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CHROMOSOMES AND CYTOGENETICS OF HELMINTHS (TURBELLARIA, TREMATODA, CESTODA, NEMATODA AND ACANTHOCEPHALA)

CROMOSOMAS Y CITOGENÉTICA DE HELMINTOS (TURBELLARIA, TREMATODA, CESTODA, NEMATODA Y ACANTHOCEPHALA)

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ABSTRACT

We review the literature from 1886 to 2014 and the current status of knowledge of the chromosomes and cytogenetics of all species of Turbellaria, Trematoda, Cestoda, Nematoda, and Acanthocephala. Karyological data are discussed and tabulated for 614 species: 115 species of Turbellaria, 278 species of Trematoda, 117 species of Cestoda, 85 species of Nematoda and 19 species of Acanthocephala. Turbellarians are not parasitic except for a few possible exceptions and they show a gradual reduction of the basic number of chromosomes. Trematodes are numerous which points towards the continued efforts in this field of research. Data on chromosomes are lacking for acetabulate cestodes of the orders: Litobothriidea, Lecanicephalidea, Cathetocephalidea, Rhinebothriidea and Tetrabothriidea.

Keywords: chromosomes – cytogenetics - Acanthocephala- Cestoda- - Nematoda- Trematoda- Turbellaria.

RESUMEN

En este artículo revisamos la literatura desde 1886 hasta 2014 y el estado actual del conocimiento de los cromosomas y la citogenética de todas las especies de las familias de turbellaria, trematoda, cestoda, nematoda y acanthocephala. Datos cariológicos son analizados y tabulados para 614 especies: 115 especies de turbellaria, 278 especies de trematoda, 117 especies de cestoda, 85 especies de nematoda y 19 especies de acantocephala. Los Turbelarios no son parásitos a excepción de unas pocas posibles excepciones y muestran una reducción gradual del número básico de cromosomas. Trematodes son numerosos requiriendo apuntar hacia los esfuerzos continuos en este campo de investigación. Los datos sobre los cromosomas se carecen para cestodos acetabulados de las órdenes: Litobothriidea, Lecanicephalidea, Cathetocephalidea, Rhinebothriidea y Tetrabothriidea.

Palabras clave: Acanthocephala- Cestoda- citogenética - cromosomas - Nematoda- Trematoda- Turbellaria.

INTRODUCTION

As with molecular data, cytogenetic information can reveal differences and similarities that may not be obvious at the morphological level. White (1978) estimated that more than 90% of all speciation events are accompanied by karyotypic change. If this is correct, then chromosomal studies should be widely applicable to the problems of sorting groups of morphologically similar (sibling) species. Chromosomes are studied as a morphological manifestation of the genome in terms of their microscopically visible size, shape and number, and karyology represents a qualitative approach to phylogeny. To what extent, though, can karyotypic features be suitable for phylogenetic inference? Patterns of chromosomal divergence within a group may not necessarily parallel those of morphological features (Gold, 1980; Baker & Bickham, 1980), but most often species related from a morphological point of view show karyological affinities. If karyotypic features are plotted over a phylogenetic tree based on molecular or morphological data, the processes involving chromosome evolution might be clarified.

A karyotype is the number and appearance of chromosomes in the nucleus of eukaryotes (Stebbins, 1950; White, 1973). The term is also used for the compliment set of chromosomes in a species or an individual organism. Karyotype describes the number of chromosomes and what they look like under a light microscope. Attention is paid to their length, the position of chromosomes, any differences between the sex chromosomes and any other physical characteristics (King *et al.*, 2006). The preparation and study of karyotypes is a part of cytogenetic. The study of whole sets of chromosomes is known as karyology. The chromosomes are depicted (by rearranging a microphotograph) in a standard format known as karyogram or ideogram: in pairs, ordered by size and position of centromeres for chromosomes of the same size. The basic number of chromosomes in the somatic cells of an individual or a species is somatic number and is designated as 2n. In normal diploid organisms, autosomal chromosomes are present in two copies. Polyploid cells have multiple copies of chromosomes and haploid cells have single copies. Karyotypes can be used for many purposes such as to study chromosomal aberrations and taxonomic relationships and to gather information about past evolutionary events.

Most karyotype studies use cells that are near the end of prophase or in early metaphase of mitosis because the chromosomes are compact and densely staining and have a characteristic size and shape. The chromosome size, the location of the centromere, and patterns of light and dark staining that occur when chromosomes are treated with different chemical dyes are collectively referred as chromosome morphology and the number and morphology of an individual's chromosomes is called that individuals karyotype. The analysis of karyotypes of different organisms proves quite useful in species description and identification (Stebbins, 1950; White, 1973).

Taxonomic identification of the helminth parasites which causes diseases is absolutely essential for effective treatment. Taxonomy plays very important role in the management and prophylaxis of diseases by biological means. Anticipating a problem is always more time and cost effective than responding to a crisis, no matter how effective the response. Systematic biology provides and integrates the knowledge that is crucial for any effort to be proactive in the arena of emerging parasitic and infectious diseases. The aim is to complete the global inventory of parasitic species, an absolute necessity if we are to assess risk of parasitic diseases. Taxonomy is important in the field of Biodiversity and Conservation, Research and Studies, Agriculture and Pest management, Quarantine, National defence, Fisheries and Aquaculture, Parasitology and Veterinary Science, Conservation of Plants, Animals and Microbes.

The purpose of this study is to: (1) Find out the chromosome number of helminths from different vertebrates; (2) Find out the Karyotype characteristics of helminthes; (3) Differentiate helminths on the basis of the karyological characteristics; (4) Role of these studies in cytotaxonomy, and (5) Find out the general aspects such as trends of karyotypic evolution and sex mechanism of trematodes.

MATERIALS AND METHODS

The present methodology is in accordance with the all articles find about chromosomes of Turbellaria, Trematoda, Cestoda, Nematoda and Acantocephala in Google Scholar, Elesiever, Jstor and Springer. For karyotyping, chromosomes descriptions were on the basis of size and centromere position (Petkeviciute & Leshko, 1991). Relative lengths of chromosomes were calculated by the division of the individual chromosome length by the total haploid length and centromeric indices (ci) were determined by division of the length. The terminology relating to centromere position follows that of Levan *et al.* (1964). A chromosome is metacentric (m) if the ci falls in the range of 37.5–50.0, submetacentric (sm) if 25.0–37.5, subtelocentric (st) if 12.5–25.0 and acrocentric (a) if < 12.5. When the centromere position was on the borderline between two categories, both are listed.

RESULTS AND DISCUSSION

Chromosomes of Turbellaria

Among the turbellarians, records of chromosome numbers among the primitive Acoela are few, but three species of the Convolutidae have been studied and all seem to indicate that the somatic number of very small chromosomes is somewhat variable but high-ranging from 20 to 30. Records for the other orders of this basically hermaphroditic and occasionally parthenogenetic class are numerous and the results have been corroborated by various researchers. Among the Alloeocoela, members of the Prorhynchidae, the Plagiostomidae, and the Bothrioplanidae usually show a basic haploid number of 10 (reduced to 5 in one species), but the Monocelididae have the haploid number of 3, while the Pseudostomidae have either 4-5 or 8-10. Since polyploidy is common among the turbellarians, the basic haploid chromosome number for the alloeocoels may be 5, although *Monocelis fusca* [Ruebush (1938)]; (n = 3) does not readily fit into the schema. Among the Tricladida there seems to be a much greater degree of variation in the basic haploid number of chromosomes. Among the Planariidae the number ranges from 6 to 24 (6, 8, 12, 16, 18, and 24 have been recorded). Curtisia and some polycelids have n = 6. In other polycelids polyploidy is believed to give rise to the species having n = 12, 18, or 24. Lepori (1953a, b) believes that in some cases among the polycelids true fertilization does not occur, and that the multiples of the basic chromosome number may perhaps be due to failure to undergo reduction divisions (a condition Lepori terms gynogenesis). In the genus *Planaria* most of the species have the basic chromosome number of 8. In the genus *Dugesia*, the number varies from 8 to 16 or to 24, again an example of possible polyploidy, but the appearance of 12 chromosomes in *Dugesia alpina* [Rappeport (1915)]; may be an indication that the basic number is 4 rather than 8, as stated by Benazzi-Lentati, 1949. Among the Dendrocoelidae we again find considerable variation in the basic haploid number. *Dendrocoelum* has species with 8 and others with 16 chromosomes (possible examples of polyploidy). Procotyla and one variety of *Dendrocoelum lacteum* [Pennypacker (1954)] (both with 7 haploid chromosomes) and *Bdellocephala* with 10 chromosomes are variants (possible aneuploidy). Other families such as the marine Bdellouridae and the Procerodidae are represented by too few species in which the basic chromosome number has been determined (*Bdelloura*, where n = 6 and fragmentation may raise the number as high as 12; and Procerodes, with n = 6) to be indicative of their evolutionary position, although the presence of fragmentation may point toward a possible compound nature of the gametic chromosomes. Turning to the Polycladida we again note variability in the haploid chromosome number which ranges from 6 to 8 and occasionally to 9 or 10. The Euryleptidae, the Leptoplanidae, and the Prosthiostomidae seem to have the basic number of 8 while the Planoceridae possess 10 chromosomes, but no such consistency appears among the genera of the Stylochidae where the basic numbers are either 9 or 10. The single pseudocerid examined has 9 chromosomes. It might be suggested that in these cases possible fusion of some of the chromosomes may have occurred, thus reducing the number from 10 to 9, or even to 8, and thus showing relationship to the basic 10 pattern set by the Planoceridae as a whole. An alternative possibility is that a doubling of one or more chromosomes has caused the deviation from a basic number of 8, as represented by the Euryleptidae. On purely morphological grounds the planocerids are regarded as the more primitive and the euryleptids as more specialized among the polyclads. Among the higher Rhabdocoela, we again find considerable variation in numbers, but the basic count is low, ranging from 2 to 6, and it is suggested that fragmentation of one or more chromosomes plus some group duplication of the basic number may be involved. Among the supposedly more primitive rhabdocoels (Catenulidae) the basic number runs much higher, ranging from 15 to 20 and the somatic numbers may reach to 40 [*Stenostomum*, *Rhynchoscolex*, *Catenula* and *Fuhrmannia* = *Suomina* are representative genera]. According to Pennypacker- (1954) - such variation is of evolutionary importance in that as a general rule a larger number of smaller chromosomes are indicative of ancestral conditions and a smaller number points toward a more recently emerged species. Among the Typhloplanidae it may be noted that *Opistomum*, *Krumbachia*, *Solenopharynx*, *Amphibolella*, some protoplanellids, and Phaenocora, as well as the North American form of *Rhynchomesostoma rostratum* show a basic number of 2. (The European race of *R. rostratum* has 3 chromosomes, as do *Trigonostomum*, some protoplanellids, and Co-strata.) Papi- (1950) - indicates that the basic number for the Mesostominae is 4, but through fusion, fragmentation, or ploidy, some species show n = 2, 3, 5, or 8. The Dalyelliidae all show n = 2. Jones, 1944, has indicated that among the Macrostomidae, the basic number is probably 3 and that a few species show multiples in the form of 6 and 9 as the reduced number of chromosomes (some species however, show 2 and 8). The Graffillidae also show at least in the genus *Paravortex* that the basic number is 2, doubled in one species to 4. The Provorticidae have a basic number of 3. The Kalyptorhynchidae vary from 2 to 3 to 8 (Table 1).The single temnocephalid examined has 8 chromosomes. As yet there seems to be no complete agreement between chromosome number and the phylogenetic position of these forms as determined by other criteria, but on the other hand no absolute contradictions have come to light. Although the turbellarians are not parasitic except for a few possible exceptions, they have been introduced into this discussion because they do show the gradual reduction of the basic number of chromosomes from a large number of small chromosomes to a smaller number of larger units, not only within the group as a whole, but in some cases within races of the same species, and may possibly give hints as to the derivation of the

