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DRACONTIASIS IN OHIO CARNIVORES AND REPTILES WITH A DISCUSSION OF THE DRACUNCULID TAXONOMIC PROBLEM

(NEMATODA: DRACUNCULIDAE)

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During March 1959, I received three large nematodes excised from the hind leg of a raccoon, *Procyon lotor lotor*, from Delaware County, Ohio. In January and February 1960, a trapper removed four specimens from the fetlock of the hind leg of a mink, *Mustela vison*, and one specimen from the muscles of the tail of a second mink trapped in the same county. These specimens were brought to me for identification by Robert Sagar and Vernon Stevens of the Ohio Wildlife Cooperative Research Unit.

All worms were adult, gravid females belonging to the genus *Dracunculus*. Specimens from the raccoon vary from 26.3 to 38.6 cm in length (30.4 cm, mean length) and from 1.0 mm to 1.3 mm in width. A sample of 20 embryos from the uterus of a specimen from raccoons ranged from 428 to 529 μ in length (mean length 514 μ) and 21 to 22 μ in width. A similar sample of embryos of a worm from mink all fell within the ranges stated above. A careful study shows that the morphological features of these helminths compare most closely with descriptions and illustrations of *Dracunculus insignis* (Leidy, 1858) given by Chandler (1942) and Cheatum and Cook (1948); they are therefore referred to this species. A morphological feature which has not been noted by previous investigators is the openings of the phasmids. These can be clearly seen in ventral view of both sides of the female tail posterior to the anus. They traverse the cuticle 402 and 496 μ from the tip of the tail. Anterior to the anus on both sides are large tubercle-like protuberances, these are 680 to 703 μ from the tip of the tail and were consistently present in all specimens from carnivores.

There is no previous report of any species of *Dracunculus* from Ohio. These parasites are of unusual interest because of their close similarity to the nematode parasite of humans, *Dracunculus medinensis*, the guinea worm. North American records of guinea worms in wild carnivores include the following hosts and localities: Raccoon, *Procyon lotor*—Florida (Layne, Birkenholz, Griffo, 1960), Maryland (Chitwood, 1933), Michigan (Wilson, 1958), New Hampshire (Seigler, 1946), New York (Cheatum and Cook, 1948; Chitwood, 1933), Pennsylvania (?) (Leidy, 1858), South Dakota (Huggins, 1958), Texas (Chandler, 1942), Ontario, Canada (Chitwood, 1933); Mink, *Mustela vison*—Iowa (Benbrook, 1940), Nebraska (Chitwood, 1933), New York (Cheatum and Cook, 1948); Weasel, *Mustela erminea*—New York (Hamilton and Cook, 1955); Boneparte weasel, *Mustela c. cicognanii* New York (Goble, 1942); Fisher, *Martes pennanti*—New York (Hamilton and Cook, 1955); Skunk, *Mephitis nigra*—New York (Cheatum and Cook, 1948); Striped skunk, *Mephitis mephitis*—Minnesota (Erickson, 1946); Otter, *Lutra canadensis*—New York (Cheatum and Cook, 1948); Muskrat, *Ondatra zibethica*—

Maryland and North Dakota (Dikmans, 1948); Silver Fox, *Vulpes fulva*—Iowa (Benbrook, 1940) and Wisconsin (Dikmans, 1948).

There have been seven cases of dracontiasis in domestic American dogs. These are summarized by Schawbe, Meier and Bent (1956) and occurred in the following localities: Illinois, Iowa, Massachusetts, Missouri, North Carolina, South Dakota, and Texas.

Recently, I obtained four large nematodes removed by Russell Williams from the body cavity and mesenteries of a snapping turtle, *Chelydra serpentina*, collected from a marsh at the Ohio Agricultural Experiment Station Farm, Erie County, Ohio, on May 5, 1959. These helminths also belong to the genus *Dracunculus*.

