



A review of *Gongylonema* spp. (Nematoda: Gongylonematidae) in North American rodents with description of a new species from the cotton rat, *Sigmodon hispidus* (Mammalia: Cricetidae)

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Abstract

Gongylonema archboldi n. sp. (Nematoda: Gongylonematidae) is described from tunnels in the gastric mucosa of the stomach of the cotton rat (*Sigmodon hispidus*) from Highlands County, Florida, U.S.A. Measurements are also given for specimens from cotton mice (*Peromyscus gossypinus*), oldfield mice (*Peromyscus polionotus*), Florida mice (*Podomys floridanus*), and golden mice (*Ochrotomys nuttalli*) from the same locality. Additional specimens were collected from the cotton rat and the rice rat (*Oryzomys palustris*) from Berry Island, San Patricio County, Texas. The new species is differentiated from congeners by a combination of the following characters: length of the left spicule, length and shape of the gubernaculum, distribution of cuticular bosses, length of esophagus, and distance of the vulva from the posterior end. The status of the genus *Gongylonema* in North American rodents is reviewed.

Key words: *Gongylonema archboldi*, n. sp., *Sigmodon hispidus*, *Podomys floridanus*, *Ochrotomys nuttalli*, *Peromyscus gossypinus*, *Peromyscus polionotus*, *Oryzomys palustris*, cotton rat

Introduction

Nematodes of the genus *Gongylonema* Molin, 1857 (Spirurida: Gongylonematidae) dwell in the epithelial mucosa of the mouth, esophagus, and stomach of mammals and birds. Although there has been no comprehensive taxonomic review of the genus since Yamaguti (1961), there are currently about 47 species recognized, 10 of which parasitize birds and 37 mammals. Of the 37 mammalian species, 15 are found in rodents. Only 5 species have been recorded in North American rodents: *Gongylonema neoplasticum* (Fibiger & Ditlevsen, 1914); *Gongylonema pulchrum* Molin, 1857; *Gongylonema dipodomysis* Kruidenier & Peebles, 1958; *Gongylonema peromysci* Kruidenier & Peebles, 1958; and *Gongylonema mysciphilia* Frandsen & Grundmann, 1961. Table 1 lists North American records from rodents for these 5 species, as well as records of *Gongylonema* not identified to species. Experimental infections and infections in zoo animals are not included.

Between 1972 and 1973, an unidentified species of *Gongylonema* was found in cotton rats, *Sigmodon hispidus* Say & Ord, in southern Florida, as well as in 4 other species of cricetid mice (Kinsella, 1974, 1991; Forrester, 1992). More recently, the same species was found in cotton rats and rice rats, *Oryzomys palustris* (Harlan) in eastern Texas. This paper describes this new species and reviews other species found in North America.

Material and methods

Some hosts infected with *Gongylonema* were collected by JMK in Sherman live traps between October, 1972 and

August, 1973 at Archbold Biological Station (ABS), Highlands County, Florida, U.S.A. The remaining hosts were collected in Sherman live traps between June and August, 2015 by WCP on Berry Island, San Patricio County, Texas. Names of hosts follow Wilson & Reeder (2005). Nematodes were teased from the gastric mucosa using fine forceps, killed in glacial acetic acid, and preserved in 70% ethanol with 5% glycerine. Specimens were cleared and studied in temporary mounts of lacto-phenol and then returned to the preservative. Drawings were made with the aid of a drawing tube. Some specimens were dried using the critical point method, examined via Scanning Electron Microscopy (SEM) (JEOL JSV 6360 LV, Tokyo, Japan), and photographed.

All measurements are in microns unless otherwise specified. Type and paratype specimens were deposited in the National Parasite Collection in the United States National Museum (USNM), Smithsonian Institute, Washington D.C., U.S.A. Vouchers from Texas collections were deposited in the Harold W. Manter Laboratory (HWML) at the University of Nebraska, Lincoln, Nebraska, U.S.A..

