern ecological background of Karakalpakstan, a specific region of Uzbekistan.

The aim of the study is to specify the species diversity of larval forms of parasites in molluscs and insects, which are intermediate hosts of the dominant species (groups) of helminths of wetland and terrestrial birds, domestic and wild mammals in the region in question. The work also discusses some issues related to the natural foci of helminthiases of animals in the studied region of Uzbekistan.

Materials and methods

The basic material used in the study was freshwater molluscs collected in bodies of water in Karakalpakstan in 2020–2023 (Fig. 1). Samples were taken using generally accepted hydrobiological methods (Zdun, 1961; Chernogorenko, 1983). Shellfish from shallow bodies of water were collected manually in spring, summer and autumn in each of the years. A total of 3,477 individuals of molluscs from the families Lymnaeidae, Planorbidae and Physidae were collected. Some of the collected material was soaked in 70% alcohol for subsequent study. The collected molluscs were placed in small jars with water, one in each jar. This was a way to immediately detect infected individuals which released cercariae.

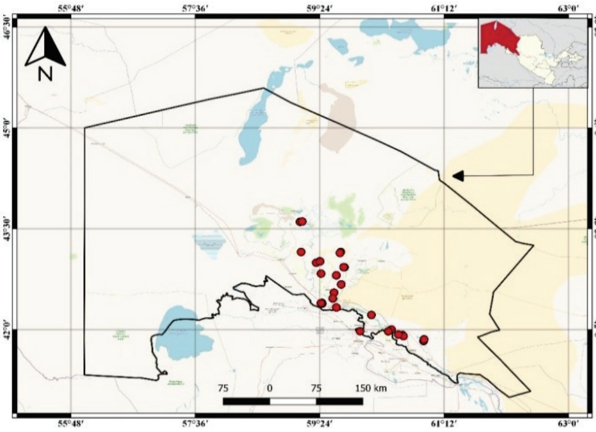

Fig. 1. Map of research areas

The morphology of parthenitae and larvae was studied on living material with the help of a phase contrast device using well-known helminthological methods (Zdun, 1961). In order to identify helminth larvae in insects from the fauna of Karakalpakstan, the insects were collected and examined in spring, summer and autumn in 2020–2023. The research team studied some insect species – Odonatoptera (3 species), Coleoptera (5 species), Orthoptera (7 species) and Diptera (about 10 species) using generally accepted methods (Kabilov, 1983; Azimov et al., 1993). The detected larvae of Cestoda, Trematoda, and Acanthocephala were soaked in 70% ethyl alcohol, and larvae of nematodes in 1.5–2.0% formalin. Most (about 90%) of the detected helminth larvae were studied live. The study was carried out with the help of modern devices: an invented microscope CK2-TR (Olympus, Japan) with a phase contrast device, a research microscope LOMO, cooling centrifuges TR7 (Dupont, USA), a binocular microscope ML – 2200 (Olympus, Japan). Most of the drawings were made by the authors; for some species, data from scientific reports by researchers at the Laboratory of General Parasitology, Institute of Zoology, Academy of Sciences of the Republic of Uzbekistan, for 2020–2023 were used. The total amount of the material is illustrated in Table 1.

Table 1
Results of parasitological dissection of molluscs and insects from Karakalpakstan (2020–2023)

Class	Family	Species	Examined, individuals
Gastropoda	Lymnaeidae	*Radix auricularia* (Linnaeus, 1758)	450
		R. peregra (O. F. Müller, 1774)	112
		Lymnaea stagnalis (Linnaeus, 1758)	442
		L. bactriana (T. Hutton, 1849)	248
		L. corvus (Gmelin, 1791)	126
	Planorbidae	*Planorbis planorbis* (Linnaeus, 1758)	420
		P. tangitarensis Germain, 1918	310
		P. gredleri Gredler, 1859	306
		P. ehrenbergi H. Beck, 1837	306
		Anisus spirorbis (Linnaeus, 1758)	302
	Physidae	*Physa fontinalis* (Linnaeus, 1758)	455
		Total:	3477
Insecta	Libellulidae	*Orthetrum brunneum* (Fonscolombe, 1837)	52
		Libellula depressa (Linnaeus, 1758)	55
		Sympetrum vulgatum (Linnaeus, 1758)	40
	Acrididae	*Calliptamus italicus* (Linnaeus, 1758)	156
		C. turanicus Tarbinsky, 1930	160
		C. barbarus (Costa, 1836)	125
		Aiolopus oxianus Uvarov, 1926	138
		Locusta migratoria (Linnaeus, 1758)	160
	Carabidae	*Carabus* sp.	48
		Calathus melanocephalus (Linnaeus, 1758)	54
		Scarites bucida Pallas, 1776	46
	Tenebrionidae	*Adesmia biseriata* Reitter, 1916	122
		A. panderi Fischer von Waldheim,. 1835	110
		Blaps halophila Fischer von Waldheim, 1822	84
		B. dispar Seidlitz,1893	52
	Scarabaeidae	*Scarabaeus sacer* Linnaeus, 1758	346
	Culicidae	*Aedes caspius* (Pallas, 1771)	650
		Ae. detritus Haliday, 1833	325
		Culex pipiens Linnaeus, 1758	650
		C. hortensis Ficalbi, 1889	536
	Simulidae	*Odagmia ornate* (Meigen, 1818)	528
		Simulium flavidum Rubtsov, 1947	520
	Musidae	*Liperosia irritans* (Linnaeus, 1758)	470
		Haematobia titillans (Bezzi, 1907)	450
		Stomoxys calcitrans Linnaeus, 1758	116
		Total:	5993

Results

We established that the class Gastropoda in the water bodies of Karakalpakstan is represented by 17 species; 9 of them belong to the family Lymnaeidae, 6 species to Planorbidae and 2 to Physidae. 3,477 molluscs representing 11 species proved to be infected with larval stages of trematodes (Table 2).

Table 2
Rate of infection with larval stages of trematodes in molluscs inhabiting bodies of water in Karakalpakstan

Molluscs	Examined, individuals	Infected, %	Number of cercariae species
Radix auricularia (Linnaeus, 1758)	450	25.5	14
R. peregra (O. F. Müller, 1774)	112	1.7	1
Lymnaea stagnalis (Linnaeus, 1758)	442	12.6	9
L. bactriana (T. Hutton, 1849)	248	2.8	1
L. corvus (Gmelin, 1791)	126	2.3	3
Planorbis planorbis (Linnaeus, 1758)	420	25.4	12
P. tangitarensis Germain, 1918	310	2.5	1
P. gredleri Gredler, 1859	306	3.3	4
P. ehrenbergi H. Beck, 1837	306	1.6	4
Anisus spirorbis (Linnaeus, 1758)	302	19.2	9
Physa fontinalis (Linnaeus, 1758)	455	1.3	2

The prevalence of infection in Lymnaeidae (*Radix* and *Lymnaea*) ranged from 1.7% to 25.5%. A similar prevalence was recorded in Planorbidae (1.6–25.4%). *Physa fontinalis* showed a prevalence of 1.3%. 27 species of cercariae were identified in infected molluscs (Table 3). The largest number of trematode cercariae species were found in molluscs from the family Lymnaeidae (14 species). They are followed by representatives of Planorbidae (12 species). The cercariae fauna recorded in molluscs from the bodies of water in Karakalpakstan were from 12 families of trematodes.

Table 3
Trematoda cercariae identified in freshwater molluscs in Karakalpakstan

Species	Definitive hosts				
	Fish	Amphibians	Reptiles	Birds	Mammals
Lymnaeidae					
Fasciola gigantica (Cobbold, 1856)	–	–	–	–	+
Notocotylus attenuatus (Rudolphi, 1809)	–	–	–	+	–
Echinostoma revolutum (Frochlich, 1802)	–	–	–	+	–
Echinoparyphium aconiatum Dietz, 1909	–	–	–	+	–
E. recurvatum (Linstow, 1873)	–	–	–	+	–
Hypoderaeum conoideum (Bloch, 1782)	–	–	–	+	–
Apatemon gracilis (Rudolphi, 1808)	–	–	–	+	–
Cotylurus cornutus (Rudolphi, 1808)	–	–	–	+	–
Diplostomum spathaceum (Rudolphi, 1808)	–	–	–	+	–
D. helveticum (Dubois, 1929)	–	–	–	+	–
Sanguinicola inermis Plehn, 1905	+	–	–	–	–
Trichobilharzia ocellata (La Valette, 1855)	–	–	–	+	–
Schistosoma turkestanicum Skrjabin, 1913	–	–	–	–	+
Planorbidae					
Notocotylus ephemera (Nitzsch, 1817)	–	–	–	+	–
Echinostoma revolutum (Frochlich, 1802)	–	–	–	+	–
Echinoparyphium aconiatum Dietz, 1909	–	–	–	+	–
Calicophoron calicophorum (Fischoeder, 1901)	–	–	–	–	+
C. erschowi Davydova, 1959	–	–	–	–	+
Liorchis scotiae (Willmott, 1950)	–	–	–	–	+
Gastrothylax crumenifer (Creplin, 1847)	–	–	–	–	+
Skrjabinoeces similis (Looss, 1899)	–	+	–	–	–
Pleurogenoides claviger (Rudolphi, 1819)	–	–	–	+	–
Strigea falconis Szidat, 1928	–	–	–	+	–
Bilharziella polonica (Kowalewsky, 1895)	–	–	–	+	–
Dendritobilharzia loossi Skrjabin, 1924	–	–	–	+	–
D. pulverulenta (Braun, 1901)	–	–	–	+	–
Gigantobilharzia acotylea Odhner, 1910	–	–	–	+	–
Gigantobilharzia sp.	–	–	–	+	–
Physidae					
Gigantobilharzia acotylea Odhner, 1910	–	–	–	+	–
Gigantobilharzia sp.	–	–	–	+	–
Total:	1	1	0	20	6

The most widespread were the cercariae of those species of trematodes that end their life cycles in wetland birds (20 species). Cercariae of 6 species of trematodes turned out to be parasites of mammals, mainly ungulates. 1 species of trematodes in a larval stage was recorded in each of the fish and amphibian groups.

The richest species composition in the studied region was shown by trematode cercariae representing Schistosomatidae (6 species), which were followed by Echinostomatidae (4 species). Cercariae of other trematode families were represented by one, two and three species.

It was established that the studied molluscs do not play an equal role as intermediate hosts of trematodes. The richest species composition was shown by populations of *Radix auricularia* (14 species), *Planorbis planorbis* (12 species), *Anisus spirorbis* (9 species), and *Lymnaea stagnalis* (5 species). Populations of *L. bactriana*, *P. tangitarensis* were infected by only one species (Table 2).

The trematode cercariae are unevenly dispersed in the studied water bodies. Most of the larvae were recorded in molluscs living in the littoral zones of lakes with weakly circulating water (Karajar, Kyzyljar, Shigneykul, Mashankul, Khojakul and other). *Radix auricularia*, *Lymnaea stagnalis*, *Planorbis planorbis* and *Anisus spirorbis* are common for such bodies of water, with the prevalence of fluke larvae ranging from 12.6% to 25.5%. Their habitats are rich in littoral aquatic vegetation and attractive for wetland birds and various species of mammals, which become infected with the trematodes.

There is a reason to believe that infected molluscs play an important role in the transmission of trematodes to vertebrates. This is supported by the updated results of research into the helminth fauna of wetland birds in Karkalpakstan (Akramova et al., 2021; Arepbaev et al., 2022), where about 60 species of trematodes were registered; highly pathogenic trematodes from the following families were recorded in domestic and wild mammals: Fasciolidae, Paramphistomidae, Gastrothylacidae, Echinostomatidae, Strigeidae and Schistosomatidae.