Trematoda which do show a much greater conformity between the chromosome number and the taxonomic position as based on other criteria. There seems to be considerable evidence already available pointing to the trematodes as evolving from a rhabdocoel stock, and possibly from the dalyelliid group. Cytological evidence seems to corroborate this interpretation of a rhabdocoel ancestry, but if such development came through the dalyelliids, it must have been from a stock much less specialized than the present day forms which are regarded by many as being among the more advanced of the rhabdocoels. In this same connection it may be of interest to point out that the acoelids and the alloeocelids are regarded as the most primitive of the turbellarian line of development and most consistently possess the highest basic number of chromosomes (10 in most of the species examined). Through some form such as *Bothrioplana* (n = 10) could have come the triclads (some of the dendrocoelids show this basic number of 10). Polyclads and the rhabdocoels lack such close cytological connection with a possible alloeocoelid ancestry although some of the polyclad planocerids and some of the rhabdocoelid macrostomids do show practically the same basic chromosome numbers.

Table 1. Chromosomes of Turbellaria (From 1905 Till Date).

Family Species	No. and Morphology of Chromosomes	Bibliographic reference
	CERCYRINAE	
Cercyra hastate	2n = 14 (3sm + 3st + 1t)	Galleni & Puccinelli (1982)
Balliania thetisae	2n = 22	Gourbalt (1978)
	UTERIPORIDAE	
Uteriporus vulgaris	2n = 16	Ball (1976)
Foviella affinis	2n = 16	Ball (1976)
	PROCERODIDAE (PROCERODINAE)	
Procerodes gerlachei	2n = 12	Bohmig (1908); Ruebush (1938)
Procerodes littoralis	2n = 14	Ball (1976, 1979); Galleni & Puccinelli (1975, 1979)
Procerodes dohrni	2n = 14	Galleni & Puccinelli (1979)
	OPISTHOBURSIDAE	
Opisthobursa mexicana	2n = 14	Benazzi & Giannini (1973)
	PSEUDOCERIDAE	
Yungia aurantiaca	2n = 18 (4m + 2sm + 2t)	Galleni & Puccinelli (1985)
Dugesia lugubris	2n = 8	Galleni *et al*. (1989)
Polycelis nigra	2n = 16; 3n = 24	Lamatsch *et al*. (1998)
Dugesia polychroa	2n = 8; 3n = 12 (1m + 3a)	Lamatsch *et al*. (1998)
Dugesia sicula Lepori	2n = 18	Fillipi *et al*. (1998)
Dugesia gonocephala	2n = 16; 8m	Baguna *et al*. (1999); Deri *et al*. (1999)
Schmidtea polychroa	2n = 8	Benazzi (1957)
Schmidtea polychroa	3n = 12	Benazzi (1957)
Schmidtea polychroa	4n = 16	Benazzi (1957)
Schmidtea polychroa	5n = 20	Benazzi (1957)
Schmidtea lugubris	2n = 8	Benazzi (1957)
Schmidtea lugubris	2n = 6	Benazzi (1957)
Schmidtea mediterranea	2n = 8	Benazzi (1957)
Schmidtea mediterranea	3n = 12	Benazzi (1957)
Dugesia benazzi	2n = 16	Baguna *et al*. (1999)
Dugesia hepta	2n = 14	Baguna *et al*. (1999)
Dugesia etrusca	2n 16	Baguna *et al*. (1999)
Dugesia subtentaculata	2n = 16	Baguna *et al*. (1999)
Dugesia sicula	3n = 27	Baguna *et al*. (1999)
Thysanozoon brocchi	2n =18	Schockaert (1905); Ruebush (1938)

Family Species	No. and Morphology of Chromosomes	Bibliographic reference
	RHYNCHODEMIDAE	
Dolichoplana carvalhoi	2n = 14 (5m + 1sm + 1st); 3n = 21 (1a,4c,5b,6,7a,7b (m) + 1b,2a,(sm) + 3c,3d (st);	Alvarez & Almeida (2007)
Pentacoelum hispaniense Sluys, 1989	2n = 14; 2m + 3t/st + 2sm	Vila-Farre *et al.* (2008)
	CONVOLUTIDAE	
Aphanostoma diversicolor	2n =40-60	Ruebush (1938)
Convoluta sp*?*	2n =40-60	Ruebush (1938)
Polychoerus caudatus	2n =62	Gardiner (1898)
Polychoerus carmelensis	2n = 34	Costello (1970)
	BOTHRIOPLANIDAE	
Bothrioplana semperi	2n =20-30	Pennypacker (1954)
	PLAGIOSTOMIDAE	
Hydrolimax grisea	2n =20	Pennypacker (1954)
Plagiostomum stetlatum	2n =10	Ruebush (1938); Pennypacker(1954)
	PRORHYNCHIDAE	
Geocentrophora applanatus	2n =20	Ruebush (1938); Pennypacker (1954)
Prorhynchus stagnalis	2n =20	Ruebush (1938); Pennypacker (1954)
	PSEUDOSTOMIDAE	
Pseudostomum caecum	2n =16-20	Jones (1943); Pennypacker (1954)
Pseudostomum sp?	2n =8-10	Ruebush (1938); Pennypacker (1954)
	MONOCELIDIDAE	
Monocelis fusca	2n =6	Ruebush (1938); Pennypacker (1954)
	PLANARIIDAE	
Curtisia foremanni	2n =12	Pennypacker (1954)
Polycelis tenuis	2n =12	Melander (1950); Lepori (1953)
Polycelis nigra	2n =36	Lepori (1953)
Dugesia benazzi	2n =16 & 32	Benazzi-Lentati and Nardi (1950)
Dugesia gonocephala	2n =16 & 32	Schleip (1907); Benazzi- Lentati (1949)
Dugesia alpina	2n =24	Rappeport (1915); Benazzi- Lentati (1949)
Dugesia sp*?*	2n =48	Ruebush (1938)
Planaria polychroa	2n =16	Mattieson (1904); Ruebush (1938)
Planaria torva	2n =16	Mattieson (1904); Ruebush (1938)
Phagocata fawcetti	2n = 38	Ball and Gourbault (1975)
	DENDROCOELIDAE	
Dendrocoelum lacteum	2n =14 & 16	Pennypacker (1954)
Dendrocoelum infernale	2n =32	Aeppli (1951); Pennypacker (1954)
Procotyla fluviatilis	2n =14	Pennypacker (1954)
Bdellocephala brunnea	2n =20	Momma (1953)
	BDELLOURIDAE	
Bdelloura candida	2n =12-24	Pennypacker (1954)
Bdellura candida	2n = 12	Pennypacker (1938)
	EURYLEPTIDAE	
Cycloporus papillosus	2n =16	Francotte (1898); Ruebush (1938)
Oligocladus aurritus	2n =16	Francotte (1897); Ruebush (1938)
Prostheceraeus vittatus	2n =12	Gerard (1901); Ruebush (1938)
	LEPTOPLANIDAE	
Leptoplana tremellaris	2n =16	Francotte (1898); Ruebush (1938)
	PROTHIOSTOMIDAE	
Prosthiostomum siphunculus	2n =16	Francotte (1898); Ruebush (1938)
	STYLOCHIDAE	
Stylochus pilidium	2n =18	Gerard (1901); Ruebush (1938)
Eustylochus ellipticus	2n =20	Von Name (1899); Ruebush (1938)
	PLANOCERIDAE	
Planocera inquilina	2n =20	Patterson & Wieman (1912); Ruebush (1938)
Planocera nebulosa	2n =20	Von Name (1899); Ruebush (1938)
	CATENULIDAE	
Fuhrmannia sp*? (= Suomina* sp*?)*	2n =32	Ruebush (1938)
Catenula virginiana	2n =40	Ruebush (1938)
Rhyncoscole simplex	2n =40	Ruebush (1938)
Stenostomum grandi	2n =40	Ruebush (1938)
Stenostomum sp*?*	2n =40	Ruebush (1938)