Results

A total of 5 of 22 (23%) cotton rats at ABS were infected with 1 to 15 (mean 6.0) specimens of *Gongylonema*. Because of the difficulty of teasing them from epithelial tunnels, only a few females were recovered intact. Infections of the same species were found in 12 of 86 (14%) cotton mice, *Peromyscus gossypinus* (LeConte); 4 of 41 (9.8%) oldfield mice, *Peromyscus polionotus* (Wagner); 15 of 102 (15%) Florida mice, *Podomys floridanus* (Chapman); and 2 of 18 (11%) golden mice, *Ochrotomys nuttalli* (Harlan) from ABS. In addition to being lower in prevalence, infections in the 4 species of mice were lower in average intensity and females tended to be less gravid.

In 2015, additional specimens were collected from 3 of 4 (75%) cotton rats and 1 of 4 (25%) rice rats, *Oryzomys palustris* (Harlan) from Berry Island in San Patricio County, Texas. Gravid worms were found in both hosts. These specimens matched the Florida material in all respects except for a longer left spicule length, which we attribute to geographic variation.

Although we believe that all of the specimens reported here represent the same species, in order to be conservative, the following description is based only on specimens from cotton rats from Florida. Measurements from the other Florida hosts are given in Table 2.

Family Gongylonematidae (Hall, 1916)

Subfamily Gongylonematinae (Nicoll, 1927)

Gongylonema archboldi n. sp.

(Figs. 1–2)

Type host: Cricetidae: *Sigmodon hispidus* Say & Ord, hispid cotton rat.

Other hosts. Cricetidae: *Peromyscus gossypinus* (LeConte), cotton mouse; *Peromyscus polionotus* (Wagner), oldfield mouse; *Podomys floridanus* (Chapman), Florida mouse; *Ochrotomys nuttalli* (Harlan), golden mouse; *Oryzomys palustris* (Harlan), rice rat.

Type locality. Archbold Biological Station, Highlands County Florida, U.S.A., 27° 10' N latitude, 81° 21' W longitude.

Other locality. San Patricio County, Texas, U.S.A., 27° 50' N latitude, 97° 14' W longitude.

Site of infection. Wall of anterior stomach.

Prevalence and intensity. 5 of 22 cotton rats infected with 1 to 15 worms.

Specimens deposited. Holotype USNM 1370746, allotype USNM 1405164, and paratypes USNM 1405165; Voucher specimens from *Peromyscus gossypinus* USNM 1370762, *Podomys floridanus* USNM 1370763; *Sigmodon hispidus* (Texas) HWML 96273, *Oryzomys palustris* HWML 96274.

Etymology. The species is named for Richard Archbold, pioneering biologist and founder of the Archbold Biological Station.

TABLE 1. Published reports of *Gongylonema* spp. from rodents in North America.