Taxonomy of trematode cercarial fauna:

Class Trematoda Rudolphi, 1808
Subclass Digenea Carus, 1863
Family Paramphistomidae Fischoeder, 1901
1. *Calicophoron calicophorum* (Fischoeder, 1901).
2. *Calicophoron erschowi* Davydova, 1959.
3. *Liorchis scotiae* (Willmott, 1950)
Family Gastrothylacidae Stiles et Goldberger, 1910
4. *Gastrothylax crumenifer* (Creplin, 1847)
Family Fasciolidae Railliet, 1895
5. *Fasciola hepatica* Linnaeus, 1758
6. *Fasciola gigantica* (Cobb., 1856)
Family Notocotylidae Lühe, 1909
7. *Notocotylus attenuatus* (Rudolphi, 1809)
8. *Notocotylus ephemera* (Nitzsch, 1809)
Family Echinostomidae Dietz, 1909
9. *Echinostoma revolutum* (Frölich, 1802)
10. *Echinoparyphium aconiatum* (Dietz, 1909)
11. *Echinoparyphium recurvatum* (Linstow, 1873)
12. *Hypoderaeum conoideum* (Bloch., 1782).
Family Hematoloechidae Freitas & Lent, 1939
13. *Skrjabinoeces similis* (Looss, 1899)
14. *Pleurogenoides claviger* (Rudolphi, 1819)
15. *Strigea falconis* Szidat, 1928
16. *Apatemon gracilis* (Rudolphi, 1809)
17. *Cotylurus cornutus* (Rudolphi, 1809)
Family Diplostomidae Poirier, 1886
18. *Diplostomum spathaceum* (Rudolphi, 1899)
19. *Diplostomum helveticum* (Dubois, 1929)
Family Aporocotylidae Odhner, 1912
20. *Sanguinicola inermis* Plehn, 1905
Family Schistosomatidae Stiles et Hassall, 1898
21. *Schistosoma turkestanicum* Skrjabin, 1913
22. *Bilharziella polonica* (Kowalewsky, 1899)
23. *Trichobilharzia ocellata* (La Valette, 1854)
24. *Dendritobilharzia loossi* Skrjabin, 1929
25. *Dendritobilharzia pulverulenta* (Braun, 1901)
26. *Gigantobilharzia acotylea* Odhner, 1910
27. *Gigantobilharzia* sp.

The morphology of the discovered trematode cercariae is described below.

Calicophoron calicophorum (Fischoeder, 1901).
Host: *Planorbis planorbis*, *Anisus spirorbis*.
Locality: hepatopancreatic gland.
Discovery location: Karakalpakstan.

Morphology (Fig. 2a). Body length 200–350 µm, width 100–250 µm. The front part of the body is heavily pigmented. The eyes in the form of spots are located in the front of the body. Numerous cystogenic cells consist of oval or rod-shaped masses. Tail length 400–500 µm, tail width 40–50 µm. The oral sucker is smaller than the abdominal one. The diameter of the ventral sucker lying at the back end of the body is 0.03 mm. The long, two-branched intestinal tube is without the pharyngeal thickening. The excretory bladder is located at the back end of the body. The two main excretory ducts begin near the oral sucker, then connect with each other with transverse tubules and enter the bladder near the ventral sucker. Cercariae with caudal suckers develop in sausage-shaped rediae, which are without outgrowths. There are 10 to 15 cercariae in each redia.

Cercariae of *C. calicophorum* are recorded in the surveyed territory of Uzbekistan for the first time.

Maritae of *C. calicophorum* are common parasites of ruminants.

Calicophoron erschowi Davydova, 1959.

Host: *Planorbis ehrenbergi*, *Planorbis gredleri*, *Planorbis planorbis*.

Locality: hepatopancreatic gland.

Discovery location: Karakalpakstan.

Morphology (Fig. 2b). Cercariae outside the rediae have an oval body and a long tail. They are usually found in the liver of molluscs, sometimes in the gonads. These cercariae are largely sedentary and reach 1620–2950 µm in length and 1490–1930 µm in width. They have a well-differentiated pharynx, aesophagus, intestinal tubes, a ventral sucker, pigmented eyes and an excretory system.

Liorchis scotiae (Willmott, 1950)

Host: *Planorbis planorbis*.

Locality: hepatopancreatic gland.

Discovery location: Karakalpakstan.

Morphology (Fig. 2c). The cercariae are sedentary and reached 1730–2500 µm in length and 1500–2100 µm in width. Their pharynx, mouth, aesophagus, intestinal tubes, ventral sucker, eyes, and excretory system are clearly distinguishable. In subsequent days, they increased in size, acquired pigmentation and, fully ripe on the 38th day, emerged from the molluscs into the water. Mature cercariae have an oval dark body flattened dorso-ventrally and quite a long translucent tail. They are very mobile, their body constantly stretching and contracting. Size of the cercariae: body length – 2900–4250 µm, body width – 1080–1590 µm, tail length – 4750–6940 µm, tail width at the base – 50–90 µm.

At the anterior end there is a mouth opening leading to a well-developed pharynx, followed by a short aesophagus entering the intestine. The excretory system consists of excretory ducts running to the middle of the body, where they merge and enter the excretory bladder. An excretory duct runs from the bladder all along the tail and opens in its posterior part. The rudiments of the genitals are located along the midline of the body. The cercariae have clearly distinguishable pigmented eyes. There are many cystogenic and pigment cells in their body. With the help of silvering, 11–13 sensillae were found on the oral sucker. They formed a rim of 1–2 rows, while on the ventral sucker they varied in numbers.

The cercariae show negative geotaxis in the light and positive geotaxis in the dark; they demonstrate positive phototaxis and positive thermotaxis. In natural light, they show a positive taxis to yellow and green. Therefore, the process of *Liorchis cercariae* exiting from molluscs and their demonstration of certain taxes should be considered as an adaptation developed in the course of evolution, facilitating contact with the body of a definitive host.

Gastrothylax crumenifer (Creplin, 1847)

Host: *Planorbis planorbis*, *Planorbis ehrenbergi*, *Anisus spirorbis*.

Locality: hepatopancreatic gland.

Discovery location: Karakalpakstan.

Morphology (Fig. 2d). The body is ovoid, 190–250 µm long. The eye spots are conical. The tail is 650–950 µm long. The oral and ventral suckers are well developed.

Biology. The cercariae float on the surface of water. They live for several hours. The larvae show positive phototaxis and negative geotaxis.

Fasciola hepatica Linnaeus, 1758

Host: *Lymnaea truncatula*.

Locality: hepatopancreatic gland.

Discovery location: Karakalpakstan.

Morphology (Fig. 3). The body is 250–300 µm in length and 200–230 µm in width. The length of the tail is 0.45–0.60 mm. The diameter of the oral sucker is 400–600 µm, and the diameter of the ventral sucker is 500–600 µm. The intestinal tract consists of a pharynx and a pair of simple unbranched tracts. The excretory ducts stretch along the sides of the body and are connected by thin threads to flame cells. The cercariae develop in cylindrical elongated worm-like rediae. The rediae have a parturient pore in the front of the body, through which the cercariae exit. For some time, they remain free in the water. The cystogenic glands function during the period of cystogony, when the cercaria, after leaving the mollusc, turns into an adolescaria in the external environment.

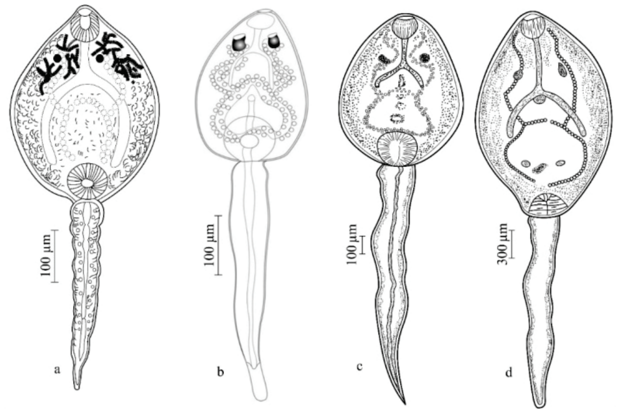

Fig. 2. *Calicophoron calicophorum* (Fischoeder, 1901) (*a*), *C. erschowi* Davydova, 1959 (*b*), *Liorchis scotiae* (Willmott, 1950) (*c*) and *Gastrothylax crumenifer* (Creplin, 1847) (*d*)

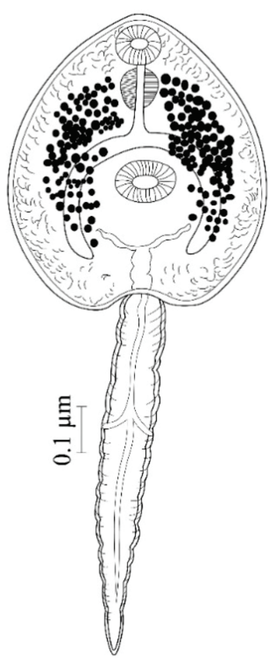

Fig. 3. *Fasciola hepatica* Linnaeus, 1758

The life of free-swimming cercariae is very short, from a few minutes to several hours.

A marita *F. hepatica* is a common parasite of mammals, including humans.

Fasciola gigantica (Cobb., 1856)

Host: *Radix auricularia*.

Locality: hepatopancreatic gland.

Discovery location: Karakalpakstan.

Cercariae of *F. gigantica* are somewhat larger than and morphologically identical to those of *F. hepatica*.

Notocotylus attenuatus (Rudolphi, 1809)

Host: *Radix auricularia*, *Planorbis planorbis*.

Locality: hepatopancreatic gland, gonad.

Discovery location: Karakalpakstan.

Morphology (Fig. 4a). The body is very mobile, reaches 120–135 µm in length and 100–140 µm in width; tail length is 170–350 µm, tail width is 27–36 µm. There are several short hairs on the head end. The oral sucker reaches 24–27 µm in diameter. The short aesophagus divides into intestinal branches that extend laterally and end blindly near the posterior end of the body. There are three eye spots, two of which lie laterally, at the level of the middle of the aesophagus, on its sides; one eye is located at the same level, but medially; all of them are concentrated from the dorsal side.

The excretory system is well developed. It is represented by one main medial tract (excretory bladder), from which two lateral vessels run forward along the dorsal side of the body, connecting near the intestinal fork. An excretory vessel departs from the posterior end of the excretory bladder, going into the tail; the vessel extends for one third of the length of the tail or a little more, and then divides into two short dorso-ventral vessels. Rudiments of sex glands in the form of a cluster of small compact cells are observed between the posterior ends of the intestinal tracts.

Cercariae develop in rediae, which vary greatly in form. There are 2 to 15 cercariae in their body cavity. Cercariae encyst after exiting the mollusc, turning into adolescariae. The diameter of the adolescaria is 225–240 µm.

Maritae of blood flukes *N. attenuatus* are widespread parasites of ducks, geese, and gulls (Shakarbaev, 2017).

Notocotylus ephemera (Nitzsch, 1809)

Host: *Planorbis planorbis*.

Locality: hepatopancreatic gland, gonad.

Discovery location: Karakalpakstan.

Morphology (Fig. 4b). This cercaria is larger than that of the previous species. The body is 560–620 µm long, 156–210 µm wide. Tail length is 510–640 µm, width 52–60 µm. The diameter of the oral sucker is 62–70 µm. The pharyngeal diameter is 60–70 µm, the intestinal length is 520 µm. The intestine is filled with dark granular substance. The maritae are parasites of birds (Shakarbaev, 2017).

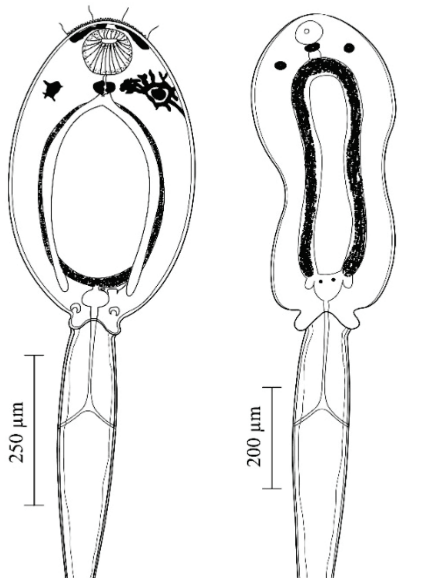

Fig. 4. *Notocotylus attenuatus* (Rudolphi, 1809) (*a*) and *N. ephemera* (Nitzsch, 1809) (*b*)

Echinostoma revolutum (Frölich, 1802)

Host: *Radix auricularia*, *Lymnaea stagnalis*, *Planorbis planorbis*, *Anisus spirorbis*.

Locality: hepatopancreatic gland, gonad.

Discovery location: Karakalpakstan.

Description (Fig. 5a). The cercariae reach 323 µm in length and 95 µm in width. The length of the tail is 450 µm. The oral sucker, reaching 43–46 µm in size, turns into a weakly pronounced prepharynx, which is followed by the pharynx 17–21 µm in size.

The aesophagus splits in front of the ventral sucker into intestinal branches, which extend to the end of the body. 12 excretory ducts of the head glands, arranged in two groups on the sides of the aesophagus, open into the oral sucker.