Three of the worms were adult females, the fourth was a juvenile. The adult specimens vary from 9.0 to 13.6 cm in length by 0.83 to 0.94 mm wide. Phasmids were 526 to 574 μ from the spiked tip of the tail. A sample of embryos from the uterus of one female specimen range from 413 to 560 μ in length (mean length 503 μ) and 19 to 21 μ in width. Except for the cephalic papillae, which are double in our specimens, the morphological features of these parasites conform with those given by Mackin (1927) for *Dracunculus globocephalus*.

The only previous report of a guinea worm from a turtle is by Mackin (1927) who described *D. globocephalus* from *Chelydra serpentina* from Oklahoma and Illinois. Records of *Dracunculus* spp. in other reptiles include the following species, hosts and localities: *D. dahomensis* in *Python natalensis* Neuman (1895); *D. medinensis* in *Nair tripudianus*, India, Turkhud (1920); *D. houdemeri*, *Natrix piscator*, Indo China, Hsu (1933); *D. dahomensis* in *Psammophis sibilans*, Belgian Congo, Schuurmans Stekhoven (1937); *D. ophidensis* in *Thamnophis sirtalis*, *T. sauritas*, and *Natrix sipedon* from Michigan, in *T. sirtalis*, Minnesota, Brackett (1938); *D. oesophagea* (Polonio) in *Tropidonotus natrix persa*, Italy, Desportes (1938). Mirza and Roberts (1957) report *Dracunculus* sp. from a gopher snake in the Washington, D. C. Zoological Park, from *Natrix erythrogaster* (locality not given) and from *Natrix sipedon*, Maryland. The only lizard host is *Varanus* sp. from India reported by Mirza and Basir (1937).

DISCUSSION

Chitwood (1933) raised the question as to whether the guinea worms from American mammals were the same species as the old world form which occurs primarily in humans. At the time, he suggested that the American form might be a different physiological strain which could not parasitize man. He investigated ten reported cases of *D. medinensis* in the United States and found that four were of foreign origin and the other six were not dracontiasis.

Chandler (1942) found the guinea worm to be rather common in raccoons in Texas. He searched for possible human infections in Texas but found none. After a study of the female specimens from raccoons he decided that the American form was a different species and called it *D. insignis* after the worm described by Leidy (1858) as *Filaria insignis*. After Chandler's paper in 1942, almost all investigators have reported guinea worms from wild carnivores in North America as *D. insignis*.

Chitwood (1950) obtained the first male specimen of the American guinea worm, taken from a raccoon. He compared it with male specimens which Moorthy (1937) had recovered from a dog experimentally infected with the old world form from man. The specimens from the raccoon varied from Moorthy's in the number and arrangement of the genital papillae and in the length of the gubernaculum. Chitwood considered the differences great enough to describe his specimens as the males of *D. insignis*. Chitwood cautions however, "it is quite possible that a more extensive series of specimens would disclose an overlap in these characters." Unfortunately, no further male specimens have been recovered from wild carnivores in North America.

Mackin (1927) gives a clear and detailed description of both males and females of *D. globocephalus* from turtles. He gives the number and arrangement of caudal papillae and the shape of the male tail and points out the markedly unequal spicules (0.8 mm by 5 μ and 0.2 mm by 10 μ).

Moorthy's paper (1937) gives an exacting redescription of *D. medinensis* and clearly differentiates it from *D. dahomensis* (Neuman, 1895). He casts doubt on the validity of *D. houdemeri* Hsu, 1933, since this species was described from a single female specimen and differentiated only on the basis of the cephalic pattern which he believed to be variable.

In 1938, Brackett described *D. ophidensis* and he clearly differentiated and illustrated the differences between it and *D. medinensis* and *D. houdemeri*. He also points to the distinctly unequal spicules of *D. globocephalus* which distinguishes it from the species found in snakes.

The validity of some species of the genus *Dracunculus* were questioned again by Mirza and Roberts (1957) and by Mirza (1957). After studying *Dracunculus* from American snakes, Mirza and Roberts (1957) give a redescription and state that in their opinion the nematodes described by Mackin from turtles and by Brackett (1938) from the snake are the same as those which they redescribe. Mirza (1957) examined the type specimens of *D. globocephalus* and compared them with fresh specimens from *Natrix sipedon*. He states that he found them identical. If this is true, then *D. ophidensis* Brackett, 1938, could be a synonym of *D. globocephalus* Mackin, 1927. This synonymy, inferred by Mirza, would mean that there is great variation in specimens from North American reptiles, since the spicule measurements and the illustration of caudal papillae given by Mirza and Roberts (1957) vary considerably with those of Mackin (1927).