Host	Species	Locality	Reference
Castoridae			
<i>Castor canadensis</i> Kuhl	<i>Gongylonema pulchrum</i>	Virginia	Ogburn-Cahoon & Nettles, 1978
Sciuridae			
<i>Sciurus niger</i> Linnaeus	<i>Gongylonema pulchrum</i>	Florida	Coyner <i>et al.</i> , 1996
<i>Sciurus carolinensis</i> Gmelin	<i>Gongylonema pulchrum</i>	Virginia	Parker & Holliman, 1971
Muridae			
<i>Rattus norvegicus</i> (Berkenhout)	<i>Gongylonema neoplasticum</i>	Washington, D.C.	Lucker, 1931; Price & Chitwood, 1931
<i>Mus musculus</i> Linnaeus	<i>Gongylonema</i> sp.	Mexico	Pulido-Flores <i>et al.</i> , 2005
Heteromyidae			
<i>Dipodomys merriami</i> Mearns	<i>Gongylonema neoplasticum</i> ¹	California	Read & Millemann, 1953
	<i>Gongylonema dipidomysis</i> ¹	California	Kruidenier & Peebles, 1958
<i>Dipodomys panamintinus</i> (Merriam)	<i>Gongylonema neoplasticum</i> ¹	California	Read & Millemann, 1953
	<i>Gongylonema dipidomysis</i> ¹	California Nevada	Kruidenier & Peebles, 1958 King & Babero, 1974
Cricetidae			
<i>Ondatra zibethicus</i> (Linnaeus)	<i>Gongylonema</i> sp.	Maine	Meyer & Reilly, 1950
<i>Peromyscus maniculatus</i> (Wagner)	<i>Gongylonema</i> sp.	Colorado	Hall, 1912
	<i>Gongylonema</i> sp. ²	Utah	Frandsen & Grundmann, 1961a
	<i>Gongylonema peromysci</i>	Arizona	Kruidenier & Peebles, 1958
	<i>Gongylonema mysciphilia</i>	Utah	Frandsen & Grundmann, 1961b
<i>Peromyscus boylii</i> (Baird)	<i>Gongylonema peromysci</i>	Arizona	Kruidenier & Peebles, 1958
<i>Peromyscus eremicus</i> (Baird)	<i>Gongylonema peromysci</i>	Arizona	Kruidenier & Peebles, 1958
<i>Peromyscus truei</i> (Shufedit)	<i>Gongylonema peromysci</i>	Arizona Nevada	Kruidenier & Peebles, 1958 Babero & Matthias, 1967
<i>Peromyscus gossypinus</i> (LeConte)	<i>Gongylonema</i> sp.	Florida	Kinsella, 1991
<i>Peromyscus polionotus</i> (Wagner)	<i>Gongylonema</i> sp.	Florida	Kinsella, 1991
<i>Podomys floridanus</i> (Chapman)	<i>Gongylonema</i> sp.	Florida	Kinsella, 1991
<i>Ochrotomys nuttalli</i> (Harlan)	<i>Gongylonema</i> sp.	Florida	Forrester, 1992
<i>Reithrodontomys megalotis</i> (Baird)	<i>Gongylonema peromysci</i>	Arizona	Kruidenier & Peebles, 1958
<i>Sigmodon hispidus</i> Say & Ord	<i>Gongylonema</i> sp.	Florida Texas	Kinsella, 1974 Melvin & Chandler, 1950

¹The specimens identified by Read and Millemann (1953) as *Gongylonema neoplasticum* were later used by Kruidenier & Peebles (1958) to describe *Gongylonema dipidomysis*.

²Later described as *G. mysciphilia* by Frandsen & Grundmann (1961b).

Description. With characteristics of the genus. Long filiform worms with prominent cuticular bosses at the anterior end, more numerous in the female than the male (Fig. 1A, 1B; 2A, 2B). Mouth opening rectangular with

lateral constrictions opposite 2 large, lateral amphids. Three triangular teeth, 1 dorsal and 2 subventral on each side of mouth opening with a circle of 4 small papillae surrounding mouth opening. Two prominent lateral alae beginning at level of base of pharynx and extending to near the anus in both sexes (Fig 2C).