The head structure is similar to that in adults: it consists of 37 spikes, 10 of which are located on the angular ventral lobes, 5 on each; next come 6 lateral spikes on each side and 15 dorsal ones arranged in two rows. Cuticular spikes are clearly visible on the ventral and dorsal surfaces in coloured specimens. The excretory bladder is divided into a smaller part at the front and a larger one at the back. Two main excretory vessels branch off it, extending forward almost as far as the pharynx and are filled with refractive granules. Reaching the level of the oral sucker, the vessels form loops and go to the posterior end of the body, where they again turn headlong and reach the oral sucker. The total number of the cirtocytes is about 36. These cells are arranged in six groups, three in each. The tail of the cercaria is characterised by the presence of a dorsal fin membrane.

Once in the body of a supplementary host, the cercariae encyst, turning into metacercariae.

Mature trematodes *Echinostoma revolutum* are common parasites of wetland birds.

Echinoparyphium aconiatum (Dietz, 1909)

Host: *Lymnaea corvus*, *L. stagnalis*, *Radix auricularia*, *Planorbis planorbis*.

Locality: hepatopancreatic gland.

Discovery location: Karakalpakstan.

Morphology (Fig. 5b). Cercariae body length is 666–682 µm, body width is 294–336 µm. The adoral disc is well developed and equipped with 37 spikes. The body is filled with glandular cells, whose ducts open in front of the oral sucker. The oral sucker is 62 x 86 µm in diameter, the abdominal one is 1100 x 1200 µm. The digestive system consists of a short pharynx, a long aesophagus and branches of the intestine. The excretory system is characteristic of other representatives of the family. The formula of the excretory system is expressed as:

2[((1+1+1)+(1+1+1)+(1+1+1)) ((1+1+1)+(1+1+1)+(1+1+1))]=36.

The tail of the cercaria is 563–623 µm long. The tail, like the body of the cercaria, bears asymmetrically arranged hairs.

Biology. Cercariae develop in large rediae. Mature cercariae leave the host mollusc. The cercariae we found do not differ in morphometric features from those described earlier by Chernogorenko (1983). Once in the body of the second intermediate host (*R. auricularia*, *L. stagnalis*), the cercariae turn into metacercariae. *E. aconiatum* maritae were recorded in wetland birds, mainly ducks.

Echinoparyphium recurvatum (Linstow, 1873)

Host: *Radix auricularia*.

Locality: hepatopancreatic gland, gonad.

Discovery location: Karakalpakstan.

Morphology (Fig. 5c). The oval elongated body (440 µm long, 240 µm wide) is equipped with a collar typical of Echinostomatidae. The tail does not have an undulating membrane, its length is 430 µm and width is 70 µm. The diameter of the oral sucker is 60 µm. The head collar is equipped with spikes. The pharynx is present. The aesophagus reaches the ventral sucker, located slightly behind the middle of the body. The diameter of the cercaria's ventral sucker is 70 µm. The intestinal tracts reach the excretory bladder. Common parasites of geese and other wetland birds.

Hypoderaeum conoideum (Bloch., 1782).

Host: *Lymnaea corvus*, *L. stagnalis*, *Radix auricularia*.

Locality: liver and mantle cavity of molluscs.

Discovery location: Karakalpakstan.

Morphology (Fig. 5d). The length of the cercaria's body is 200–420 µm, the width is 190–210 µm. Tail length is 280–390 µm, width 40–44 µm. The tail has no undulating membrane. The surface of the body is covered with small spikes arranged in transverse rows. The oral sucker is slightly displaced ventrally and reaches a size of 53–63 µm; it is surrounded by a poorly developed adoral disc, along the circumference of which small spikes reaching 99 µm in length form a double alternating row. The total number of spikes is 50–54. The ventral sucker is located in the posterior half of the body and has a diameter of 76–81 µm. The oral sucker is followed by a prepharynx, passing into a pharynx, reaching a size of 26–28 x 14–15 µm. In front of the ventral sucker, the intestine bifurcates and extends its branches to the posterior end of the body. The excretory system consists of a bladder with two vessels branching off its front part. Both excretory vessels go to the front of the body, reach the level of the adoral disc, where they form a loop and descending branches filled with rounded refractive bodies. Cirtocytes are present in large numbers. Inside the tail there is a median excretory vessel, which in the first third of the tail branches into two short lateral ducts opening outside.

The maritae are common parasites of geese, including domestic ones (Sultanov, 1963; Shakarbaev et al., 2020).

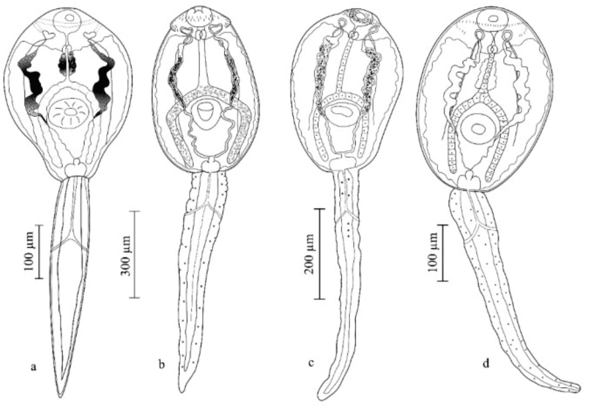

Fig. 5. *Echinostoma revolutum* (Frölich, 1802) (*a*), *Echinoparyphium aconiatum* (Dietz, 1909) (*b*), *E. recurvatum* (Linstow, 1873) (*c*) and *Hypoderaeum conoideum* (Bloch., 1782) (*d*)

Skrjabinoeces similis (Looss, 1899)
Host: *Planorbis planorbis*.
Locality: hepatopancreatic gland.
Discovery location: Karakalpakstan.

Morphology (Fig. 6). The cercariae of this species are small, relatively sedentary. The body length is 84–146 µm, the width is 42–72 µm. The length of the tail is 90–152 µm. The tail has no natatory membrane. The mouth sucker bears a long and narrow stylet (28–32 µm). The diameter of the oral sucker is 33–38 µm. The ventral sucker is located just below the middle of the body and is significantly smaller in size than the oral one – 18–28 µm in diameter.

The digestive system of the cercaria consists of a short pre-pharynx, an oval pharynx, a narrow and relatively long aesophagus and two intestinal branches.

The glandular system of the cercaria consists of six pairs of penetration glands located on the sides of the body. The ducts of these glands open at the tip of the stylet. The excretory formula is expressed as 2[(3+3+3)+(3+3+3)] = 36. The bladder is large and U-shaped. Cercariae develop in sporocysts of various sizes. Mature trematodes are widespread and are common parasites of amphibians.

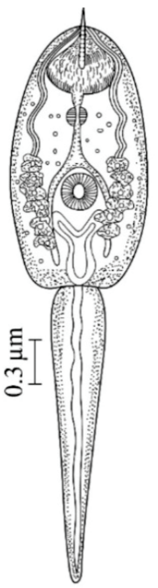

Fig. 6. *Skrjabinoeces similis* (Looss, 1899)

Strigea falconis Szidat, 1928
Host: *Planorbis planorbis*.
Locality: hepatopancreatic gland.
Discovery location: Karakalpakstan.

Morphology (Fig. 7). The body is 140–188 x 39–56 µm in size, the tail is 0.156–0.186 mm long, the furcae are 166–620 µm long. The terminal organ is almost round, 36–44 µm, larger than the ventral sucker (22–26 µm), and is equipped with 7 rows of relatively large spikes. The spikes go as far as the anterior edge of the ventral sucker. The ventral sucker bears two concentric rows of spikes. The pharynx is 80–90 µm in diameter, the intestinal fork lies somewhat behind the middle point between the pharynx and the ventral sucker. The intestinal tracts do not reach the level of the excretory bladder. Four pairs of the penetration glands form two longitudinal rows situated more dorsally than the intestine. The formula of the excretory system is 2[(1+1)+(1+1+(1)] = 10. The elongated caudal corpuscles make up 5–6 pairs. The tail carries 5 rows of sensitive bristles, the first row at the base of the tail, the other four in its rear half.

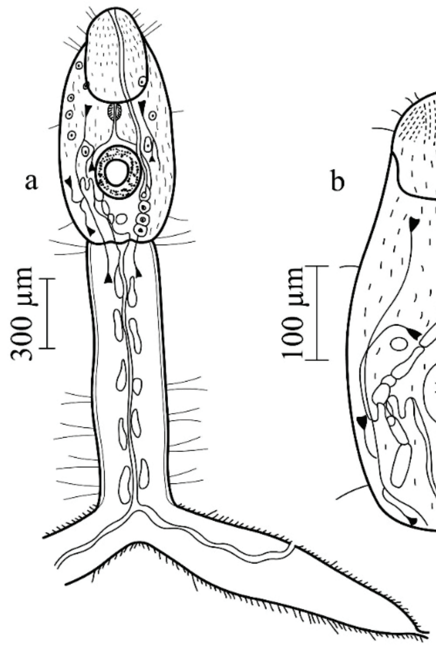

Fig. 7. *Strigea falconis* Szidat, 1928:
a – cercaria; *b* – body of a cercaria without a tail

The penetration glands begin at the level of the posterior edge of the ventral sucker. The ventral sucker is equipped with numerous spikes arranged in 2–4 rows. In general, the structures of the cercariae correspond to the descriptions given by Arystanov (1968) and Odening (1967).

In the body of amphibians, performing the role of intercalary hosts, cercariae turn into mesocercariae.

Metacercariae of this trematode are recorded in a number of species of amphibians, reptiles, birds and mammals. Mature forms parasite in the intestines of numerous bird species (Shakarbaev, 2017; Shakarbaev et al., 2020).

Apatemon gracilis (Rudolphi, 1809
Host: *Lymnaea stagnalis*, *Radix auricularia*.
Locality: hepatopancreatic gland.
Discovery location: Karakalpakstan.

Morphology (Fig. 8a). Body length is 12–16 µm, width 45 µm; tail length is 180 µm, width 40 µm; furcae length is 17 µm, diameter of the anterior organ is 40 x 45 µm, diameter of the ventral sucker is 28–30 µm.

The front part of the body is covered with small spikes. The anterior organ is pear-shaped. The ventral sucker is equipped with two rows of small spikes. The penetration glands are arranged in three rows: there are three cells in each of the first two rows, and two cells form the third row. The cytoplasm of the cells is granular. They have a pharynx. The aesophagus is tubular, the intestinal branches are long, reaching to the posterior end of the body. Unpigmented eyes lie in front of the ventral sucker.

The excretory bladder is V-shaped. The formula of the excretory system is 2[(2)+(2+2)+(1)] = 14.

Cotylurus cornutus (Rudolphi, 1809)
Host: *Lymnaea stagnalis*, *Radix auricularia*.
Locality: hepatopancreatic gland, gonad.
Discovery location: Karakalpakstan.

Morphology (Fig. 8b). Body length is 16–22 µm, width (maximum) 66 µm. The length of the tail stem is 18–25 µm, the branches of the tail are 22–23 µm long. The cuticle has bumps. There is a short pre-pharynx, a round pharynx, a tubular aesophagus and long intestinal branches which separate at a short distance from the ventral sucker. The anterior organ is large, round or pear-shaped, 50–52 µm long. The penetration glands form 2 pairs, located directly in front of the ventral sucker. The diameter of the ventral sucker is 38–42 µm. The formula is 2[(2+2)+(2+2)+(2)] = 20. There are colourless eyes (2). Cercariae develop in long sporocysts.

Maritae are common parasites of birds.

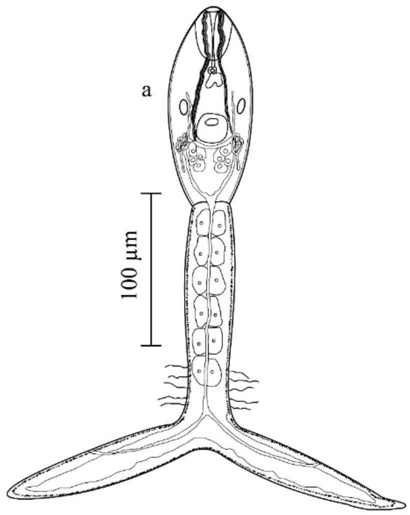

Fig. 8. *Apatemon gracilis* (Rudolphi, 1809) (*a*) and *Cotylurus cornutus* (Rudolphi, 1809) (*b*)

Diplostomum spathaceum (Rudolphi, 1808)
Host: *Lymnaea stagnalis*, *Radix auricularia*.
Locality: hepatopancreatic gland.
Discovery location: Karakalpakstan.

Morphology (Fig. 9a). Body length body is 20–26 µm, width is 50–60 µm, Length of the tail is 28 µm, width is 38 µm, length of the furcae is 25 µm. The diameter of the anterior organ is 45–55 µm, the diameter of the anterior organ is 28 µm.