Family Species	No. and Morphology of Chromosomes	Bibliographic reference
TEMNOCEPHALIDAE		
Temnocephalus canis	2n =16	Ruebush (1938)
TYPHLOPLANIDAE		
Promesostoma marmoratum	2n =12	Ruebush (1938)
Bothriomesostoma personatum	2n =10	Ruebush (1938)
Bothriomesostoma essenii	2n =10	Papi (1950)
Byrsophlebs sp?	2n =8	Ruebush (1938)
Mesostoma rhynchotum	2n =16	Valkanov (1938)
Mesostoma ehrenbergii (Europe)	2n =10	Papi (1950)
Mesostoma ehrenbergii wardi (U.S.A.)	2n =8	Husted *et al*. (1939)
Mesostoma benazzii	2n =8	Papi (1950)
Mesostoma lingua	2n =4 & 6	Ruebush (1938)
Costrata subsala	2n =6	Ruebush (1938)
Costrata virginiana	2n =6	Ruebush (1938)
Costrata sp?	2n =6	Ruebush (1938)
Typhloplana viridata	2n =6	Ruebush (1938)
Trigonostomum lillei	2n =6	Ruebush (1938)
Protoplanella sp?	2n =6	Ruebush (1938)
Protoplanella sp?	2n =4	Ruebush (1938)
Opistomum pallidum	2n =4	Ruebush (1938); Papi (1952, 1953)
Opistomum sp?	2n =8	Ruebush (1938)
Krumbachia minuta	2n =4	Ruebush (1938)
Krumbachia virginiana	2n =4	Ruebush (1938)
Solenopharynx sp?	2n =4	Ruebush (1938)
AmphibolelIa virginiana	2n =4	Ruebush (1938)
Phaenocora kepneri	2n =4	Ruebush (1938)
Phaenocora lutheri	2n =4	Ruebush (1938)
Phaenocora virginiana	2n =4	Ruebush (1938)
Phaenocora sp?	2n =4	Ruebush (1938)
Rhynchomesostoma rostratum	2n =4 & 6	Volkanov (1938); Papi (1950)
KALYPTORHYNCHIDAE		
Polycystis goettei	2n =16	Ruebush (1938)
Microkalyptorhynchus virginianus	2n =6	Ruebush (1938)
Acrorhynchus reprobatus	2n =4	Ruebush (1938)
Gyratrix hermaphroditicus	2n =4	Ruebush (1938)
PROVORTICIDAE		
Provortex affinis	2n =6	Ruebush (1938)
Provortex sp?	2n =6	Ruebush (1938)
GRAFFILLIDAE		
Paravortex cardii	2n =4	Hallez (1908); Ruebush (1938)
Paravortex gemellipara	2n =8	Ball (1916); Ruebush (1938)
MACROSTOMIDAE		
Macrostomum hystrix	2n =4	Ferguson (1940)
Macrostomum viride	2n =4	Ferguson (1940)
Macrostomum beaufortensis	2n =6	Ferguson (1940)
Macrostomum tuba	2n =6	Ferguson (1940)
Macrostomum rirginianum	2n =6	Ferguson (1940)
Macrostomum hustedi	2n =12	Jones (1944)
Macrostomum bispiralis	2n =16	Ferguson (1940)
Macrostomum kepneri	2n =18	Ferguson (1940)
DALYELLIIDAE		
Castrella truncata	2n =2	Ruebush (1938)
Dalyellia abursalis	2n =2	Ruebush (1938)
Dalyellia armigera	2n =2	Ruebush (1938)
Dalyellia triangulata	2n =2	Ruebush (1938)
Dalyellia virginiana	2n =2	Ruebush (1938)
Dalyellia riridis	2n =2	Ruebush (1938)
Dalyellia (4 sp'?)	2n =2	Ruebush (1938)

a = acrocetric; a, b, c, d = chromosome variants; m = metacentric; sm = sub-metacentric; st = subtelocentric acrocentric.

Chromosomes of Trematoda

A number of workers on trematode cytology, especially Jones and his co-workers, have pointed out the possible taxonomic value of the study of the numbers, volume, and/or size and shape of chromosomes, and much of our information along these lines is based upon their investigations. Among the Monogenea only the Polystomidae have been investigated for the purpose of determining the chromosome numbers. *Polystoma integerrimum* (Frolich, 1791) has the haploid number of 4 chromosomes and *Gyrodactylus elegans* has 6. This could point to a dalyelliid ancestry (n = 2 in all species studied) although more primitive ancestors of the dalyelliids may have had a larger basic number of chromosomes (Table 2). Among the Digenea, the paramphistomatids have been regarded as the most primitive group, but from a cytological standpoint the basic chromosome number is quite variable and is therefore of little guidance in determining possible relationships. For example, Gigantocotyle shows a basic number of 6, *Gastrothylax* and *Zygocotyle* have 7, *Cotylophoron* and *Diplodiscus* have 8, while *Heronimus* chelydrae has 10. No one family of the rhabdocoel group could be regarded as being directly ancestral based on such divergent records. As much as the exact phylogenetic relationships of the remaining families of the Digenea are not as yet fully determined, even on morphological grounds, and the various authorities disagree as to their proper taxonomic positions, no attempt will be made to discuss our knowledge of chromosome numbers in any significant succession. The diploid chromosome numbers vary among studied digenean taxa, from 12 to 28 (Bariene, 1993); chromosome sets with 20 or 22 elements predominate. But 56 chromosomes were found in diploid sets of *Clonorchis sinensis* (Cobbold, 1875) (Park *et al.*, 2000). Allocreadiid species possess comparatively large chromosomes, up to 13–14 mm, but low haploid numbers of six, seven or eight were recorded in most species (for a review see Petkeviciute & Staneviciute, 2008). The chromosome complement of *Cercariaeum crassum* (Wesenberg-Lund, 1934) is unusual among digeneans due to the low number, 2n=10. The karyotype is composed of large and exclusively bi-armed chromosomes. Such a karyotype presumably results from a decrease in chromosome number through centromere–centromere Robertsonian fusions that have affected mono-armed chromosomes leading to the formation of large metacentric elements. Comparative analysis of chromosomes of related trematode species indicated that the reduction of chromosome numbers resulted from centromeric fusion rather than elimination of chromosomes (Grossman *et al.*, 1981). Acrocentric mono-armed chromosomes prevail in the karyotypes of larval *B. luciopercae*, 2n = 14, and larval *A. isoporum sensu* Wisniewski, 1959, 2n = 14 (Petkeviciute & Staneviciute, 2008). It is notable that the mean total length of haploid complements (TCL) of these two species does not exceed the TCL of *C. crassum*, despite different chromosome numbers.

It may be noted, however, that all of the heterophyids (*Cryptocotyle* and *Acetodextra*), bucephalids (*Bucephalus* and *Rhipidocotyle*), fasciolids (*Fasciola*), and zoogonids (*Zoogonus*) examined (7 species), as well as 1 species of a gorgoderid (*Probolitrema*) and 1 of a paramphistomatid (*Gigantocotyle*) have a basic number of 6 [perhaps thus indicating some relationship to the more primitive paramphistomatids (n = 7)]. The notocotylids (*Notocotylus*) have 7 chromosomes, but too few examples have been studied to determine the value of such counts. One species of an allocreadid (*Bunodera*), 1 gorgoderid (*Gorgoderina*), and 1 schistosomatid (*Schistosomatium*) have 7 chromosomes, in addition to the 2 amphistomids (*Zygocotyle* and *Gastrothylax*). All of the *Schistosoma* species studied show n = 8, as do 2 species of gorgoderids (*Gorgodera* and