Male. (n=10). Body 13.0–19.0 mm (mean 17.0) long and 149–211 (182) in maximum width. Cuticular bosses at anterior end sparse, rounded, oval, or rectangular (Fig. 1A, 2A). Nerve ring 230–270 (250) from anterior end. Excretory pore near posterior end of muscular esophagus, 365–419 (396) from anterior end. Pharynx short, thin-walled, 32–41 (40) long. Esophagus 3082–3734 (3374) long, divided into short, anterior muscular portion 338–500 (425) long, and long, glandular posterior portion 2555–3320 (2960) long. Posterior end coiled ventrally and twisted to right, with narrow, asymmetrical caudal alae, right ala extending more anteriorly than left (Fig. 1C). Caudal papillae asymmetrical, pedunculate and variable in number, with 5 to 6 pairs pre-cloacal and 5 to 6 pairs post-cloacal. Post-cloacal pairs consist of 3 to 4 pairs of pedunculate and 1 to 2 pairs of sessile papillae near tail, often with unpaired papillae. Spicules dissimilar and very unequal in length (Fig. 1C, 1D).. Right spicule boat-shaped, 97–113 (106) long, with rounded distal end and ventral depression (Fig. 1D, 1E). Left spicule thin, needle-tipped, 1400–1745 (1539) long (Fig. 1D). Gubernaculum 76–92 (81) long with a cup-shaped base in which the right spicule rests and a long irregular flange extending anteriorly on the sinistral side (Fig. 1E).

TABLE 2. Measurements of specimens of *Gongylonema archboldi* n. sp. from rodents other than cotton rats in Florida. All measurements in microns unless otherwise specified.

	<i>Podomys floridanus</i>	<i>Ochrotomys nuttalli</i>	<i>Peromyscus gossypinus</i>	<i>Peromyscus polionotus</i>
Males				
n	5	1	7	4
Total length (mm)	6.8–11.6	10.4	8.6–14.2	8.6–14.3
Pharynx length	27–46	35	30–43	38–43
Muscular esophagus length	293–400	324	311–398	338–378
Glandular esophagus length	1890–2300	2444	1790–2490	2370–2380
Left spicule length	956–1290	1228	672–1433	1089–1467
Right spicule length	86–108	95	89–116	89–108
Gubernaculum length	57–70	84	59–81	65–78
Females				
n	2	-	4	-
Total Length (mm)	39.8, 47.4	-	44.4–55.9	-
Pharynx length	41, 43	-	43–49	-
Muscular esophagus length	473, 554	-	529–570	-
Glandular esophagus length	3860, 4400	-	4150–5400	-
Vulva to end	5820, 5820	-	5400–8340	-
Tail Length	190, 240	-	246–291	-
Egg length (n=10)	54–59	-	55–58	-
Egg width (n=10)	36–41	-	34–35	-

Female. (n=8). Body 67.4–69.1 mm (68.3) long (n=3) by 280–381 (321) in maximum width. Cuticular bosses much more extensive than in male, rounded, oval, or rectangular, extend to about 3 mm from anterior end (Fig. 1B, 2B, 2D). Nerve ring 321–378 (343) from anterior end. Excretory pore at level of posterior end of muscular esophagus, 650–710 (680) from anterior end. Pharynx, short, thin-walled, 43–47 (46) long. Esophagus 6320–6573 (6465) long, divided into short, muscular anterior part, 583–680 (622) long, and long, glandular posterior part, 5640–5990 (5840) long. Circular vulva 7000–10560 (9120) from posterior end. Eggs (n=10) larvated, 57–60 (58) long by 35–38 (37) wide. Tail blunt, 235–302 (276) long.