The front part of the body is covered with spikes. Behind the ventral sucker there are 4 cells, penetration glands with a granular substance. The excretory system is characteristic of trematodes in the genus *Diplostomum*. The cirtocytes are arranged according to the formula 2[((1+1+1)+(1+1+1))+(1+1)] = 16. The digestive system consists of the prepharynx, p*harynx, aesophagus and intestine.*

Biology. Cercariae develop in thread-like sporocysts. Developed cercariae exit from the host mollusc into water.

They begin to search very actively for the next host. The immobile position is very characteristic of them. When they float, the furcae are positioned perpendicular to the axis of the tail stem, and the body is lowered down.

Maritae of *D. spathaceum* are common parasites of gulls. They also parasitise a wide range of wetland birds, including the domestic duck.

Diplostomum helveticum (Dubois, 1929)
Host: *Lymnaea stagnalis*, *Radix auricularia*.
Locality: hepatopancreatic gland, gonad.
Discovery location: Karakalpakstan.

Morphology (Fig. 9b). The cercariae are spindle-shaped. Body length is 168–210 µm, tail stem length is 175–210 µm. The length of the tail branches is 180–215 µm, the width of the body is 63–78 µm. The front organ is pear-shaped, 62 x 32 µm in size, equipped with a number of hooks. Behind them is a section of randomly arranged spikes. The ventral sucker is 55 x 55 µm, equipped with large spikes arranged in regular rows.

The digestive system consists of a short prepharynx, pharynx, aesophagus and two long intestinal branches. The large penetration glands forming two pairs are located behind the ventral sucker, with two median cells lying one behind the other, and two large lateral ones on either side of the median cells. There are six pairs of flame cells in the body of the cercaria. The excretory system is expressed by the formula 2[(1+1+1)+(1+1+1)+(1+1)] = 16. The colourless eyes are at the level of the pharynx.

Biology. Cercariae develop in thin thread-like sporocysts. Developed cercariae exit from the host mollusc into water. They show a positive phototaxis, and penetrate into the body of fish – the second intermediate host – after turning into metacercariae.

Mature flukes are parasites of wetland birds, mainly gulls.

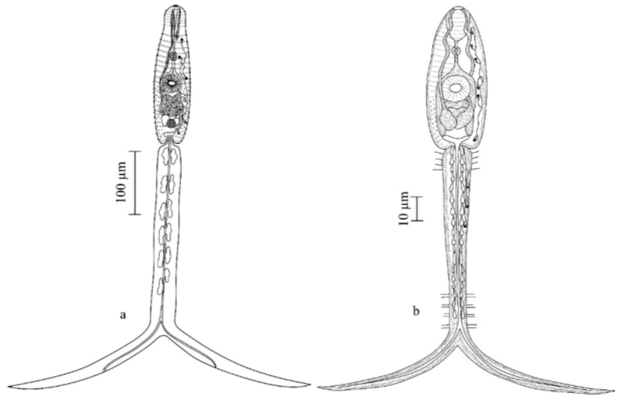

Fig. 9. *Diplostomum spathaceum* (Rudolphi, 1899) (*a*) and *D. helveticum* (Dubois, 1929) (*b*)

Sanguinicola inermis Plehn, 1905
Host: *Radix auricularia*, *R. peregra*.
Locality: hepatopancreatic gland, gonad.
Discovery location: Karakalpakstan.

Morphology (Fig. 10). Cercariae are usually small. The front end is pointed, the back end is rounded. The dorsal surface of the body is provided with a transparent fin membrane that stretches from the lower end of the anterior organ to the base of the tail. The tail consists of a long stem and two short branches equipped with a membrane. The body length of the cercariae is 95–99 µm, the body width is 28–30 µm. The length of the tail stem is 242–250 µm, the length of the tail branches (furcae) is 112–116 µm.

The anterior organ is conical and separates the rest of the body by a noticeably depressed area. At the very end of it there is a pair of conical spikes. The penetration glands consist of seven to eight pairs of rounded cells. The intestine is pouch-like. The intestinal branches are poorly visible. The eyes are present, but they are hardly noticeable. The excretory formula is expressed as 2[(2+2)] = 8. The urine bladder is small. Two excretory channels run from it to the tail, opening at the end of the forks. Development occurs in light yellow thread-like sporocysts. After leaving the body of a mollusc, the cercaria penetrates into the body of Cyprinidae fish.

Schistosoma turkestanicum Skrjabin, 1913
Host: *Radix auricularia*.
Locality: hepatopancreatic gland.
Discovery location: Karakalpakstan.

Morphology (Fig. 11a). Cercariae are apharyngeal brevifurcocercariae, which have no eyes.

The tegument is equipped with numerous clearly visible spikes. They become increasingly smaller from head to tail. The body of the cercaria is oval, 160–189 µm long and 48–64 µm wide. The tail stem is cylindrical, slightly tapering towards the end. Tail length is 193–231 µm, tail width is 24 µm. The tail furcae are 80–96 µm long.

The anterior organ is muscular, pear-shaped or oval, 58–63 µm long and 50–54 µm wide. It is located in the front of the body.

The penetration glands consist of 5 pairs of cells. Their ducts are directed forward, towards the anterior organ.

The ducts are very long. These glands almost fill the entire inner surface of the cercaria. The ventral sucker is well developed and located in the back of the body. Its dimensions are 50–59 µm.

Digestive system. The mouth opening is located ventrally. It leads to the aesophagus, which is connected to the intestine. The configuration of the intestinal tube varies depending on the position of the body. The nervous system consists of nerve cells forming clusters that are connected by thin fibres. The nerve ganglion is located in the middle part of the body. The excretory system consists of four pairs of flame cells and tubes connecting them. The excretory canal opens at the end of the tail bifurcation. The location of the flame cells is expressed by the formula 2[(1+1)+(1+1)+(1)] = 10.

The genital system is usually not differentiated. It consists of a cluster of spherical cells located behind the ventral sucker.

Biology. Cercariae develop in sporocysts. Developed cercariae exit the host mollusc into the water and actively penetrate through the skin into the mammalian bloodstream, where they reach the maturity stage (Azimov et al., 2019; Shakarbaev et al., 2020). The cercariae show positive phototaxis and negative geotaxis.

Maritae of *Sch. turkestanicum* are focally distributed parasites of mammals, including domestic animals (Azimov, 1975, 1986; Azimov et al., 2019; Akramova et al., 2023).

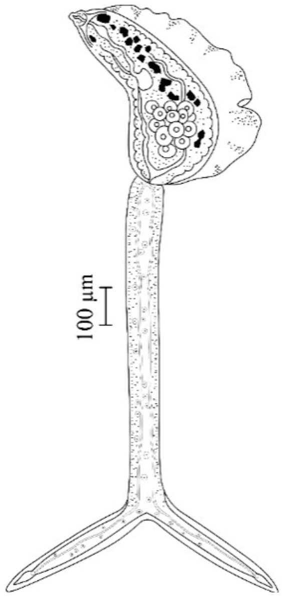

Fig. 10. *Sanguinicola inermis* Plehn, 1905 (=*Cercaria critata* La Valette, 1852)

Bilharziella polonica (Kowalewsky, 1895)
Host: *Planorbis planorbis*, *P. tangitarensis*.
Locality: hepatopancreatic gland.
Discovery location: Karakalpakstan.

Morphology (Fig. 11b). The body of the cercaria is 217–228 µm long and 42–68 µm wide. The length of the tail stem is 274–302 µm, the width is 22–32 µm, the length of the branches (furcae) of the tail is 118–128 µm. The cuticle of the body is covered with spikes. The head organ is large and well developed. The digestive system consists of a mouth, aesophagus and intestinal branches.

There is one pair of eyes in the middle part of the body. The ventral sucker is located behind the intestinal branches. The penetration glands are strongly developed and form five pairs. The ducts of the penetration glands open in the front part, on the sides of the mouth opening.

The excretory system consists of 7 pairs of flame cells (cirtocytes), which are connected by outgoing channels. The excretory system is expressed by the formula 2[(1+1+1)+(1+1+1)+(1)] = 14. Cercariae develop in thread-like sporocysts.

B. polonica is a common parasite of wetlands birds, including domestic ducks and geese (Akramova, 2011; Shakarbaev, 2017; Akramova et al., 2022).

Trichobilharzia ocellata (La Valette, 1855)
Host: *Lymnaea stagnalis*, *Radix auricularia*.
Locality: hepatopancreatic gland, gonad.
Discovery location: Karakalpakstan.

Morphology (Fig. 11c). The cercariae are light grey. The body is cylindrical. The body, tail stem and branches (furcae) of the tail of the larvae are equipped with small spikes. Body length is 22–42 µm, width is 10–11 µm. The length of the tail is 32–54 µm. The length of the tail branches is 22–44 µm, width is 50–60 µm.

There are two pigmented eyes on the anterior surface of the body of the cercaria. The cercaria is equipped with an anterior organ and an abdominal sucker.

The anterior organ is large, pear-shaped, 850–990 µm long and 60–70 µm wide. The ventral sucker is small (diameter 33–38 µm). The digestive system is characterised by a rudimentary intestine. The penetration glands are large, making up five pairs. The two front pairs are located in front of the ventral sucker and have coarse granules. The other three pairs are located one after the other in the back of the body. The excretory system is expressed by the formula 2[(1+1+1)+(1+1+1)+(1)] = 14. There is an excretory atrium. The tail stem is well developed. The branches of the tail (furcae) carry an inconspicuous natatory membrane.

Biology. Cercariae develop in thread-like sporocysts. Mature cercariae leave the host mollusc into water. Cercariae of this species are known as *Cercaria ocellata* (Dubois, 1929). They are larvae of the trematode *T. ocellata*, which parasitises the circulatory system of waterfowl, including domestic ducks and geese (Chernogorenko, 1983; Akramova, 2011).

The cercariae show positive phototaxis and negative geotaxis and characterised by a specific resting position (Shakarbaev, 2017). Cercariae leave molluscs most actively in the morning and evening hours. The cercariae make rapid swaying movements, ascend to the surface layers of water and attach themselves with the help of ventral suckers.

The cercariae stay live in water from 72 hours to several days.

Dendritobilharzia loossi Skrjabin, 1924
Host: *Anisus spirobis*.
Locality: hepatopancreatic gland.
Discovery location: Karakalpakstan.

Morphology (Fig. 11d). The body of the cercariae is elongated. Body length is 220–246 µm, width is 63–78 µm. The anterior organ is elongated and oval (70–82 µm long). The ventral sucker is significantly displaced from the middle of the body backwards. It has a rounded shape and is 32–34 x 28–30 µm in size. The tail stem is 1.5 times longer than the body and is 260–370 µm long and 26 µm wide. The tail furcae are slightly shorter than the tail stem, their length ranging from 126 to 146 µm. The natatory membrane is missing.

The digestive system consists of the aesophagus and two rudimentary intestinal branches which reach the level of the first pair of penetration glands. The penetration glands are large and form 5 pairs, 2 of which are pre-acetabular and 3 are post-acetabular. There are two pigmented eyes.

The excretory system is expressed by the formula 2[(1+1+1)+(1+1+1)+(1)] = 14. The cercariae that have emerged from molluscs into the water are very active. They can move with either head or tail forward. They move solely by contracting the muscles of their tail stem. They use their tail furca to steer. Cercariae actively penetrate into the bloodstream through the skin of birds.

Mature trematodes *D. loossi* are parasites of pelicans and ducks. *D. loossi* has a limited distribution (Shakarbaev, 2017).

Dendritobilharzia pulverulenta (Braun, 1901)
Host: *Anisus spirobis*, *Planorbis planorbis*.
Locality: hepatopancreatic gland.
Discovery location: Karakalpakstan.

Morphology (Fig. 11e). Cercariae of this species are similar to those of *D. loossi*. Cercariae of *D. pulverulenta* parasitise molluscs *Anisus vortex* and *Planorbis planorbis* (Khalifa, 1976). The morphometric parameters of the cercariae given by Khalifa (1976) largely coincide with our data (Table 4, Fig. 23a).

Table 4
Basic morphometric parameters of the cercaria of *Dendritobilharzia pulverulenta* (Braun, 1901)

Parameters	According to Khalifa (1976), μm		Our data, μm
	in *Planorbis planorbis*	in *Anisus vortex*	*Anisus spirobis*
Body length	232–243	174–220	184–244
Body width	69.6–81.2	50.0–63.8	59–68
Tail length	371.2	224.8–371.2	220–282
width	23.2–29.0	23.3–34.8	23–30
Furcae length	127.6	127.6–150.8	127–137
width	11.6–17.4	17.4–29.2	12–18
Length of the anterior organ	85.1–89.7	69–80.5	70–79
width	52.9–55.2	46–48.3	48–52
Ventral sucker	34.5 x 27.6	32.2 x 29.9	32–28

Gigantobilharzia acotylea Odhner, 1910

Host: *Physa fontinalis*.