Phyllodistomum), 1 troglotrematid (*Paragonimus*), 3 species of allocreadids (*Bunodera*, *Crepidostomum* and *Allocreadium*), 1 species of a rhopaliid (*Rhopalias*), and 2 species of the reniferids (*Staphylodora* and *Telorchis*), in addition to the 2 species of paramphistomatids (*Cotylophoron* and *Diplodiscus*). Two species of the azygiids (*Azygia* and *Proterometra*), 2 species of the plagiorchids (*Eustomas* and *Glypthelmins*), 1 species of a spirorchid (*Spirorchis*), 1 pronocephalid (*Macrovestibulum*), 1 lecithodendriid (*Brandesia*), 1 monorchid (*Asymphylodora*), 1 hemiurid (*Halepegus*), and 1 reniferid (*Auridistomum*), in addition to 1 race of the paramphistomatid *Diplodiscus* (*temperatus*) have 9 chromosomes. Those having a basic number of 10 chromosomes are 1 species of a cyclocoelid (*Cyclocoelum*), 2 species of dicrocoelids (*Brachycoelium* and *Dicrocoelium*), 1 clinostomatid (*Clinostomum*), and 1 hemiurid (*Isoparorchis*). Only *Heronimus* of the paramphistomatids falls in this cate-gory. Four species of plagiorchiids (3 *Pneumonoeces* and 1 *Plagitura*), 1 echinostomid (*Parorchis*), 2 lecithodendriids (*Acanthatrium* and *Loxogenes*), and 15 species of reniferids (1 *Dasymetra*, 1 *Lechriorchis*, 1 *Natriodora*, 6 *Neorenifer*, 2 *Pneumatophilus*, 1 *Renifer*, and 3 *Telorchis*) have 11 chromosomes. In these cases again no direct relationship to the paramphistomatids can be noted in terms of chromosome number, although in terms of the presence of an increased number of chromosomes as indicating a possible primitive condition, these forms might be regarded as less specialized than others of the Digenea. It should be pointed out, however, that in many cases it is not only in the matter of actual number of chromosomes that similarities (relationships) may be indicated: total volume of chromatic material, shapes and sizes of the chromosomes, point of spindle attachment to individual chromosomes, and behavior during division may afford evidence of equal importance. It is also definite that sufficient differentiation occurs to facilitate identification of species. One species of *Cephalogonimus* has 14 chromosomes which may be a case of doubling of the usual number of 7 in this genus. If one follows the belief of Ciordia (1949), who doubts the existence of polyploidy among the Trematodes, this would be an example of extreme aneuploidy-duplication of individual chromosomes and not of the set as a unit. The matter of the presence or absence of the so-called heterochromosome ("sex chromosome") has not been determined in most of the trematode species examined, but in a few cases the recognition of two types of sex cells differing from each other in terms of the number, size, shape, volume or behavior of the chromosomal elements would seem to indicate that such sexual differentiation does occur. As examples we may mention the studies on *Schistosoma* and *Schistosomatium*. The earlier observations on *Schistosoma haematobium*, *S. mansoni*, and *S. japonicum* (Katsurada, 1904); seemed to indicate that two types of sperm could be identified and that adult males possessed 15 and adult females possessed 16 somatic chromosomes. This would seem to mean that an X-O condition obtained in these forms. Other studies reported the numbers as 14 and 16, respectively, and were interpreted as showing the presence of a 2X + 12 and a 4X + 12 chromosome complex. Niyamasena (1940) in his studies on *S. mansoni* found the somatic number of chromosomes to be 16 in each sex, and could not find any evidence of the presence of recognizable sex chromosomes although the possibility of an X-Y condition could not be ruled out. Most recent studies support the finding of 16 chromosomes as the diploid number in all adults of all three of the above *Schistosoma* species and the inability to recognize sex chromosomes as being present, 16 chromosomes are also present in each sex of *S. mansoni* carcariae (Bilharz, 1852). Recent studies on *Schistosomatium douthitti* (Bilharz, 1852); have presented 2 different interpretations of what is undoubtedly an example of the presence of distinguishable sex chromosomes. One study (Woodhead, 1957) indicates the presence of a single "X" chromosome in the male, while the other (Short, 1957) presents evidence of the heterogametic condition as prevailing in the female. Studies in this laboratory seem to substantiate this second interpretation. The somatic (diploid) number of chromosomes in each sex is 14, with the male showing a pair of large V-shaped chromosomes that are not matched in the female. In the latter case there is a single large V-shaped chromosome apparently paired with a single rod-shaped body. This rod-shaped chromosome does not appear in any of the male cells. It is interpreted as indicative of a ZZAA condition in the male and a ZWAA condition in the female. Short & Menzel (1957) report a similar condition in the cercariae of *Ornithobilharzia canaliculata*, where 2n = 16. No other records of the presence of recognizable sex chromosomes among the trematodes seem to have been substantiated by recent investigations. No records of the "diminution" phenomenon have been brought to our attention. Le Roux (1958) in a study of mammalian blood flukes, has suggested a division of the genus *Schistosonmai* into several groups: *Schistosoma* (*S. haematobium*, type), *Afrobilharzia* (*A. mansoni*, type), *Sinobilharzia* (*S. japonicum* type), *Rhodobilharzia* (*R. margrebovici*, type), and *Eurobilharzia* (*E. bomfordi*, type). These genera are in addition to the already recognized genera of *Bivitellobilharzia*, *Heterobilharzia* and *Schistosomatium* as members of this group of flukes. Restudy of the chromosomes of these species might help to evaluate such a separation. The same technique might also help solve the complexities of the taxonomy of avian *Schistosomes*.

Table 2. Chromosome number of Trematoda from 1902 Till Date.

Family Species	No. and Morphology of Chromosomes	Reference
	SCHISTOSOMIDAE	
Schistosum japonicum Katsurada, 1904	2n = 16 (6t +2at)	Short & Menzal (1960)
Austrobilharzia variglandis	2n=16	Short & Menzal (1960)
Gigantobilharzia huronensis	2n=16(+B)	Short & Menzal (1960); LoVerde & Kuntz (1981)
Heterobilharzia americana	2n=20(ZW); ZZ/ZW, m/st; 6m+4sm+2sm-st+ 8st	Short & Grossman (1986)
Texas (Male)	2n=20(ZZ); ZZ, m; 4m + 2m-s m+4sm-st+2sm+2st-1+6st	Short *et al.* (1987)
Louisiana (Female)	2n=20(ZWA); WA, m; 3m+2m -sm +4sm-st+2sm+2st-t+6st	Short *et al.* (1987); Britt (1947)
Ornithobilharzia huronensis	2n=16 (XY)	Short & Menzel (1960)
Schistosoma bovis, Schistosoma haematobium, Schistosoma intercalatum, Schistosoma mattheei	2n=16	Short & Menzel (1960); Grossman *et al.* (1981a)
Schistosoma japinicum	2n=16; ZZ/ZW, m/sm	Grossman *et al.* (1981b)
Schistosoma mekongi	2n=16; ZZ/ZW, sm/sm; 4sm+8 a + 4t	Grossman *et al.* (1981b)
Schistosoma mansoni	2n=16 (ZW No. 1)	Short & Menzel (1960); Short *et al*. (1979); Grossman *et al.* (1980)
Schistosoma mansoni	2n=16; ZZ/ZW; st/st-sm; 2m + 4 m-sm + 4 s t-sm + 4st + 2t	Atkinson (1980); Short & Grossman *et al*. (1981a)
Schistosomatium douthitti	2n=16 (ZW No. 2); m/st; 4m + 2sm-m + 2m-sm + 2 s m-st+ 2st + 2t-st	Atkinson (1980); Grossman *et al.* (1981); Grossman (1981)
	2n=14 (ZW No. 1); m/st; 4m + 2sm-m + 2m-sm + 2 s m-st+ 2st + 2t-st	Short & Menzel (1960); Short & Grossman (1981); Puente & Short (1985); Short (1957); Short & Menzel (1959)
Trichobilharzia physellae,	2n=16	Short & Menzel (1960); Short (1983)
Trichobilharzia stagnicola	2n=16	Short & Menzel (1960); Short (1983)
Trichobilharzia szidati	2n=16 (5m+2sm+1sm-st)	Spakulova *et al*. (1996)
Trichobilharzia regent Horak, Kolarova *et* Dvorak, 1998	2n=16 ((5m+1sm+1sm-m+1sm-m(Z)+1m(W)+1sm (Supernumerary B)	Spakulova *et al*. (2001)
Schistosoma rodhaini	2n=16; ZZ/ZW, s t /st; 2m+2sm-m+4sm-st +4st +2t-st	Atkinson (1980); Grossman *et al*. (1981a); Short & Grossman (1981)
Schistosoma haematobium	2n=16; ZZ/ZW, s t/st;8m +8st	Short (1983)