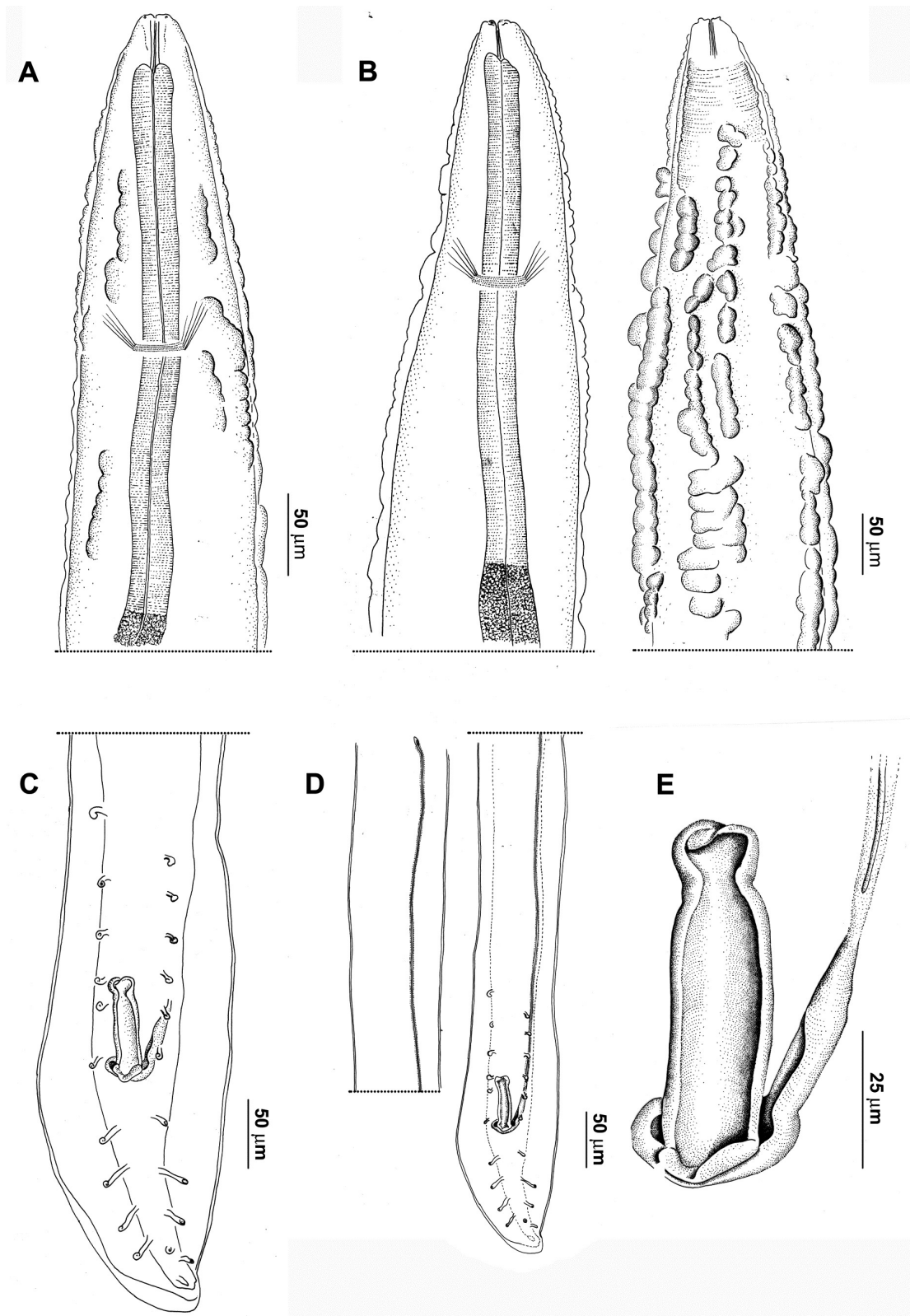


FIGURE 1. Drawings of *Gongylonema archboldi* n. sp. **A.** Male, anterior end with detail of nerve ring, muscular esophagus and beginning of glandular esophagus and cuticular bosses, internal and surface view. **B.** Female, anterior end with detail of nerve ring, muscular esophagus and beginning of glandular esophagus and cuticular bosses, internal and surface view in two different figures. **C.** Male, caudal papillae asymmetrical, pedunculate and variable in number of pre-cloacal and post-cloacal papillae and sessile papillae near tail, ventral view. **D.** Male, spicules dissimilar and very unequal in length, right spicule boat-shaped and left spicule thin, needle-tipped. **E.** Male, detail of gubernaculum with a cup-shaped base in which the right spicule rests.