Yamaguti (1961) has taken exactly the opposite stand. In his consideration of dracunculids from reptiles, he establishes two new genera, the genus *Chelonidracunculus* for the species found in turtles, *D. globocephalus* Mackin, 1927, and the genus *Ophiodracunculus* for the species described from snakes. In *Ophiodracunculus* he places *D. oesophageus* (Polonio, 1859), *D. dahomensis* Neuman, 1895, *D. ophidensis* Brackett, 1938, and, in his words, probably *D. houdemeri* Hsu, 1933. He makes *D. oesophageus* the type for his new genus *Ophiodracunculus*. In view of the work of Mirza and Mirza and Roberts this seems an extremely tenuous position to take. The morphological differences used by Yamaguti have been used in the past to distinguish species but it is doubtful that they are of great enough magnitude to establish genera, especially since they have already been questioned at the species level. In his generic diagnosis of *Ophiodracunculus*, Yamaguti uses the dorsal spine and long tail of the free-swimming first stage larvae and the bilobed tail of the infective larval stage found in copepods as generic characters. These characters were established by Desportes (1938) for *D. oesophageus*. Brackett (1938) does describe the infective stage of *D. ophidensis* as having a bifid tail but he does not describe the first stage larvae with a dorsal spine. At present, there is nothing known about the larval stages of *D. dahomensis* or *D. houdemeri*. Mackin (1927) states that he infected copepods with the first stage larvae of *D. globocephalus* but he does not describe the infective larvae which developed. Since these similarities and differences are not yet well established they can hardly be accepted as diagnostic characters. At the present time, it would seem more reasonable to retain those species from snakes and those from turtles in the genus *Dracunculus* and not place them in separate genera. Since my specimens from turtles are very similar in morphology and size to those described by Mackin I have classified them as *D. globocephalus*.

Mirza (1957) makes the following statement:

Due to hygienic conditions prevalent in the United States the guinea worm, in its struggle for existence, has adapted itself to animals. We should not forget that

Moorthy and Sweet (1936) successfully infected dogs with *D. medinensis*, the human parasite. On the contrary, in other warmer countries where habitats of the people differ, it is a common parasite of human beings and is rarely found in animals.

This paragraph states views which must be questioned seriously. Hygienic conditions will not completely explain satisfactorily the fact that there has never been an authentic recorded case of human dracontoid infection in the United States. Leidy first discovered the guinea worm in raccoons in the United States in 1858. Public health records show that, at this time, most people drank from wells and springs in rural areas of the United States. Before this time and after it people are known to have washed clothes and bathed in quiet pools and streams in warmer areas of the southern United States. Hygienic conditions in these areas were poor enough for hookworm, which usually involves skin exposure, and for typhoid and other water-borne bacterial disease to be common. These conditions existed up into the nineteen twenties.

Dracunculoid species occur in fish in the United States, as well as in carnivores and reptiles. Meyer (1960) reviews the occurrences of *Philonema agubernaculum* and other related dracunculoids in salmonid fishes. The salmonids are believed to have had their origin in the Tethys Sea during the Eocene and to have radiated into North America and Europe. Thomas (1929, 1944) found dracunculoids in catostomid fishes in Illinois and New York, and Huggins (1958, 1959) reports them as present in catostomid fishes in South Dakota. I have taken *Philometra nodulosa* from the golden red horse sucker, *Moxostoma erythrurum*, in Ohio. Darlington (1957) gives evidence which indicates the catostomid fishes had their origin in eastern Asia, moved across a Bering Strait land bridge, and radiated in North America. Haag (1962) presents excellent evidence for the existence of a broad Bering Strait Land bridge both before and after the Pleistocene. The genus *Catostomus* evolved twenty species in North America and fossil castostomidae have been found from Eocene and Miocene in North America. Fossil Chelydridae, the family to which the snapping turtle belongs, are mid-Tertiary in the United States. Williams (1952) thinks that the family existed, "perhaps since the Cretaceous, certainly since the earliest Tertiary." Darlington also states the Procyoninae have been in Eurasia and North America since the Miocene. Fossils show that the Mephitinae have been in Eurasia and North America since the upper Miocene and the Pliocene.