Family Species	No. and Morphology of Chromosomes	Reference
Schistosoma bovis	2n=16;	LoVerde & Kuntz (1981); Short (1983)
Schistosoma matthei	2n=16;	LoVerde & Kuntz (1981); Short (1983)
Schistosoma intercalatum	2n=16;	Short (1983)
Schistosoma margrebowiei	2n=16;	Grossman *et al*. (1981a); Short (1983)
Schistosoma japonicum	2n=16; ZZ/ZW, sm/sm	Gao Longsheng *et al*. (1985)
Schistosomatium sp.	2n=14; ZZ/ZW, m/a; 12m+2m-sm	Barsiene *et al*. (1989)
Bilharziella polonica	2n=16; ZZ/ZW, st-sm (Male); 4m 4sm-m+2m-sm+4sm+2st	Barsiene & Stanyavichyute (1993)
Ornithobilharzia caniculata	2n=16; ZZ/ZW	Short (1983)
Austrobilharzia variglandis	2n=16; ZZ/ZW, sm-m/a; 12m+2sm +2a	Barsiene *et al*. (1989)
Triehoilharzia physellae	2n=16;	
Triehoilharzia szidati	2n=16; 6m+2sm-m+6sm+ 2st-sm	Barsiene & Stanyavichyute (1993)
Trichobilharzia sp. 1	2n=18; 14m +4sm-m	Barsiene *et al*. (1989)
Trichobilharzia sp. 2	2n=16; 12m +2sm-m+2sm	Britt (1947)
Gigantobilharzia huronesis	2n=16;	Britt (1947)
	PRONOCEPHALIDAE	
Macrovestibulum kepneri	2n = 20	Jones *et al*. (1945)
	PARAMPHISTOMIDAE	
Ceylonocotyle dicranocoelium	2n = 18	Subramanyam & Venkat Reddy (1977)
Cotylophoron cotylophorum	2n=16	Subramanyam & Venkat Reddy (1977)
Cotylophoron sp.	2n=16	Subramanyam & Venkat Reddy (1977)
Fischoederius elongates	2n=16	Subramanyam & Venkat Reddy (1977)
Gastrothylax crumenifer	2n=18; 4m +6sm+2a+6st	Romanenko (1974); Subramanyam & Venkat Reddy (1977)
Gigantocotyle explanatum	2n=18	Subramanyam & Venkat Reddy(1977)
Liorchis scotiae	2n=18	Romanenko (1974)
Megalodiscus (Diplodiscus) temperatus	2n=20	Grossman & Cain (1981)
Paramphistomum cervi	2n=14	Venkat Reddy & Subramanyam (1975)
Paramphistomum epiclitum	2n=18	Subramanyam & Venkat Reddy (1977)
Paramphistomum ichikawal	2n=18	Romanenko (1974)
Paramphistomum microbothrium	2n=18	Mutafova (1983a)
Stichorchis subtriquetrus	2n=18	Romanenko (1974)
Diplodiscus temporatus	2n = 16	Cray (1909)
Paramphistomum microbothrium	2n=14	Sey (1971)
	2n=18, 2 s m + 10m + 6st	Mutafova (1983a)
Paramphistomum explanatum	2n=18, 2sm+16a	Sharma & Lal (1984)
Paramphistomum hiberniae	2n=12	Willmott (1950)
Paramphistomum ichikawai	2n=18; 2 m + 4 s m + 12st	Romanenko (1974)
Paramphistomum epiclitum	2n=18; 2 m + 14sm + 2st	Subramanyam & Venkat Reddy (1977)
Paramphistomum crassum	2n= 14;	Srivastava & Iha (1964a)
Paramphistomum cervi	2n= 14; 4m +l0sm	Subramanyam &Venkat Reddy (1977)
	2n=18; 6m + 4sm + 8 st	Rhee *et al*. (1987a)
Paramphistomum elongatum	2n=16; 6m+6sm +4st	Dhingra (1955a)
Paramphistomum sp.(*Planorbarius corneus*)	2n=18; 2m + 2m-sm+6sm + 8st	Barsiene (1991)
Paramphistomum sp. (*Planorbis planorbis*)	2n=18; 2m + 10sm + 6st	Barsiene (1991b)
Gigantocotyle bothycotyle	2n= 12;	Willmott (1950)
Gigantocotyle explanatum	2n=18; 4m+l0sm + 4a	Venkat Reddy & Subramanyam (1975b); Subramanyam & Vekat Reddy (1977)
Liorchis scotiae	2n=18; 4m + 14a	Romanenko (1972)
	2n=18; 2m + 8 sm + 8a	Romanenko (1974)
Gastrothylax cruminifer	2n=18; m + sm	Britt (1947)
	2n=14;	Dhingra (1955a)
Fischoederium cobboldi	2n=18; 8 m + l0sm	Rhee *et al*. (1988)
Zygocotyle lunata	2n=14;	Willey & Godman (1951)
Cotylophoron elongatum	2n=16;	Dhingra (1955b)
Cyclonocotyle dicranocoelium	2n=18; 4m + 10sm + 4st	Britt (1947)
Cyclonocotyle orthocoelium	2n=18;	Sharma *et al*. (1968)
Cyclonocotyle dawesi	2n=20;	Britt (1947)
Cyclonocotyle scoliocoelium	2n=22;	Britt (1947)
Stuncardia dilymphosa	2n=18;	Sharma & Nakhasi (1974)
Megalodiscus temperatus	2n=18;	Van der Woude (1954); Saksena (1969)
Diplodiscus amphichrus magnus	2n=18; 6m + 6sm+6a	Saksena (1962)

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Diplodiscus subclavatum	2n=20; 2sm -m + 8sm + 2st-sm + 6 s t + 2a	Petkeviciute *et al.*(1989b)
Notocotylus noyeri Joyeux, 1922	2n=20; 2 m + 12 + sm + 4st + 2a	Britt (1947)
	2n=21-30;	Britt (1947)
	2n=20; 2sm-m+12sm+4st+2a	Barsiene & Grabda-Kazubska (1991b)
Gastrodiscoides hominis	2n=20;	Romenenko (1974)
Stichorchis subtriguentrus	2n=20;	Britt (1947)
Heronimus chelydrae	2n=18; 4sm 14a	Guilford (1955)
	ZOOGONIDAE	
Zoogonus mirus	2n = 10	Goldschmidt (1905)
	2n = 12	Schreiner (1908); Gregoire (1909); Wassermann (1913)
	DICROCOELLIDAE	
Dicrocoelium lanceolatum	2n = 20	Goldschmidt (1908); Dingler (1910)
Dicrocoelium lanceolatum	2n=24	Romanenko (1979)
Eurytremum pancreuticum	2n=26	Romanenko (1979)
Paradistomoides orientalis	2n=28	Scharma & Nakahasi (1974)
Dicrocoelium lanceatum	2n=24; 22m + 2sm	Sharma & Nakhasi (1974)
Eurytrema coelomaticum	2n=26; 1 0 m + 2 sm+12st + 2t	Moriyama (1982a, 1982b)
Eurytrema pancreaticum	2n=26; 10m+4sm + 8st + 4t	Britt (1947)
Paradistomoides orientalis	2n=28; 1 4 s t + 10st + 4t	Dhar &Sharma (1984)
	BRACHYCOELIDAE	
Brachycoelium salamandrae	2n = 20	Von Kemnitz (1913)
	HETEROPHYIDAE	
Cryptocotyle lingua	2n = 12	Cable (1931); Britt (1947)
Apophallus miiehlingii	2n = 14 (3m+4sm)	Barsiene *et al.* (1995)
	ECHINOSTOMIDAE	
Parorchis acanthus	2n = 22	Rees (1939)
Episthmium bursicola	2n=18; 12m+4sm+2st	Barsiene &Kiseliene (1990a)
Echinochasmus baleocephallus	2n=14; 6m+2m-sm+4sm+2a	Britt (1947)
Parorchis acanthus	2n=22;	Rees (1939)
Echinostoma reuolutum	2n=22;	Churchill (1950)
	2n=22; 2m +20st	Mutafova & Kanev (1986)
Echinostoma revolutum (L. stagnalis)	2n=22; 2m+4sm+2 st-sm +10st+4a	Barsiene & Kiseliene (1991)
Echinostoma revolutum (L. ovata)	2n=22; 2m 2sm-m+4sm+14st	Britt (1947)
	2n=24; 2 B	Britt (1947)
Echinostoma jurini	2n=22; 6m+8sm+4st+4a	Britt (1947)
Echinostoma miyagawai	2n=22; 2m+2sm+2st-sm+16st	Barsiene & Kiseliene, 1991
Echinostoma echinatum	2n=22; 2m + 20st	Mutafova & Kanev (1986)
	2n=22; 2m+2sm-m+2sm+12st+4a	Barsiene & Kiseliene (1991)
	2n=22; 2m + 2sm-m +2sm+16st	Britt (1947)
Echinostoma barbosai; *Echinostoma echinatum*	2n=22; 2sm + 20a	Mutafova & Kanev (1983)
Echinostoma hortense	2n=20; 2m+2m-sm+8sm-st + 8st-t	Terasaki *et al.* (1982)
Echinostoma tinetorchis	2n=22; 2m + 2sm-st+12st+4st + 2t	Britt (1947)
Echinostoma caproni	2n=22; 4sm-st, t	Richard & Voltz (1987)
Neoacanthoparyphium echinatoides	2n=20; 2m + 4 s t + 1 4a	Barsiene & Kiseliene (1990b)
Moliniella anceps	2n=20; 2m + 8 s t + 1 0a	Barsiene *et al.* (1990b)
Isthmiophora metis (из Lymnaea stagnalis)	2n=20; 4m+4sm+2st+10asm	Britt (1947)
Pegosomum asperum	2n=20;	Aleksandrova & Podgornova (1978)
Lymnaea saginatum	2n=20;	Britt (1947)
Echinoparyphium recurvatum	2n=20; 2m + 2sm + 16t	Mutafova *et al.* (1987)
Echinoparyphium recurvatum A (Lymnaea auricularia, Lymnaea ovata)	2n=20; 2m-+4sm + 14st	Barsiene (1991a)
Echinoparyphium recurvatum B (Lymnaea coruus, Lymnaea palustris)	2n=20; 4m + 6sm+10a	Britt (1947)
Echinoparyphium pseudorecurvatum A (PI. planorbis	2n=20; 2sm -m+4 sm+4st +10a	Britt (1947)
Echinoparyphium pseudorecurvatum B (A. acronicus)	2n=20; 2sm-m + 2st-sm + 8st + 8a	Britt (1947)
Echinoparyphium bacutus (Vatvata piscinatis)	2n=20; 2 m+12 s t+2a-st+4a	Britt (1947)
Echinoparyphium aconiatum	2n=20; 2m-sm + 2sm + 16t	Mutafova *et al.*(1987); Mutafova & Kanev (1984)
	2n=20; 2m + 2st-sm+ 4st+4st-a +8a	Barsiene & Kiseliene (1990b)
Hypoderaeum conoideum	2n=20; 4 m + 1 6 s t	Mutafova *et al.*,1986
	2n=20; 2 m + 4 s m + 12st	Barsiene & Kiseliene, 1990b
Cathamaesia hians (Lymnaea stagnalis ПНР)	2n=20; 8m 4sm-m +4sm+4st	Barsiene (1990)
Cathamaesia hians (Planorbis planorbis. ПНР)	2n=20; 4m + 4sm-m+8sm +2st-s m + 2 s t	Barsiene (1991b)