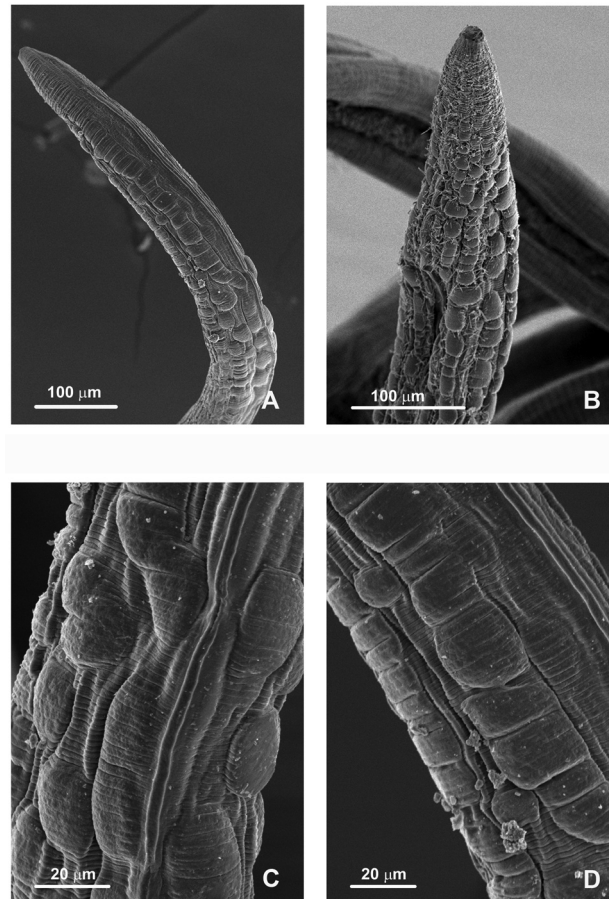


FIGURE 2. Scanning electron micrographs of *Gongylonema archboldi* n. sp. **A.** Male, anterior end with prominent cuticular bosses, ventro-lateral view. **B.** Female, anterior end with more numerous prominent cuticular bosses than the male, ventral view. **C.** Female, detail of lateral alae, lateral view. **D.** Female, detail of prominent cuticular bosses.

Remarks. Of the 5 species previously reported from North American rodents, *G. pulchrum* is easily distinguished from *G. archboldi* n. sp. by its much larger size (up to 51 mm in males and 130 mm in females) and much longer left spicule (up to 20 mm). The left spicules of *G. neoplasticum*, *G. dipodomysis*, and *G. peromysci* are all shorter than 750 microns while that of *G. archboldi* n. sp. is 1400 to 1745. In addition, the female of *G. dipodomysis* has a very limited field of cuticular bosses and the gubernacula of *G. dipodomysis* and *G. peromysci* have very different shapes than the gubernaculum of *G. archboldi* n. sp. *Gongylonema mysiciphilia* is the species most similar in measurements to *G. archboldi* n. sp., but this species was found in the wall of the cecum rather than the wall of the stomach, a singular anomaly within the genus. Since the description of *G. mysiciphilia* was based only on a single male and female, it is difficult to compare measurements. However, both spicules of this species are shorter (1130 and 72) than those of *G. archboldi* n. sp. (1400–1745 and 97–113), the esophagus of females is considerably shorter (3740 vs 6180–6680), as is the distance from the vulva to the tail (4800 vs 7000–10,560).

European, Asian, and African species of *Gongylonema* from rodents with left spicules less than 2 mm long include *G. brevispiculum* Seurat, 1914 (590); *G. problematicum* Schulz, 1924 (430–635); *G. pithyusensis* Mas Coma, 1977 (623–866); *G. aegypti* Ashour & Lewis, 1986 (318–420), and *G. madeleinensis* Diouf *et al.* 1997 (1125–1750). Only the spicules of *G. madeleinensis* overlap with *G. archboldi* n. sp. But both males (8.2 to 10.5 mm) and females (25 to 32 mm) of the former are shorter than *G. archboldi* n. sp. and the distance from the vulva to the tail (540 to 2400) is barely a third of *G. archboldi* (7000–10,560). The gubernacula of all 5 species are shorter than that of the new species and also differ in shape.