The preceding material would indicate the possibility of a long standing occurrence of dracunculoid worms in hosts on the North American Continent. The present populations of *Dracunculus* spp. in North America are geographically and perhaps reproductively isolated from the Asian populations. It is possible, that at one time, there may have been a cline of dracunculoids and their hosts from Asia across the North American Continent. We know these things of a cline. Divergence in a cline may be great enough to prevent interbreeding between distant forms, if these forms are brought together they do not interbreed and are now distinct biological species. If a cline breaks up as a result of part of its range becoming unsuitable for the species, the populations of its parts will be isolated and given time will evolve independently. By the estimates of Simpson (1955) there has been abundant time for evolution to occur. Whether this has happened or not can only be considered an assumption, it is however, an assumption with as much evidence to confirm it as a recent introduction *Dracunculus* spp. into the United States.

Mirza cautions that we should not forget the experiments of Moorthy and Sweet where they successfully infected Indian dogs with Asian dracunculids from man. I would agree that we should not forget this, also, we should not forget that this experiment yielded worms of a different size from those found in man. Parasitologists have come to expect some host induced variations. This experiment, however, does not prove that the Asian species from man will interbreed

with species from North American carnivores. Even if we were to infect North American carnivores with the dracunculids from North American reptiles, as some writers have suggested, this would not suffice to show that they normally interbreed and are thus the same biological species. It has been shown that the host-conditioning effect over long periods of time will tend to split populations of parasites into isolated groups and thus, of itself, will tend to prevent cross-breeding. If the host strain is held in an environment, favorable mutations in the parasite may be selected and incorporated into its hereditary system.

The criterion of successful interbreeding is always difficult to demonstrate in helminth parasites. It is particularly difficult in this case because we are dealing with parasites which have different geographical distributions; which have an intermediate host, where the larvae in the infective stage can not be differentiated as to sex; and where the adult male is buried deep in the tissues of the definitive host and may disintegrate before the females produce viable juveniles (Moorthy and Sweet, 1936; Onabamiro, 1956).

Physiological studies, immunological studies and studies of the chromosomes may all contribute to the knowledge of this problem. At the present time, on the basis of the morphology of the cephalic structures, which in my specimens and those of several American workers, are similar to those described by Chandler, (1942), and on the basis of no demonstrated overlap in the characteristics of the males, it seems best to designate the specimens from North American carnivores as *Dracunculus insignis* (Leidy, 1858) Chandler, 1942.

This does not mean that Mirza is incorrect when he states that he believes that there are only two species of guinea worms, one in reptiles and one in mammals. The guinea worm found in Asia and Africa may have a world wide distribution. If more evidence is produced to show this I would be one of the first to agree.

The differences in species are sometimes very slight, in fact as Thorpe (1940) says, "There seems no doubt that finally in certain cases no satisfactory structural differences will be discoverable, and it will then be necessary to distinguish some perfectly good species on biological grounds alone." This leaves the parasitological taxonomist with a puzzle. Should he recognize species which he can not easily distinguish? The worker who distinguishes species on a morphological basis may fail to recognize two species that are very similar morphologically. He may also recognize as two species forms which vary morphologically but by the biological definition of a species may later be shown to be one species. He does this not because he believes that species are his own creations. He realizes that they are a product of nature, indeed, his work is an attempt to reflect in the shortest and most practical way the natural situation. Perhaps, Thorpe's quotation given above is also true when reversed. There seems no doubt that finally, in certain cases, there is no practical way to distinguish species on a biological basis alone, and it will then be necessary to distinguish some perfectly good species on morphological grounds. Certainly no reasonable person will ridicule a taxonomist who explains that a group can be identified to species only on the basis of demonstrable differences.

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