Locality: hepatopancreatic gland.

Discovery location: Karakalpakstan.

Morphology (Fig. 11f). Cercariae are found in molluscs in June, July, August and in the first third of September.

The cuticules of the cercariae are covered with small spikes, whose number decreases from the head to the tail. Cuticular spikes are densely concentrated near the anterior organ and ventral sucker. The mouth opening is located subterminally. The aesophagus is quite long. The intestinal branches (2) are located in front of the ventral sucker.

There are 5 pairs of penetration glands: the first one is located in front of the ventral sucker, the second pair is at the level of the ventral sucker, and the other three are behind it. All the glands are large, their sinuous ducts pass inside the anterior organ and reach the mouth opening. The excretory system of the cercariae consists of the flame cells (cirtocytes) and channels branching off them. The main excretory tract runs along the longitudinal axis of the caudal stem, at the end of which it bifurcates and opens with excretory pores at the back of the furcae. The structure of the excretory system is expressed by the formula 2[(1+1+1)+(1+1+1)+(1)] = 14. The cirtocytes are arranged in the following way: three pairs in the front of the body, three pairs behind them and one pair in the front part of the caudal stem. Cercariae develop in sporocysts. Mature cercariae leave the host mollusc. In the water, the cercariae make quite active movements, rising to the surface. They show positive phototaxis and negative geotaxis.

An increase in illumination and the rising of temperature to 25–32 °C makes cercariae exit most actively from infected molluscs.

The ability of cercariae to actively penetrate into the bloodstream through the skin of birds was experimentally confirmed by Azimov (1986), Akramova (2011) and Shakarbaev (2017). These cercariae are larvae of the trematode *Gigantobilharzia acotylea*, which parasitises the circulatory system of gulls and ducks (Akramova, 2011; Shakarbaev et al., 2020).

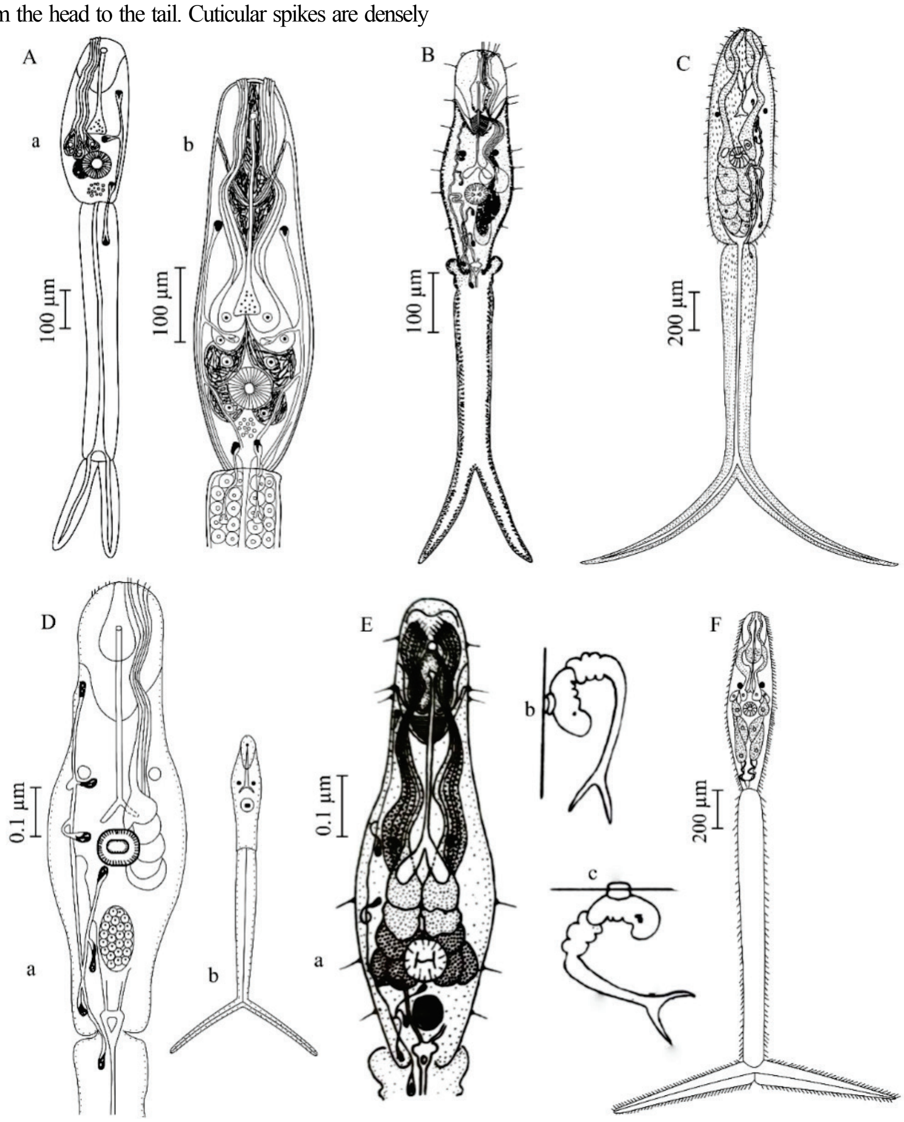

Fig. 11. The trematode cercarial fauna: *A – Schistosoma turkestanicum* Skrjabin, 1913: *a* – general view of the cercaria; *b* – organ details; *B – Bilharziella polonica* (Kowalewsky, 1899); *C – Trichobilharzia ocellata* (La Valette, 1854); *D – Dendritobilharzia loossi* Skrjabin, 1924: *a* – details of the cercaria's organs; *b* – general view; *E – Dendritobilharzia pulverulenta* (Braun, 1901): *a* – details of the cercaria's organs, *b–c* – resting pose (according to Khalifa, 1976); *F – Gigantobilharzia acotylea* Odhner, 1910

Gigantobilharzia sp. Cercaria
Host: *Physa fontinalis*.
Locality: liver.
Discovery location: Karakalpakstan.

Morphology. This cercaria is larger than the previous species. The structure of the organism is very similar to that of the cercariae of *Gigantobilharzia acotylea*. Since there is not enough material, we leave this cercarium – *Gigantobilharzia* sp.

Of the 27 cercaria species found in the molluscs of Karakalpakstan, 20 are larvae of trematodes of wetland birds, and 6 are those of mammals. Fish and amphibians are parasitised by one cercariae species each.

Comparing the list of cercariae we found with the list of fluke larvae provided by Arystanov (1969), we see that we did not identify many of the cercariae species in molluscs. The author studied the fauna of trematode cercariae in molluscs in the south of the Aral Sea and in the Amu Darya Delta, where 37 species of flukes from 12 families were registered. It should be noted that over the past period (1969–2019), large environmental changes occurred in the territory of Karakalpakstan associated with the drying of the Aral Sea, the negative consequences of which are well known.

Currently, the Aral Sea has lost its former importance. The remaining part has turned into a highly saline body of water unsuitable for the habitation of molluscs – trematodes' intermediate hosts, – and does not attract wetland birds or other vertebrates which flukes use as their definitive hosts. Probably, all these factors have led to a change in the fauna of molluscs and, as a result, to a drop in the species diversity of the cercarial fauna.

Larval species, whose intermediate hosts were *Anadonta piscinalis*, *Thedoxus pallasi*, and *Bithynika caerulans*, were not found in the trematode cercarial fauna recorded by Arystanov (1969). At the same time, the cercarial fauna of trematodes in the molluscs *Radix auricularia*, *Lymnaea stagnalis*, *Planorbis planorbis*, *P. gredleri* and *P. planorbis* remains stable in floodplain lakes. The cercarial species discovered in these molluscs form the core of the modern cercarial trematode fauna in Karakalpakstan.

The trematode cercarial fauna in the studied region differs significantly from that of fluke larvae in other parts of Uzbekistan. Thus, the following elements are most characteristic of the cercarial fauna of Karakalpakstan: *Schistosoma turkestanicum*, *Bilharziella polonica*, *Trichobilharzia ocellata*, *Dendritobilharzia loossi*, *D. pulverulenta*, *Gigantobilharzia acotylea*, *Gastrothylax crumenifer* and *Fassiola gigantica*. Although widely present in Karakalpakstan, these species are not found in other regions of Uzbekistan, with the exception of *Bilharziella polonica* and *Trichobilharzia ocellata* (Shakarbaev, 2017). The role of different species of molluscs as intermediate hosts of trematodes varies greatly. The richest cercarial fauna is recorded in *Radix auricularia* (14 species), *Planorbis planorbis* (12 species) and *Lymnaea stagnalis* (9 species). Significantly fewer species of trematode larvae are recorded in other species.

The presented materials show the great role of molluscs in the spread of parasitic diseases of vertebrates caused by trematodes in Karakalpakstan. This particularly concerns trematodes of wetland birds and agricultural and commercial animals, in which about 95 species of flukes have been recorded (Toremuratov, 1964; Osmanov, 1971; Sultanov et al., 1975; Azimov et al., 2019; Arepbaev et al., 2022). Species of trematodes from a number of families, such as Echinostomidae, Notocotylidae, Strigeidae, Diplostomidae, Aporocotylidae, Fasciolidae, Gastrothylacidae and Schistosomatidae cause serious helminthiases in animals and humans.

A comparative analysis of trixenic parasitic systems, including aquatic molluscs (Gastropoda) and related helminths, reveals some ways of evolution in the life cycles of parasitic worms. The life cycles of trematodes occurring exclusively with the participation of molluscs are thoroughly studied (Ginetsinskaya, 1968). The authors' views generally coincide in that the life cycle of modern trematodes consists in the alternation of several independent generations, differing primarily in the method of reproduction and adherence to certain host animals. Molluscs are parasitised by parthenogenetic generations – sporocysts and rediae. In most cases, parthenitae are represented not by one, but several generations, replacing each other. The ontogenesis of the first parthenogenetic generation is accompanied by a metamorphosis experienced by a free-living dispersal larva, a miracidium, penetrating into molluscs. Parthenitae are replaced by a hermaphrodite (bisexual) generation, whose final developmental phase, a marita, parasitises in a vertebrate host. The ontogenesis of individuals from this generation is characterised by a wide diversity of variants resulting from the complex adequate evolution of trematodes. Adhering to the hypothesis of trematode heterogeneity, we note that events that occurred during the evolution of trematode life cycles are implemented in time and space within the existing parasite–host systems. The regularity of the formation and functioning of the system depends on the ecological and trophic relationships between the components of the parasite–host system. The ecological relationships between flukes and hosts are quite clear and, apparently, do not require much discussion.

We also conducted studies of some representatives of the class Insecta in the rangelands of Karakalpakstan in order to specify their infection with helminth larvae (Table 5).

The prevalence recorded in the studied insects infected with helminth larvae ranged widely from 1.1% to 14.4%. The identified larvae turned out to be representatives of Cestoda (3 species), Trematoda (1 species) and Nematoda (11 species, Table 5).

Table 5
Natural rate of infection with helminth larvae
in the insects of Karakalpakstan

Family	Examined, individuals	Infected, %	Helminth larvae detected
Libellulidae	147	2.7	*Prosthogonimus ovatus* (Rudolphi, 1803) Lühe, 1899
Acrididae	739	2.4	*Aprocta cylindrica* Linstow, 1883 *Diplotriaena isabellina* Koroliova, 1926
Carabidae	148	1.9	*Raillietina cesticillus* (Molin, 1858) *Echinolepis carioca* (Magalhães, 1898)
Tenebrionidae	368	2.7	*Gongylonema pulchrum* Molin, 1857 *Spirura rytipleurites* (Deslongchamps, 1824) *Choanotaenia infundibulum* (Bloch, 1779)
Scarabaeidae	346	14.4	*Gongylonema pulchrum* Molin, 1857 *Choanotaenia infundibulum* (Bloch, 1779) *Echinolepis carioca* (Magalhães, 1898)
Culicidae	2161	1.1	*Dirofilaria immitis* (Leidy, 1856) *Dirofilaria repens* Railliet & Henry, 1911 *Dipetalonema evansi* (Lewis, 1882) *Setaria labiatopapillosa* (Alessandrini, 1838)
Simulidae	1048	2.5	*Onchocerca lienalis* Stiles, 1892
Musidae	1036	2.1	*Stephanofilaria stilesi* Chitwood, 1934 *Parabronema skrjabini* Raskowska, 1924

The largest number of species (4) of helminth larvae was found in scarab beetles – *Gongylonema pulchrum*, *Spirura rytipleurites*, *Choanataenia infundibulum* and *Echinolepis carioca*, and flies (2 species) – *Stephanofilaria stilesi* and *Parabronema skrjabini*. The recorded species belong to the classes Nematoda and Cestoda. The intensity of infection ranged from single to 11–17 individuals.