Discussion

The present description brings to six the number of species of *Gongylonema* reported in North American rodents (Table 1). The fact that specimens from the 4 species of cricetid mice were generally smaller in most dimensions than specimens from cotton rats (Table 2) and also less gravid may indicate that the cotton rat is the primary host for this species, although it could also be host-induced morphological variation. Support for the former hypothesis comes from the infections in cotton rats and rice rats in eastern Texas, which is outside the range of 3 of the 4 species of mice. This is the first record of any *Gongylonema* species from the rice rat. More information is needed to fill in the geographic and host ranges of the new species but it appears to already have more hosts and a wider distribution than any other North American species.

Information on infections of *Gongylonema* spp. in rodents in North America, in general, has been very limited. This could be because these nematodes are hidden in tunnels in the esophageal and stomach epithelium and, unless the wall is stretched and examined under a dissecting scope, they are very likely to be missed. Here is the current status of species from North American rodents.

1. *Gongylonema neoplasticum* is a cosmopolitan parasite with a wide host range, but most published records have come from Muridae (Yamaguti, 1961). The only verified North American records are from brown rats (*Rattus norvegicus*) in Washington, D.C. (Table 1). The specimens identified as *G. neoplasticum* by Read & Millemann (1953) from *Dipodomys* spp. in California were later redescribed by Kruidenier & Peebles (1958) as *Gongylonema dipodomysis*.

2. *Gongylonema pulchrum* is also a cosmopolitan parasite with very little host specificity, having been reported from a great variety of domestic and wild ruminants, equids, suids, and primates, including man (Yamaguti, 1961). There are a few records in North America from beaver (*Castor canadensis*) and tree squirrels (*Sciurus niger* and *Sciurus carolinensis*) and these are so far restricted to the eastern United States (Table 1). Lichtenfels (1971) studied morphological variation in *G. pulchrum* from natural and experimental infections of 8 species of hosts, including white rats, and found that the most stable taxonomic characters were total body length, left and right spicule lengths, glandular esophagus length and ratios between these characters.

3. *Gongylonema dipodomysis* is still only known from the original collections from *Dipodomys* by Read & Millemann (1953) in California. Kruidenier & Peebles (1958) did not collect any new material despite examining 396 mammals of 42 species in Arizona. Whether it is a specific parasite of the Heteromyidae remains to be seen.

4. *Gongylonema peromysci*, based on the original description, appears to have the potential for a wide host spectrum in cricetid mice, having been reported from 4 species of *Peromyscus* and the harvest mouse, *Reithrodontomys megalotis* (Kruidenier & Peebles, 1958). But its known range is still restricted to Arizona. The authors know of one additional record from *P. maniculatus* in Utah (unpub. data).

5. *Gongylonema mysciphilia* is perhaps the most enigmatic species of the genus. It was described from a single male and female from *P. maniculatus* collected from an island in the Great Salt Lake in Utah and is the only species of the genus ever found in the wall of the cecum rather than the stomach (Frandsen & Grundmann, 1961b). No other specimens have been recorded despite extensive surveys of this host in North America (Dyer, 1969). One of the authors (JMK) examined the type material (USNPC 74953 and 74954) and found that the specimens had been darkened by the preservative over time and were of little use. However, the original description was adequate and the species should stand until more material is available. Although it is morphologically similar to *G. archboldi* n. sp., the location in the cecum and differences in some measurements justify their separation.

It is clear that there remains much to learn about the systematics of *Gongylonema* and molecular studies are especially badly needed. The paper by Setsuda *et al.* (2015), which includes molecular data on *G. pulchrum*, *G. neoplasticum*, and *G. aegypti* is a step in the right direction but other North American species need to be collected and extracted for comparison.

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