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	BUCEPHALIDAE	
Bucephalus elagans	2n = 12	Woodhead (1931)
Bucephalus pusillus	2n = 12	Woodhead (1931); Britt (1947)
Rhipidocotyle papillosum	2n=12	Ciordia (1956)
	TROGLOTREMATIDAE (PARAGONIMIDAE)	
Paragonimus kellicotti	2n = 16	Chen (1937)
Paragonimus kellicotti	2n = 22 (2a + 9sm)	Loverde (1979)
Paragonimus ohirai	2n = 22 (2a + 9sm)	Loverde (1979)
Paragonimus miyazakii	2n=22	Sakaguchi & Tada (1975, 1976); Terasaki (1977); Hirai *et al.* (1985)
Paragonimus ohirai; 2 geographical races *(Paragonimus iloktsuemensis; Paragonimus sadoensis)*	2n=22	Sakaguchi & Tada (1975, 1976); Terasaki (1977); Hirai *et al.* (1985)
Paragonimus westermani	2n=22	LoVerde (1979); Hirai *et al.* (1985); Sugiyama *et al.* (1985)
Paragonimus westermani, (Paragonimus pulmonalis)	2n=22	Sakaguchi & Tada (1976b); Terasaki (1977); Agatsuma & Habe (1985); Hirai *et al.* (1985)
Paragonimus westermani	2n=22	Blair (2000)
Paragonimus heterotremus	2n=22 (1m+4st+3m/sm+3sm/st)	Komalamisra (2005)
Paragonimus kellicotti	2n=16	Benazzi &Benazzi Lentati (1976)
Paragonimus ohirai	2n=22;	Britt (1947)
	2n=22; 4m + 18sm	Britt (1947)
	2n=22; 2 m + 1 0 sm + 10st	Hirai *et al.* (1985)
Paragonimus westermani	2n=22; 4 m + 10sm + 8st	Sakaguchi & Tada (1976a); Terasaki (1977)
	3 n = 33;	Sakaguchi & Tada (1976a); Miyazaki (1978)
	2n=22; 6m+8sm+8st	Pengpeng *et al.* (1986)
	2n=33; 2m + 8 st + 12m, sm, st	He Lian-Yin *et al.* (1982)
	2n=22; m + 6 st + 2 sm + 12m, sm, st	Britt (1947)
Paragonimus westermani Shoawu, Fujian	2n=22; 2m + 4st + 4sm + 12m, sm, st	Britt (1947)
Paragonimus westermani filipinus	2n=22; 2m + 6m-sm + 6sm-st + 8st	Terasaki (1983)
Paragonimus westermani westermani	2n=22; 8m + 6sm-st + 8st	Britt (1947)
Paragonimus skrjabini	2n=22; 6m+6sm-m + 2sm +8st	Li and Zheng (1983)
Paragonimus pulmonalis	3n=33; 2m+6m- sm+6sm-st+ 8st	Terasaki (1980); Sakaguchi & Tada (1976b)
	2n=22; 2m + 6m-sm + 6sm- st + 8st	Terasaki (1977)
	3n=33; 3 m + 12sm + 6 st +12a	Hirai *et al.* (1985)
Paragonimus iloktsuenensis	2n=22; 2m + 6m-sm+6sm-st + 8st	Terasaki (1977); Sakaguchi & Tada (1980)
	2n=22; 2m + 10sm+10st	Hirai *et al.* (1985)
Paragonimus sadoensis	2n=22;	Terasaki (1977); Sakaguchi & Tada (1980)
	2n=22; 2m + 10sm+ l0st	Hirai *et al.* (1985)
Paragonimus peruvian us	2n=22; 2m+6m-sm + 6sm-st + 8st	Terasaki (1978)
Paragonimus hueitungensis	2n=22; 2m + 8 st + 12m, sm, st	He Lian-Yin *et al.* (1982)
Euparagonimus cenocopiosus	2n=22; 6 m + 8 s m + 8 s t	Lei Changqui *et al.* (1985)
	AZYGIIDAE	
Proterometra macrostoma	2n =18	Anderson (1935)
Azygia acuminata	2n = 18	Britt (1947)
Azygia lucii	2n=20; 10m + 6 a + 4 st	Barsiene (1991b)
	ALLORCEADIIDAE	
Allocreadium isoporum	2n =16	Britt (1947)
Crepidostomum serpentinum	2n = 16	Britt (1947)
Bunodera saculata	2n = 16	Britt (1947)
Bunodera luciopercae	2n = 14	Britt (1947)
Cercariaeum crassum Wesenberg-Lund, 1934	2n=10 (1m+1sm+sm-m+1m-sm)	Petkeviciute *et al.* (2011)
Allocreadium fasciatusi	3n=21; 3 m + 12sm + 6st	Ramanjaneyulu &Madhavi (1983)
Bunodera sacculata	3n=23;	Cannon (1971)
Allocreadium fasciatusi	3n=21	Ramanjaneyulu & Madhavi (1984)
Allocreadium handiai	2n=14	Ramanjaneyulu & Madhavi (1984)
Bunodera luciopercae	2n=14 (2m+1sm/st+4a)	Petkeviciute & Staneviciute (2008)
Allocredium isoporum	2n=14 (2m+5a)	Petkeviciute & Staneviciute (2008)
Crepidostomum serpentinum	2n=14 (1m+5a)	Petkeviciute & Staneviciute (2008)
Cercariaeum crassum Wesenberg-Lund, 1934	2n=10 (1m+1sm+2sm-m+1m-sm)	Petkeviciute *et al.* (2011)
	CLINOSTOMIDAE	
Clinostomum marginatum	2n = 20	Britt (1947)
	LECITHODENDRIIDAE	
Loxogenes bicolor	2n = 22	Britt (1947)
Acanthatrium pipistrella	2n = 22	Britt (1947)
Ganeo kumaonensis	2n=20;	Saksena (1969)
Acanthatrium pipistrella	2n=22;	Britt (1947)
Mahroarchis ranarum	2n=22;	Saksena (1969)
Pleurogenoides medians	2n=22; 16m + 4st + 2a	Barsiene, Grabda-Kazubska (1991c)

Family Species	No. and Morphology of Chromosomes	Reference
Pleurogens claviger	2n=22; 1 2 m + 6 s t + 4a	Barsiene, Grabda-Kazubska (1991c)
Pleurogonidum orientalis	2n=18;	Saksena (1969)
Prosotocus kashabia	2n=12;	Britt (1947)
Ganeo tigrinum	2n=22	Subramanyam & Venkat Reddy (1977)
	CEPHALOGONIMIDAE	
Cephalogonimus americanus	2n = 28	Britt (1947)
	GORGODERIDAE	
Probolitrema californiense	2n = 12	Markell (1943)
Gorgoderina attenuate	2n = 14	Britt (1947)
Gorgodera amplicava	2n = 16	Britt (1947)
Phyllodistomum folium	2n=18	Petkeviciute *et al*. (2003)
Gorgodera amplicava	2n=16;	Britt (1947)
Gorgodera pagenstecheri	2n=18; 2m +2sm +2st-a+12a	Barsiene (1991)
Gorgoderina attenuata	2n=14;	Willey & Koulish (1950)
Probilotrema californiense	2n=12;	Britt (1947)
Phyllodistomum spatula	2n=16;	Dhingra (1954a)
Phyllodistomum pungitti	2n=18; 2 m + 12st +4a	Britt (1947)
	PLAGIORCHIDAE	
Eustomas chelydrae	2n = 18	Britt (1947)
Glypthelmins quieta	2n = 18	Britt (1947)
Plagitura salamandra	2n = 22	Britt (1947)
Pneumobites breviplexus	2n = 22	Britt (1947)
Pleumocoeces medioplexus	2n = 22	Pennypacker (1936)
Pleumocoeces similiplexus	2n = 22	Pennypacker (1940)
Pleumocoeces similiplexus	2n = 22	Britt (1947)
Trematorchis ranarum	2n=18	Subramanyam & Venkat Reddy (1977)
Glypthelmins guieta	2n=18;	Britt (1947)
Plagitura salamandrae	2n=22;	Britt (1947)
Haematoloechus mediplexus	2n=22;	Burton (1960)
Haematoloechus parviplexus	2n=22;	Pennypacker (1936)
Haematoloechus semiplexus	2n=22;	Britt (1947)
Haematoloechus similis	2n=22; 12m+6sm + 2sm-m+2st	Barsiene, Grabda-Kazubska (1988b)
Haematoloechus asper	2n=22; 14m+4sm + 2sm-m +2st	Britt (1947)
Skrjabinoeces sp.	2n=22; 10m + 2sm-m + 4sm +2sm-st + 4st	Petkeviciute *et al.* (1990)
Monodistomum salamandra	2n=20;	Britt (1947)
Encylometra colubrimurorum	2n=12;	Saksena (1969)
Staphylodora bascaniensis	2n=16;	Britt (1947)
Haplometra cylindracea	2n=20;	Sanderson (1959)
	2n=22; 4m + 8 s m-m + 4 sm +6st	Barsiene, Grabda-Kazubska (1988a)
Plagiorchis sp. *(L. stagnalis, ПНР)*	2n=22; 2m + 8sm-m + 4sm + + 8st	Barsiene, Grabda-Kazubska (1988b)
Opisthioglyphe ranae	2n=22; 2m + 6sm-m+6sm+ 4st + 4a	Barsiene, Grabda-Kazubska (1988a)
Opisthioglyphe ranae (L. stagnalis)	2n=22; 6m +6sm + 2sm-st +2st +4a-st+2a	Petkeviciute *et al*. (1990)
Leptophallus nigrouenosus	2n=20; 12m + 2sm-m + 2sm +2st + 2a	Barsiene, Grabda-Kaka (1988a)
Paralepoderma progeneticum	2n=20; 14m + 2sm + 2st-a + 2a	Barsiene, Grabda-Kaka (1991a)
Paralepoderma brumpti	2n=20; 10m+2m-sm + 2sm+ 2st + 4a	Petkeviciute *et al*. (1990)
Omphalometra flexuosum	2n=20; 4sm-m + 4 sm + 4st +8a	Barsiene, Grabda-Kazubska (1991a)
	RENIFERIDAE	
Natriodera verlatum	2n = 22	Britt (1947)
Dasymetra villicoeca	2n = 22	Britt (1947)
Pneumatophilus leidyi	2n = 22	Britt (1947)
Pneumatophilus variabilis	2n = 22	Britt (1947)
Lechriorchis abduscens	2n = 22	Britt (1947)
Renifer ellipticus	2n = 22	Britt (1947)
Neorenifer wardi	2n = 22	Britt (1947)
Neorenifer georgianus	2n = 22	Britt (1947)
Neorenifer aniarum	2n = 22	Britt (1947)
Neorenifer orula	2n = 22	Britt (1947)
Neorenifer drymarchon	2n = 22	Britt (1947)
Neorenifer elongates	2n = 22	Britt (1947)
Staphylodora bascaniensis	2n = 16	Britt (1947)
Auridistomum chelydrae	2n = 18	Britt (1947)
Telorchis robustus	2n = 16	Britt (1947)
Telorchis lobusus	2n = 22	Britt (1947)
Telorchis medius	2n = 22	Britt (1947)
Telorchis corti	2n = 22	Britt (1947)
	RHOPALIADIDAE	
Rhopalias macracanthus Chandler, 1932	2n = 16	Ciordia (1949)