Let us take a closer look at the fauna of helminth larvae found in certain groups of insects – intermediate hosts of the parasites.

Representatives of the order Odonatoptera (dragonflies) are relatively large insects with an elongated body. Uzbekistan is inhabited by about 60 species (Azimov et al., 1993), some of which are found on the territory of Karakalpakstan. The most common are dragonflies from the family Libellulidae (about 30 species). Helminthological examination revealed larvae (metacercariae) of trematodes in 3 species of dragonflies – *Orthetrum brunneum*, *Libellula depressa* and *Sympetrum vulgatum* on the territory of the Karadjar lake system in the Kungrad District in July 2022. Dragonflies infected with metacercariae showed an average prevalence of 2.7%. The intensity of infection ranges from 3 to 5 individuals. The metacercariae were recorded in the body cavity of dragonflies. The larvae found turned out to be identical to the metacercariae of *Prosthogonimus ovatus* (Rudolphi, 1803) described by researchers (Kabilov, 1983).

Class Trematoda Rudolphi, 1808
Family Prosthogonimidae Lyhe, 1899
Prosthogonimus ovatus (Rudolphi, 1803)
Intermediate host: *Planorbis gredleri*.

Supplementary host: *Orthetrum brunneum*, *Libellula depressa*, *Sympetrum vulgatum*.

Locality: abdominal cavity.

Discovery location: Karakalpakstan.

Metacercariae of *P. ovatus* are enclosed in large round cysts 325–384 µm in diameter (Fig. 12). The cyst's shell is thick and transparent. The suckers are well developed. The size of the oral sucker is 86–92 x 60–66 µm, the ventral one is 90–96 x 64–68 µm. The pharynx is spherical. The excretory bladder is well distinguished (Kabilov, 1983). The adult form of *P. ovatus* parasitises birds in Uzbekistan (Sultanov, 1963).

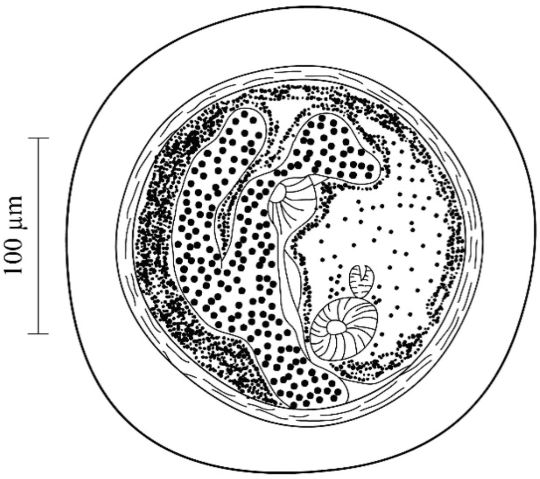

Fig. 12. *Prosthogonimus ovatus* (Rudolphi, 1803) larvae from a dragonfly

Locusts – Acarididae. Insects from the locust family are the largest representatives of the order Orthoptera. They inhabit various natural landscapes – deserts, steppes, arid foothills and mountains. Acarididae in Uzbekistan comprise 85 species, many of whose representatives are very abundant (Medetov, 2018). Many species are serious pests of plants in both natural complexes and agrocoenoses. On the other hand, many locust species are involved in the life cycles of helminths, mainly nematodes (Anderson, 2000; Saparov, 2016; Medetov, 2018).

Our study of 739 individuals of locusts revealed nematode larvae in 5 species: *Calliptamus italicus*, *C. turanicus*, *C. barbarous*, *Ailopus oxiana* and *Locusta migratoria*. Prevalence ranged from 0.7% to 4.3%, depending on the species, with the intensity of infection from 1 to 7 larval individuals. The average prevalence in the studied locusts in Karakalpakstan was 2.4%. 2 species of nematodes were identified.

Class Nematoda Rudolphi, 1808

Family Aproctidae (Yorke et Maplestone, 1926)

Aprocta cylindrica Linstow, 1883

Intermediate host: *Locusta migratoria*, *Calliptamus italicus*, *C. turanicus*.

Locality: hemocoel, abdominal cavity.

Discovery location: Karakalpakstan.

The body of the larva (L_3) is cylindrical, 410–412 µm long and 30–32 µm wide. The body is wrapped in a cover. The nerve ring is located at the anterior end of the body; behind it, the excretory pore opens. The aesophagus is long – 30 µm, the intestine is short. The rectum is at the end of the tail (Fig. 13).

Mature forms of *Aprocta cylindrica* parasitise in the eye orbits and nasal cavity of birds, mainly passerines (Quentin et al., 1976; Anderson, 2000; Saparov, 2016).

Family Diplotriaenidae (Skrjabin, 1915)

Diplotiaena isabellina Koroliowa, 1926

Intermediate host: *Calliptamus barbarus*, *Aiolopus oxianus*.

Locality: fat body.

Discovery location: Karakalpakstan.

The body of the larvae is cylindrical, 530–580 µm long and 42–48 µm wide (Fig. 14). It tapers slightly towards the front and rear ends. The nerve ring is located at a distance of 56 µm from the anterior end. The muscular part of the aesophagus is short – 74 µm, the glandular part is 456 µm in length. The larva is located in the lumen of a transparent capsule. Mature nematodes parasitise the air sacs and body cavities of birds (Anderson, 2000; Saparov, 2016).

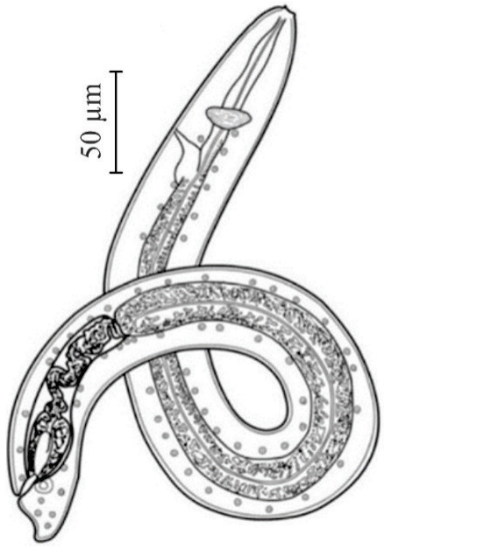

Fig. 13. *Aprocta cylindrica* Linstow, 1883, larvae from locust *Calliptomus turanicus* Tarb: stage III infectious larva

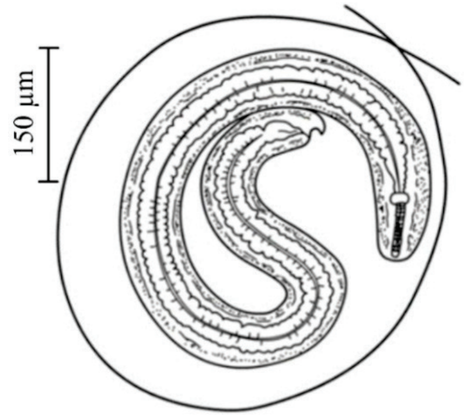

Fig. 14. *Diplotiaena isabellina* Koroliowa, 1926 larvae from locusts

The ground beetle family Carabidae is one of the largest groups of insects. About 400 species have been recorded in Uzbekistan, some of which have been registered in the study area (Azimov et al., 1993). The study of 148 individuals of ground beetles representing 3 species – *Carabus* sp., *Calathus melanocephalus* and *Scarites bucida*, revealed larvae (cysticercoids) of cestodes. The average prevalence was 1.9%. Cysticercoids of *Raillietina cesticillus* (1.8%) and *Echinolepis carioca* (2.1%) were identified.

Class Cestoda Rudolphi, 1808

Family Davaineidae Braun, 1900

Raillietina cesticillus (Molin, 1858)

Intermediate host: *Calathus melonocephalus*.

Locality: body cavity.

Discovery location: Karakalpakstan.

Cysticercoids of *Raillietina cesticillus* were found in the body cavity of ground beetles *Calathus melanocephalus* in a number of regions of the Republic of Karakalpakstan in summer (June, 2022) and autumn (September, 2022). The prevalence was 1.8% and the intensity of infection ranged from 1 to 13 individuals.

The cysticercoids are oval, 342–374 µm long, 310–320 µm wide. The scolex has a proboscis equipped with double rows of hooks. In saline solution, individual worms move actively and turn out the scolex, which makes the cysticercoid takes on a wave-like shape (Fig. 15).

Mature forms parasitise the small intestine of domestic and wild chickens in Karakalpakstan (Jangabaev, 2021).

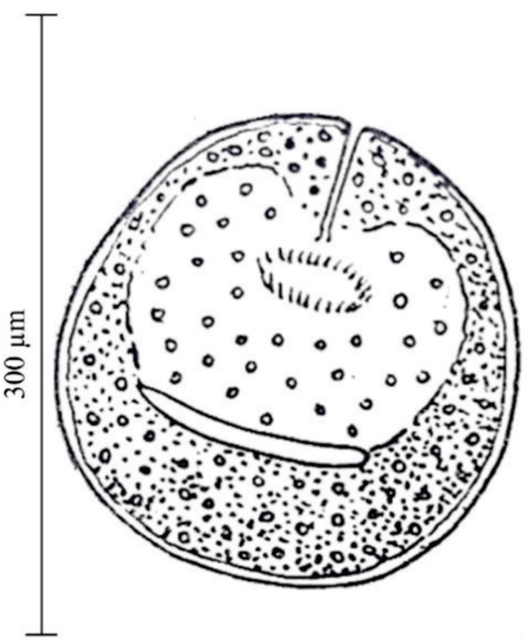

Fig. 15. *Raillietina cesticillus* (Molin, 1858), cysticercoid from a ground beetle

Family Hymenolepididae Perrier, 1897
Echinolepis carioca (Magalhaes, 1898)
Intermediate host: *Scarites bucida*.
Locality: body cavity.
Discovery location: Karakalpakstan.

Cysts live in the body cavity of an insect. A mature cysticercoid reaches 210–230 µm in length and 188–190 µm in width. The scolex is unequipped. The tail of the cysticercoid is short.

The definitive host becomes infected by eating insects parasitised with cysticercoids (Kabilov, 1983). Mature forms are quite widespread in domestic and wild chickens in Karakalpakstan (Jangabaev, 2021).

Insects from the family Tenebrionidae are beetles of diverse appearance. They are widespread and play a big role in ecosystems. In the fauna of Uzbekistan, darkling beetles comprise about 300 species. Many of them are intermediate hosts of various nematodes (Kabilov, 1983).

Helminth larvae were recorded in 3 species of darkling beetles (*Adesmia biseriata*, *Blaps caraboides* and *B. dispar*). Three species were identified – *Gongylonema pulchrum*, *Spirura rytipleurites* and *Choanataenia infundibulum*, belonging to the families Gongylonematidae, Spiruridae and Choanataeniidae.

Family Choanataeniidae Mathevossian, 1953
Choanataenia infundibulum (Bloch, 1779)
Intermediate host: *Adesmia biseriata*, *Blaps caraboides*.
Locality: hemocoel, body cavity.
Discovery location: Karakalpakstan.

Choanataenia cysticercoids are milky-white formations consisting of a transparent capsule and a parasite larva enclosed in it. The encapsulated cysticercoid is 328–560 µm long and 212–520 µm wide. The larva has a scolex with suckers and a proboscis equipped with 17–22 hooks. The prevalence in darkling beetles ranged from 2.1% to 4.5%, the intensity of infection was 3–17 individuals.

Class Nematoda Rudolphi, 1808
Family Spiruridae Oerley, 1885
Spirura rytipleurites (Deslongchamps, 1824)
Intermediate host: *Blaps dispar*.
Locality: body cavity.
Discovery location: Karakalpakstan.

It was found in darkling beetles *Blaps dispar* in the summer and autumn of 2022 in Kungrad, Bozatau and Takhtakupyr Districts of the Republic of Karakalpakstan. The prevalence in black beetles was 1.9%. The intensity of the infection was 5–7 individuals.

The body of the larva is 5128–6208 µm long and 104–118 µm wide. The cuticle is gently patterned. The length of the muscular part of the aesophagus is 202–240 µm, the glandular part is 2542–2846 µm. The distance from the head tip to the excretory opening is 242 µm, to the nerve ring 166–178 µm. The larvae are enclosed in transparent capsules. The adult form of this nematode in Uzbekistan has been recorded in a fox.

Family Gongylonematidae Sobolev, 1949
Gongylonema pulchrum Molin,1857
Intermediate host: *Adesmia biseriata*.
Locality: body cavity.
Discovery location: Karakalpakstan.

Infectious *Gongylonema* larvae are capsuled in the abdominal cavity of insects. The larva is 3230–3662 µm long and 66–76 µm wide. The body narrows towards the anterior and posterior ends. The head end has developed lips. The total length of the aesophagus makes up ½ of the length of the body. The distance from the head end of the body to the nerve ring is 136–172 µm, to the excretory opening – 226–462 µm. The cuticle is covered with transverse strokes. The sexual germ is oval in shape, 28–30 µm long, located on the front of the larva. The length of the tail is 110–116 µm.

Mature forms parasitise in the submucosal layer of the aesophagus in many animal species (Azimov et al., 2015; Safarov et al., 2021).

The family Scaralaeidae is one of the most prominent groups of beetles. They are widespread in the biogeocoenoses of Uzbekistan. The beetle fauna in Uzbekistan is represented by more than 200 species.

Our team studied 346 individuals of *Scarabaeus sacer* and found nematode and cestode larvae. The prevalence was 14.4%. 4 species were identified: *Gongylonema pulchrum*, *Gongylonema* sp., *Echinolepis carioca* and *Choanataenia infundibulum*.

Representatives of the mosquito family Culicidae are widespread in all landscapes in Uzbekistan. The tugai riverside forests in the valleys of large rivers such as the Amu Darya and Syr Darya feature special faunas. The mosquito fauna includes about 25 species, among which representatives of the genera *Aedes* and *Culex* can transmit pathogens of viral, bacterial and parasitic diseases of animals and humans by biting them (Azimov et al., 1993).

It was established that out of the studied 2,161 individuals of mosquitoes, 4 species (*Aedes caspius*, *Ae. detritus*, *Culex pipiens* and *C. hortensis*) were infected with nematode larvae. The average prevalence was 1.1%. A total of 4 species of infected mosquitoes were identified – *Dirofilaria immitis*, *D. repens*, *Setaria labiatopapillosa* and *Dipetalonema ewansi*.

Family Onchocercidae (Leiper, 1911)
Setaria labiatopapillosa (Alessandrini, 1848)
Intermediate host: *Aedes caspius*, *Culex pipiens*, *C. hortensis*.
Locality: body cavity, fat body, pectoral muscles, proboscis.
Discovery location: Karakalpakstan.

Mature Setariae concentrate in the abdominal cavity and in the lymph nodes of sheep, goats and cattle (Azimov et al., 2015; Gaipova, 2020).

In the body of mosquitoes *Aedes caspius*, *Culex pipiens*, larvae of *Setaria labiatopapillosa* were found in different stages of development in the body cavity, pectoral muscles and fat body.

The prevalence in mosquitoes, which are infected in summer and autumn, ranges from 0.7% to 2.5%. Infectious larvae (L_3 stages) were concentrated in the pectoral muscles and proboscis of insects. As they get together with the blood sucked from infected cattle into the stomach of an intermediate host, microfilariae exit the cover and migrate into the pectoral muscles of the insect, where they reach the infectious stage. They migrate from the musculature of the mosquito to the proboscis of the insect. The body length of infectious stage III larvae ranges from 22 to 256 µm, the width is 40–44 µm (Fig. 16). When bitten by blood-sucking dipterans, infectious larvae penetrate into the blood of the definitive host animals through damaged skin.

The range of intermediate hosts of the nematode under study in the biogeocoenoses of Karakalpakstan includes mosquitoes: *Culex pipiens*, *C. hortensis* and *Aedes caspius* (Culicidae).

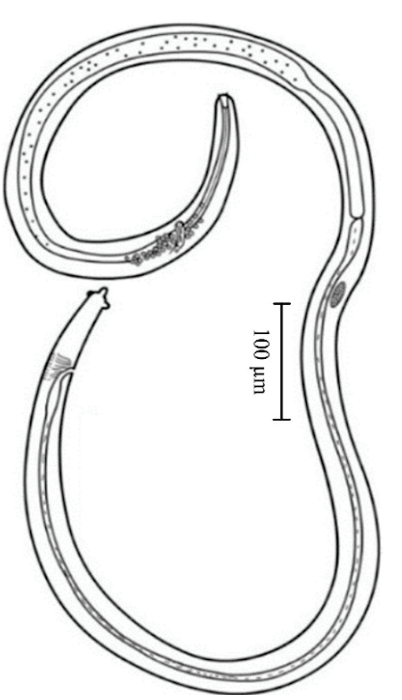

Fig. 16. *Setaria labiatopapillosa* (Alessandrini, 1848): infectious larva from the probosis of *Culex hortensis*

Dipetalonema ewansi (Lewis, 1882)
Intermediate host: *Aedes caspius*.
Locality: abdominal cavity, fat body, pectoral muscles.
Discovery location: Karakalpakstan.

Infectious larvae (L_3) of *Dipetalonema* were found in naturally infected mosquitoes caught on camels in Kungrad, Muynak, Bozatau and Takhtakupyr Districts of Karakalpakstan in the summer and early autumn of 2022. Of the 650 studied mosquitoes (*Aedes caspius*), 11 (1.6%) had larvae of this nematode in the pectoral muscles and proboscis, which reached 94–162 µm in length and 40–44 µm in width. The front end of the body is bluntly rounded. The length of the aesophagus is 578–602 µm. The sexual germ in the form of a cluster of cells is located 40 µm behind the junction of the esophagus with the intestine. The nerve ring is located 70–76 µm and the excretory pore 124–138 µm from the head end.

The adult form of *Dipetalonema* was found in camels (Sultanov et al., 1975; Saparov, 2016).

Dirofilaria immitis (Leidy, 1856)
Intermediate host: *Aedes caspius*, *Culex pipiens*.
Locality: Malpighian vessels, head.
Discovery location: Karakalpakstan.

Our studies show that infectious larvae of *Dirofilaria immitis* were detected in blood-sucking mosquitoes – *Aedes caspius*, *Culex pipiens* – on the territory of Kegeyli, Kungrad, Bozatau, Takhtakupyrsky, Amudarya and Turtkul districts of Karakalpakstan in the summer and autumn of 2022. The prevalence in mosquitoes was 2.4-5.6%. The intensity of infection ranged from 11 to 20 individuals.

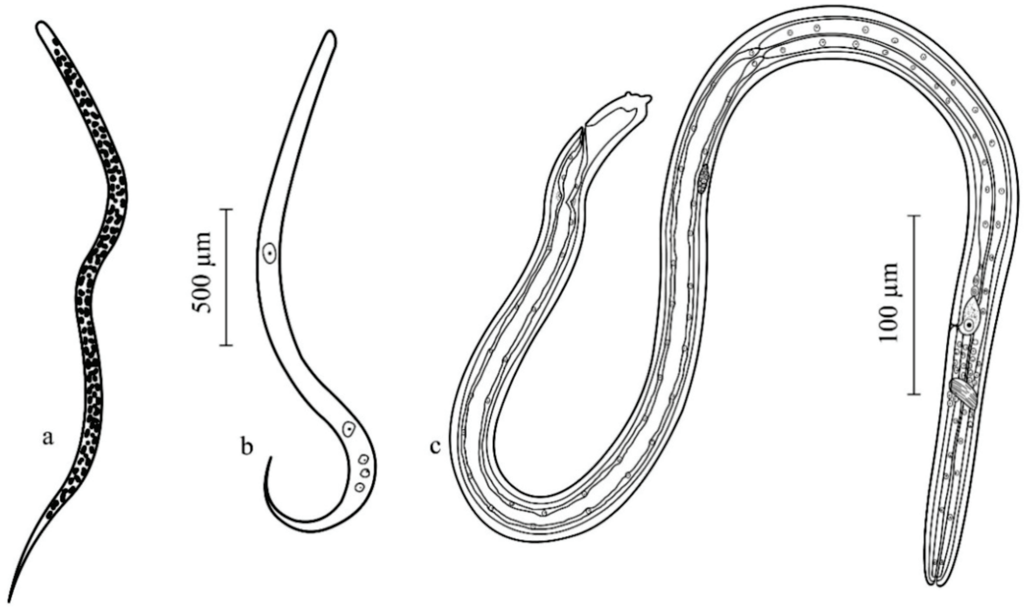

Fig. 17. *Dirofilaria immitis* (Leidy, 1856): *a* – microfilaria, *b* – stage1 larva, *c* – infectious larva

Infectious larvae (L_3) of *Dirofilaria immitis* found in the Malpighian vessels and the head of mosquitoes reach 1320–1842 µm in length and 28–48 µm in width. They are very mobile, the front end of the body is cylindrical, the tail end is short and conical. The aesophagus reaches 1/3 of the larvae body in length. The distance from the head end to the nerve ring is 168–160 µm, to the genital rudiment – 532–540 µm (Fig. 17).

Further development of larvae occurs in the body of a definitive host.

Mature Dirofilariae were recorded in dogs and a number of wild carnivores (Berdibaev, 2021; Safarov, 2021; Safarov et al., 2023).

The midge family Simulidae is widely spread in Uzbekistan. The midge fauna includes more than 50 species, among which the most common are those from the genera *Odagmia* and *Simulium*, which cause great harm to agricultural animals (Azimov et al., 1993).

Midges as intermediate hosts of helminths of animals are objects of research for many parasitologists (Golovanov, 1973; Saparov, 2016).

A parasitological examination of 1,048 individuals of midges revealed that two species of midges – *Odagmia ornata* and *Simulium flavidum* – were infected by larvae of nematodes from the genus *Onchocerca*. The total prevalence in midges was 2.5%. The discovered larvae represented the species *Onchocerca lienalis*.

Family Onchocercidae (Leiper, 1911)
Onchocerca lienalis (Stiles, 1892)
Intermediate host: *Odagmia ornata*, *Simulium flavidum*.
Locality: pectoral muscles, head.
Discovery location: Karakalpakstan.

Infectious larvae of *Onchocerca lienalis* tend to concentrate in the pectoral muscles and head of insects. The length of infectious larvae is 546–680 µm, the width is 18–22 µm. The nerve ring and excretory cell are well developed. The aesophagus is long – 320–340 µm, the tail length is 28–30 µm.

Attacking sick animals, midges ingest microfilariae of *Onchocerca lienalis* with blood. From the intestines of midges, microfilariae penetrate into the body cavity, and then migrate to the pectoral muscles of Simuliidae, where they undergo further development. After 8–14 days, they reach the infectious stage. Infectious larvae migrate to the head. When a definitive host is bitten by an infected midge, the larvae (L_3) of *O. lienalis* enter its body, where they develop to the adult stage (Ivashkin & Golovanov, 1974). Adult *Onchocerca* have been recorded in cattle in Uzbekistan (Golovanov, 1973; Azimov et al., 2015).

The fly family Mussidae has a wide distribution in all landscapes in Uzbekistan. Among them, there are representatives involved in the life cycles of helminths, mainly nematodes – parasites of agricultural and commercial animals.

A parasitological study of 1,036 individuals representing this family revealed that three species – *Liperosia irritans*, *Haematobia titillans* and *Stomoxys calcitrans* are infected with larvae of nematodes from the genera *Stephanofilaria* and *Parabronema*. The total prevalence was 2.1%. *Stephanofilaria stilesi* and *Parabronema skrjabini* were identified.

Stephanofilaria stilesi Chitwood, 1934

Intermediate host: *Liperosia irritans*, *Haematobia titillans*, *Stomoxys calcitrans*.

Locality: hemocoel, head, proboscis.

Discovery location: Karakalpakstan.

The infectious larva of *Stephanofilaria stilesi* is 610–824 µm long and 40–46 µm wide. Its body narrows towards the head and tail ends. At the head end there is a small protrusion in the form of a crown, studded with 16–18 spikes. The well-developed nerve ring is located at a distance of 22–46 µm from the head end of the body. The length of the anterior end of the body. The length of the aesophagus is 72–96 µm. The length of the tail is 60–80 µm (Fig. 18).

The adult form of *Stephanofilaria* was found in cattle in Karakalpakstan (Gekhtin, 1969; Azimov et al., 1976; Saparov, 2016).