Family Species	No. and Morphology of Chromosomes	Reference
	DICLYBOTHRIIDAE	
Diclybothrium hamulatum (Simer, 1929) Price, 1942	2n = 12	Pickle &Jones (1967)
	SPIRORCHIIDAE	
Spirorchis magnitestis	2n = 18 (4a/t + 1a + 3sm)	Teehan & Short (1989)
Spirorchis parvus	2n = 18 (4a/t + 1a + 3sm)	Teehan & Short (1989)
Spirorchis magnitestis	2n=18; 2m + 16a	Jones & Mayer (1953)
Spirorchis parvus	2n=18; 2m + 16st	Grossman *et al.* (1981b)
Spirorchis sp.	2n=18; 2 sm + 6 st-sm +8t-st + 2t	Teehan & Short (1989)
	CONVOLUTIDAE	
Convolute convolute	2n = 16 (7m-sm + 1st)	Birstein (1990)
Baltalimania agile	2n = 14	Birstein (1990)
	MIROPHALLIDAE	
Microphallus pygmaeus	2n = 18	Birstein & Mikhailova (1990)
Microphallus piriformis	2n = 18; 8m + 2sm + 4st + 4?	Birstein & Mikhailova (1990)
Microphallus triangulatus	2n = 18	Birstein & Mikhailova (1990)
Microphallus pygmaeus	2n=18; 8m + 2sm + 4st +4?	Britt (1947)
Microphallus triangulatus	2n=18; 8m + 6 s m + 4?	Britt (1947)
	MONORCHIIDAE	
Asymphylodora sp.	2n=18;	Dhingra (1955a, 1955b)
	2n=20; 6m+2m -sm + 2sm+ 4st + 6a	Dhingra (1955a)
	2n=20; 12m + 6sm-m + 2 s t-sm	Dhingra (1955a)
	2n=22; 8m + 8sm-m+2sm-st + 2st	Dhingra (1955a)
Palaeorchis sp.	2n=14; 2m + 2sm-m+6sm+ 2st + 2a	Dhingra (1955a)
Asymphylodora spp.	2n = 20 (5m+4sm+1st)	Barsiene *et al.* (1995)
	NOTOCOTYLIDAE	
Notocotylus attenuates, Notocotylus imbricatus,	2n=20	Petkeviciute & Barsiene (1988)
Notocotylus ephemera	2n=20,21	Petkeviciute & Barsiene (1988)
Notocotylus filamentis	2n=14;	Ciordia (1950)
Notocotylus ephemera	2n=20; 2m + 6sm-m+ 4sm+ 2st + 6a	Petkeviciute & Barsiene (1988)
	2n=21;	Britt (1947)
	2n=22;	Britt (1947)
Notocotylus attenuatus	2n=22; 4m + 4sm-m+4sm+ 8a	Britt (1947)
	2n=20; 4sm + ?	Rao & Venkat Reddy (1982)
Notocotylus imbricatus	2n=20; 2 m + 10sm +2st+6a	Petkeviciute & Barsiene (1988)
Notocotylus noyeri	2n=20; 2m + 2m-sm + 4sm+ 4st +8a	Petkeviciute *et al*. (1989a)
	2n=21;	Britt (1947)
	2n=20; 4m + 4sm +4st +8t	Barsiene & Grabda-Kazubska (1991b)
Notocotylus sp. *(Anisus acronicus,)*	2n=20; 2m +6sm+4 st+8a	Barsiene *et al.* (1990)
	2n=21;	Britt (1947)
	2n=21-30;	Britt (1947)
	CYCLOCOELIDAE	
Cyclocoelium oculeum	2n=20;4m + 6sm + 8st + 2a	Taft & LeGrande (1979)
Cyclocoelum bivesiculatum	2n=20;	Dhingra (1954a)
	FASCIOLIDAE	
Fasciola gigantica	2n=20 (2sm+1t+7st)	Romanenko & Pleshanova (1975); Subramanyam & Venkat Reddy (1977)
Fasciola gigantica	2n=20 (6sm+1m-sm+3st)	Venkat Reddy & Subramanyam (1973); Subramanyam & Venkat Reddy (1977)
Fasciola hepatica	2n=20 (1sm-m+5st+2sm+1m+1sm)	Romanenko & Pleshanova (1975)
Fasciola hepatica	2n=20 (5sm+4st+1t)	Li *et al.* (1988)
Fasciola hepatica	2n=20 (1sm-m+4st+5sm)	Spakulova & Kralova (1991)
Fasciola hepatica	2n=20 (1m+5sm+4st)	Reblanova *et al*. (2011)
Fasciola sp.	2n=20	Sakaguchi & Wakako (1976); Sakaguchi (1980); Moriyama *et al*. (1979); Rhee *et al.* (1987); Yin & Ye (1990)
Fasciola sp.	3n=30 (8sm+2st)	Sakaguchi and Nakayama (1975); Sakaguchi & Wakako (1976);
Fasciola gigantica	2n=20	Sakaguchi (1980)
Fasciola hepatica	2n=12	Srimuzipo *et al*. (2000);
	2n=22 (1sm-m+1sm+9st)	Henneguy (1902); Schubmann (1905); Schellenburg (1911)
Fascioloides magna	2n=22 (9st+1sm-m+1sm)	Reblanova *et al*. (2010)
Fasciolopsis buski	2n = 14 (6m+1t)	Gao (1985)
Fasciolopsis buski	2n = 14 (4m+2sm+1t)	Dai (1990)
Parafasciolopsis fasciolaemorpha	2n=20 (1m+1t+6st+2sm)	Barsiene (1990)
Fasciola sp.	3n=30	Britt (1947)
	2n=20/30;	Britt (1947)
	2n=20; 2m + 10sm + 8st	Rhee *et al.* (1987b)
	2n=20/30;	Sakaguchi, Yoneda (1976)
	2n=20;	Britt (1947)
	3n=30; 3m + 12sm+ 15st	Rhee *et al*. (1987b)
Fasciola hepatica	2n=20	Sanderson (1953, 1959)
	2n=20; 6 m + 2 sm + 1 2 st	Li *et al*. (1988)