Cattle infection occurs during the warm season (spring, summer and early autumn). Feeding on infected animals, flies ingest eggs or microfilariae of nematodes. In the intestines of flies, the larvae exit the egg shell and then penetrate into the insect hemocoel, where they go through next developmental stages. The larvae reach the infectious stage within 8–10 days. They migrate to the head and proboscis of flies (Hibler, 1964; Azimov et al., 1976, 2015; Saparov, 2016).

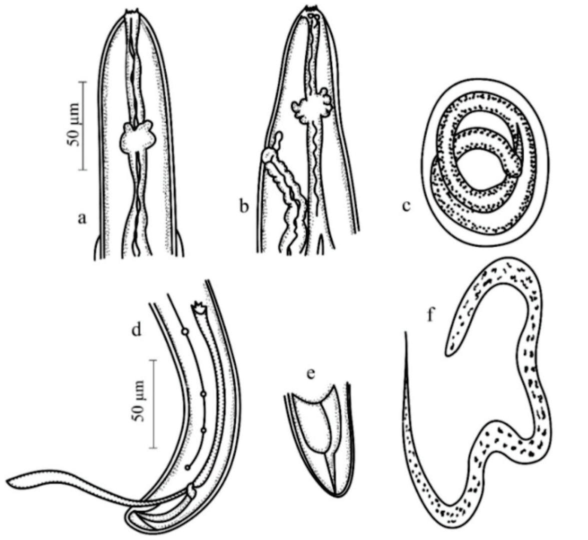

Fig. 18. *Stephanofilaria stilesi* Chitwood, 1934: *a* – head end of male; *b* – tail end of male; *c* – head end of female; *d* – tail end of female; *e* – egg with larva; *f* – microfilaria

We considered for the first time the role of insects in the life cycles of some species of helminths – parasites of vertebrates in the vast region of Karakalpakstan.

The obtained results are very modest against the background of the wide distribution and diversity of insect fauna in the biogeocoenoses of the basin of the lower reaches of the Amu Darya. Our research is purely preliminary. It should be noted that the insects of Karakalpakstan had not been earlier considered as intermediate hosts of helminths. The available data (Kabilov, 1983) on the participation of insects in the development cycle of Cestoda, Trematoda, Acanthocephala and Nematoda relate to the north-eastern, eastern and southern regions of Uzbekistan. The author has conducted extensive research covering many representatives of 10 orders in the class Insecta. In the studied insects, the author identified 103 species of larval forms of helminths belonging to 4 classes. Among them 21 species represent Cestoda, 3 Trematoda, 6 Acanthocephala and 73 Nematoda (Kabilov, 1983). There is also information about the detection of larvae (metacercaria) of trematodes by national parasitologists (Salimov et al., 2016), who identified ants from the genus *Formica* as a supplementary host of *Dicrocoelium dendriticum* in the central part of Uzbekistan (Samarkand region).

Golovanov (1973) identified species of midges – *Odagmia ornata* and *Friesia alayensis* as intermediate hosts of the nematode *Onchocerca gutturosa* in the Tashkent and Samarkand regions of Uzbekistan. There is evidence that *Liperosia irritans*, *Haematobia titillans* and *Stomoxys calcitrans* – act as intermediate hosts of nematodes *Stephanofilaria stilesi* and *S. assamensis* in Southern Uzbekistan (Surkhandarya region, Azimov et al., 1976).

The results of the research conducted in Karakalpakstan complement the data of the above-mentioned authors on the role of some insect species involved in the life cycles of helminths.

Let's take a closer look at the ecological and trophic relationships of larval forms of nematodes with insects that affect the composition of their helminthofauna in the studied region of Uzbekistan.

Our study identified about 11 species of larval forms of nematodes in insects. Table 6 provides information on intermediate and definitive hosts of helminths (nematodes).

Table 6

Insects as intermediate hosts of nematodes in Karakalpakstan

Larval species	Hosts	
	intermediate	definitive
Spirura rytipleurites (Deslongchamps, 1824)	darkling beetles	mammals
Gongylonema pulchrum Molin, 1857	scarab beetles	mammals
Parabronema skrjabini Raskowska, 1924	muscidae	mammals
Aprocta cylindrica Linstow, 1883	locusts	birds
Diplotriaena isabellina Koroliova, 1926	locusts	birds
Dirofilaria immitis (Leidy, 1856)	mosquitoes	mammals
D. repens Railliet & Henry, 1911	mosquitoes	mammals
Dipetalonema evansi (Lewis, 1882)	mosquitoes	mammals
Setaria labiatopapillosa (Alessandrini, 1838)	mosquitoes	mammals
Onchocerca lienalis Stiles, 1892	midges	mammals
Stephanofilaria stilesi Chitwood, 1934	flies	mammals

Insects from many families are involved in the transmission of infectious nematode larvae to vertebrates. Below we will briefly consider the role of each of them.

Darkling beetles are intermediate hosts for 3 species of nematodes. They become infected when vertebrates feed on darkling beetles or when they accidentally swallow them with other food.

Locusts are intermediate hosts for 2 species of nematodes – *A. cylindrica* and *D. isabellina* – parasites of birds. Birds become infected by eating infected locusts.

Flies from the genera *Lyperosia* and *Stomoxys* participate in the life cycles of the nematodes *Parabranema skrjabini* and *Stephanafilaria stilesi*, parasites of mammals, mainly ruminants (sheep, goats and cattle). The second species is a specific parasite of cattle.

Pasture flies are widespread and highly abundant in the studied area. With the large numbers of flies and their close contact with animals, nematodes can go through their entire life cycle, in which flies are intermediate hosts (Tamarina & Khromova, 1980).

Mosquitoes are intermediate hosts of 4 species of nematodes – parasites of mammals (predatory and ruminant). Animals become infected through the bites of blood-sucking dipterans.

Midges are intermediate hosts of the nematode *O. lienalis*, a parasite of cattle. Infected larvae are transmitted by biting insects.

Therefore, out of 6 groups (families) of insects – intermediate hosts of nematodes – 4 or 66% turned out to be dipterans. By their dietetic habits, they are coprophages and hematophages. 7 species of infectious larvae were identified in them.

The biology of dipterans and nematodes, taking into account their ecological and trophic connections with vertebrates and, as a result, the transformation of the ways of receiving and transmitting infection between an intermediate and definitive hosts (Tamarina & Khromova, 1980), is implemented within the framework of the Nematodes – Dipterans – Vertebrates parasitic system with various modifications. It should be noted that the evolution of an insect's trophism leads to a change in the type of its connection with a vertebrate animal, which in turn should entail the inevitable adaptation of the pathogen to a new system of connections in its hosts. The parasite is transmitted directly from the body of a definitive host to the body of an intermediate one. Here, a complete independence of the parasite's development from environmental factors is observed at all stages, which is characteristic of progressive nematodes from the suborder Filariata.

Discussion

Based on the above, it seems possible to consider the role of molluscs and insects in the formation of naturally occurring helminthiasis and the circulation of infection in the wild in Karakalpakstan. The formation of natural foci of diseases is a phenomenon in which the causative agent of a disease, its intermediate hosts and the animals that carry the infection have existed in the wild for a long time independently of humans (Pavlovsky, 1961). The eradication of naturally occurring helminthiasis depends mainly on the awareness of specialists and practitioners about the definitive and intermediate hosts of helminths, about their circulation routes in nature, foci of infection and other. Skrjabin (1962) indicates that "the availability of information about the foci of infection in the wild and knowledge of the ways of circulation of the infectious origin between natural and synanthropic foci are in some cases the base for the development of specific plans for health measures".

An analysis of literary data on this issue shows that the participation of molluscs and insects in the spread and maintenance of naturally occurring helminthiases, taking into account the specific ecology of their pathogens and anthropogenic factors in a certain territory, has not been studied sufficiently. No one has considered this issue in Karakalpakstan.

The role of molluscs and insects in maintaining the natural foci of some helminthiases of domestic and wild animals and humans in the studied region consists in their participation as intermediate (or supplementary) hosts in the life cycles of a number of pathogens.

As was mentioned, we registered 27 species of larval forms of trematodes in 11 species of aquatic molluscs. They can parasitise domestic and wild animals, which are their definitive hosts, and some of them pose a danger to humans (Bronstein & Tokmalaev, 2004). Species that form natural foci and develop with the participation of molluscs are the trematodes *Schistosoma turkestanicum*, *Bilharziella polonica*, *Trichobilharzia ocellata*, *Dendritobilharzia loossi*, *D. pulverulenta* and *Gigantobilharzia acotylea*, parasitising vertebrates in Karakalpakstan and showing high prevalence (Akramova, 2011; Azimov et al., 2019; Toremuratov, 2022). We recorded larval forms of these flukes in the corresponding species of molluscs in the water bodies of the lower reaches of the Amu Darya. The prevalence recorded in the studied molluscs infected with larval forms of trematodes was quite high. It ranged from 1.3% to 25.5% (Table 2). Mature forms turned out to be obligate parasites of domestic and wild birds and mammals. Their tendency to form natural foci can be exemplified by two species – *Bilharziella polonica* and *Schistosoma turkestanicum*. The first species is a specific parasite of wetland birds, and the second one is specific to mammals.

The development of *Bilharziella polonica* in the natural conditions of Karakalpakstan occurs with the participation of the molluscs *Planorbis planorbis* and *P. tangitarensis*. Numerous species of wetland birds, including domestic ducks and geese, have been recorded as their definitive hosts (Arepbaev et al., 2022).

The life cycle develops with the participation of animal species of wild fauna and natural foci of infection form independently of humans.

A similar process is observed in relation to the biology of *Schistosoma turkestanicum*, with the difference that the role of an intermediate host is played by populations of *Radix auricularia* molluscs. The definitive hosts were about 20 species of mammals from 5 orders – Lagomorpha, Rodentia, Carnivora, Artiodactyla and Perissodactyla (Azimov et al., 2019). According to observations, wild animals in the natural complexes of the studied region also participate in the circulation of *Schistosoma turkestanicum*. We believe that historically the circulation of *Schistosoma* occurred with the participation of wild animals (intermediate and definitive hosts) in natural foci of infections. Much later, domestic animals (sheep, goats, cattle and other) were involved in the process, which contributed to the development of synanthropic foci of schistosomiasis. Currently, the natural and synanthropic foci of the studied helminthiasis – schistosomiasis – are recorded in Karakalpakstan, which must be taken into account when developing methods for the prevention of natural focal helminthiasis of domestic and wild commercial animals.

Among the larval forms of helminths identified by our team in insects in Karakalpakstan, 14 species parasitise in the adult form various domestic and wild animals that are their definitive hosts, and some of them can infect humans (Bronstein & Tokmalaev, 2004). The following helminth species developing with the participation of insects can form natural foci of infection: *Aprocta cylindrica*, *Diplotriaena isabellina*, *Gongylonema pulchrum*, *Dirofilaria immitis*, *D. repens* and *Setaria labiatopapillosa*. They are quite common among domestic and wild birds and mammals (Sultanov, 1963; Sultanov et al., 1975) on the territory of Karakalpakstan. The natural foci of the corresponding helminthiases are supported by wild animals. The following groups of insects are the main intermediate (supplementary) hosts for the identified helminths: dragonflies, locusts, ground beetles, darkling beetles, scarab beetles, mosquitoes, midges and flies.

In the natural and climatic conditions of the studied region, the circulation of helminths characterised by the formation of natural foci takes place within trixenic parasitic systems which contribute to the maintenance of foci of infections.

Conclusion

Our research shows that molluscs and insects in the territory of Karakalpakstan are infected with larval forms of helminths. The fauna of helminth larvae comprises 42 species; of these, 27 species of cercariae are identified in molluscs and 15 in insects.

Intermediate hosts are infected during the warm season, when the animals remain physiologically active. The long duration of the warm season facilitates the contact between intermediate hosts and infectious elements and ensures the development of larval forms of helminths in their body. Molluscs and insects are infected through ecological connections in places of concentration of vertebrates – definitive hosts of helminths.

The successful completion of helminth development depends on the level of contact between an intermediate host and the eggs or larvae of parasites, on the one hand, and on the ecological relationships of molluscs and insects infected with helminths with vertebrate hosts in space and time. Therefore, the nature of the spread of helminth larvae is specified by the following factors: the degree of concentration of definitive and intermediate hosts, the biological features of the development of the initial stages of helminths, and the ecological features of molluscs and insects that ensure the transmission of infectious elements to vertebrates – their definitive hosts. All this contributes to the formation of foci of helminthiases and the circulation of infection in nature.

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