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Fasciola gigantica	2n=20; 4sm+4sm-s t + 12st	Moriyama *et al*. (1979)
	2n=20; 2m + 12sm + 6st	Subramanyam & Venkat Reddy (1977)
	3n=30;	Sakaguchi (1980)
	2n=20/30;	Mariyama *et al*. (1979)
	PHILOPHTHALMIDAE	
Philophthalmus gralli	2n=20	Grossman & Cain (1981)
Philophthalmus sp.	2n=20	Venkat Reddy & Subramanyam (1971)
Philophthalmus sp. (Georgia, USSR; Bulgaria)	2n=20	Mutafova *et al*. (1986)
Philophthalmus megalurus	2n=20;	Kahlil & Cable (1968)
Philophthalmus indieus	2n=20; 2sm + 2 a + 1 6t	Subramanyam & Venkat Reddy (1977)
Philophthalmus hegeneri	2n=20;	Fried (1975)
Philophthalmus sp.	2n=20; 2sm + 18a	Mutafova (1983b)
Philophthalmus gralli	2n=20; 8sm + 12a	LoVerde (1978)
	HEMIURIDAE	
Isoparorchis euritremum; Isoparorchis hypselobargi	2n=20 (XY)	Chattopadhyay & Manna (1987)
Halipegus occidualis	2n=18;	Jones (1956); Guilford1(1961)
Halipegus eccentricus	2n=22;	Guilford (1961)
Isoparorchis eurytreum	2n=18;	Srivastava & Iha (1964b)
Isoparorchis hypselobagri	2n=20; 10sm + 8a + 2XY (X = sm; Y = a)	Chattopadhyay & Manna (1987); Dhingra (1954b)
	2n=18; 4m + 14a	Srivastava & Iha (1964b); Iha (1975)
	DIPLOSTOMATIDAE	
Diplostomum indisticum; Diplostomum mergi; Diplostomum pseudospathaceum; Diplostomum spathaceum	2n=20	Romanenko & Shigin (1977); Mutafova & Niewiadomska (1988)
Tylodelphys clavata	2n=20	Romanenko & Shigin (1977)
Diplostomum sp. 1	2n=20; 6m + 4sm-m + 2st-sm + 8 s t	Barsiene & Staneviciiite (1991)
Diplostomum sp. 2	2n=20; 6m+2sm-m + 4sm + 4st + 2st- a + 2a	Britt (1947)
Diplostomum baeri	2n=20; 2m + 2sm-m + 6sm + 6st + 4a	Barsiene *et al*. (1990a); Barsiene & Staneviciute (1991)
Diplostomum mergi	2n=20; 10m + l0t	Romenenko & Shigin (1977)
Diplostomum pseudospathaceum	2n=20; 6m + 4sm + 6st + 4a	Barsiene & Staneviciute (1991) Barsiene *et al*. (1991)
Diplostomum paracaudum	2n=20; 6m+6sm +8st	Barsiene *et al.* (1990a) Barsiene & Staneviciute (1991)
Tylodelphys clavata	2n=20; 8m + 2m-sm + 8st + 2?	Romenenko &Shigin (1977)
	2n=20; 6m + 2sm-m + 4st+ 2st-a + 6 a	Barsiene (1991c)
Proalorioides tropidonotis	2n=16;	Saksena (1969)
Posthodiplostomum cuticola	2n=20; 4 sm + 6 st + l0t	Barsiene (1991c)
	STRIGEIDAE	
Gogatea serpentium indica	2n=16	Subramanyam & Venkat Reddy (1977)
Ichthyocotylurus erraticus (Rudolphi, 1809)	2n=20 (4m+2sm+1sm-st+3st-a)	Bell *et al.* (1998)
Ichthyocotylurus variegates (Creplin, 1825)	2n=20 (4m+1sm+1m-sm+4st)	Bell *et al.* (1998)
Apatemon gracilis (Rudolphi, 1819)	2n=20 (3m+1m-sm+3sm-st+1sm+1a+1st-a)	Bell *et al.* (1998)
Apatemon gracilis	2n=20 (3m+3sm-st+1sm+2a+1st-a)	Petkeviciute & Staneviciute (1999)
Cotylurus cornutus (Lymnaea zazuriensis)	2n=20; 2m + 6st + 2a-s t + 1 0a	Barsiene *et al*. (1990)
Apatemon gracilis (Lymnaea ovata)	2n=20; 6m + 4sm + 4sm-st +2st + 4a	Petkeviciute (1991)
Apatemon minor (Planorbarius planorbis)	2n=20; 2 m + 6 s m + 4st + 2a-st + 6a	Barsiene (1992)
	2n=21;	
Apatemon fuligulae	2n=20; 4 m + 8 s m + 4 s t + 6a	Barsiene *et al*. (1990)
	OPISTHORCHIIDAE	
Opisthorchis felineus	2n=14	Romanenko (1973)
Opisthorchis felineus	2n=14 (4sm+3m)	Polyakov *et al*. (2010)
Clonorchis sinensis	2n=56 (3m+1m-sm+16sm+8st) – Korea (2m+2m/sm+16sm+8st) – China	Park *et al*. (2000)
Clonorchis sinensis	2n=56	Park & Young (2003)
Opisthorchis felineus (Rivolta, 1884)	2n=14 (2m/sm+5)	Zadesenets *et al*. (2012)
Opisthorchis viverrini (Poirier, 1886)	2n= 12 (2sm+1sm+1sm/st+1st/a +1a)	Zadesenets *et al*. (2012)
Metorchis xanthosomus (Creplin, 1846)	2n=14	Zadesenets *et al*. (2012)
Metorchis billis (Braun, 1893)	2n=14	Zadesenets *et al*. (2012)
Clonorchis sinensis (Cobbold, 1875)	2n=14, 2n=56	Zadesenets *et al*. (2012)
Opisthorchis viverrini	2n=12 (4m+1sm+1a)	Kaewkong *et al.* (2012)
	TRANSVERSOTREMATIDAE	
Transversotrema patialense	2n=20	Madhavi & Ramanjaneyulu (1986)

Family Species	No. and Morphology of Chromosomes	Reference
	OMPHALOMETRIDAE	
Rubenstrema exasperatum	2n=16 (3m+4sm-m+1sm(X_1)+1st(X)	Mutafova &Kanev (1996)
	NEODIPLOSTOMATIDAE	
Neodiplostomum seoulense	2n=20 (2m+5sm/st+3t)	Park *et al.* (1998)
	ASPIDOGASTREA	
Aspidogaster conchicola	2n=10 (1st+4a)	Petkeviciute (2001b)
Cotylogaster occidentalis	2n=12 (2m+2sm+2a)	Loverde & Fredericksen (1978)
Cotylapis insignis	2n=22	Loverde & Fredericksen (1978)
	DIPLOZOIDAE	
Diplozoon paradoxum	2n=8 (3m+1a)	Koskova *et al.* (2011)
Paradiplozoon bliccae	2n=14 (7a)	Koskova *et al.* (2011)
Paradiplozoon sapae	2n=14 (7a)	Koskova *et al.* (2011)
Paradiplozoon nagibinae	2n=14 (7a)	Koskova *et al.* (2011)
Eudiplozoon nipponicum	2n=7	Koroleva (1968b)
Paradiplozoon megan	2n=7	Koroleva (1968b)
Diplozoon paradoxum	2n=8, (3m+1a)	Koroleva (1968a,b)
Paradiplozoon bliccae (syn. *Diplozoon gussevi)*	2n=14, (7a)	Koroleva (1968a,b)
Paradiplozoon bliccae (syn. *Diplozoon markevitchi)*	2n=14, (7a)	Koroleva (1968b, 1969)
Paradiplozoon sapae	2n=14, (7a)	Koroleva (1969)
Paradiplozoon nagibinae	2n=14, (7a)	Koroleva (1969)
Paradiplozoon pavlovskii	2n=14, (7a)	Koroleva (1968a,b)
Paradiplozoon homoion	2n=14, (7a)	Koroleva (1968a,b)
Diplozoidae sp.	2n=14, (7a)	Bovet (1967)
Diplozoidae sp. (sp. n.)	2n=10, (2m+3a)	Koroleva (1969)
Diplozoidae sp.	2n=7	Baer & Euzet (1961)
Diplozoidae sp.	2n=7	Bovet (1967) Incorrect data according to Koroleva (1968b)
	PSILOSTOMIDAE	
Psilotrema sp.	2n=16; 4m + 2sm-m + 2sm+ 8st	Britt (1947)
Sphaeridiotrema globulus	2n=14; 4m + 4sm-m + 4s m+ 2a	Britt (1947)
	SANGUINICOLIDAE	
Sanguinicola sp.	2n=22; 1 6 m + 2 sm + 4st	Britt (1947)
	BRACHYLAEMIDAE	
Leucochloridiomorpha constantiae	2n=16;	Filippone & Fried (1974)
	CYATHOCOTYLIDAE	
Gogotea serpentium	2n=16;	Saksena, 1969, Subramanyam, Venkat Reddy (1977)
	CRYPTOGONIMIDAE	
Acetodexira amiuri	2n=12;	Perkins (1956)
Atrophecaecum bur minis	2n=14; 14sm	Madhavi & Ramanjaneyulu (1988)
	OPECOELIDAE	
Sphaerostoma bramae	2n=24;	Gresson (1958)
	EUCOTILIDAE	
Cercaria pectinata	2n=12; 6m + 2st+4m-sm	Ieyama & Ozaki (1987)
Cercaria tapidis	2n=16; 8m + 2st-sm + 2st +2sm-st +2sm-m	Britt (1947)

Sm =sub-metacentric; a = acrocentric; m =metacentric. t =telocentric. X =sex chromosome. Y =sex chromosome. ZZ =sex chromosomes. ZW =sex chromosomes.

Chromosomes of Cestoda

Studies of the chromosomal patterns among the Cestoidea have not been numerous. Most of the recent ones have originated from one laboratory, and there seems to have been no broad sampling of the Class as a whole. No records of studies on members of the Cestodaria have come to our attention, and attempts in this laboratory have not been successful in obtaining reliable results. Among the Cestoda only one of the nine commonly recognized orders, the Cyclophyllidea, seems to have been examined for chromosome numbers. Among the cyclophyllideans the family Hymenolepididae is represented by records from four genera (8 species). These indicate that in *Diorchis* (*ralli* and *reynoldsi*) and in *Protogynella* (*blarinae*), the diploid number of chromosomes is 10. One species of *Hymenolepis* (*H. fraterna*) has 10 chromosomes but in 3 other species (*H. ananthocephalus* (van Gundy, 1935), *H. diminuta* (Rudolphi, 1819), and *H. serpentulus* (Goeze, 1782) the number is 12. Twelve chromosomes are also present in an unidentified species of *Aploparaksis*. *H. serpentulus* is represented by two sub-races (*sturni* and *turdi*), each with the same number of chromosomes (12), but the two sets of chromosomes show such consistent and easily recognizable differences that the races can be readily separated on the basis of cytological grounds alone, without reference to collection records. The Hymenolepididae, while not having a common basic number of chromosomes, are cytologically quite uniform. The same may not be said for the Dilepididae. For example, *Dipylidium caninum* (Linnaeus, 1758) has the diploid number of 10 chromosomes; *Liga brasiliensis* has 14 chromosomes, and unnamed species of *Anonchotaenia* and *Choanotaenia* each have 16 chromosomes. Among the Anoplocephalidae, *Avitellina centripunctata* (Rivolta, 1874) has somatic chromosomes, Oochoristica has 10, and *Moniezia expansa* (Rudolphi, 1805) and *M. planissima* (Moniez, 1879) have 12. For the Taeniidae records of 2n = 16 for *Hydatigera taeniaeformis* (Batsch, 1786) and 2n = 20 for *Taeniarhynchus saginatus* (Goeze, 1782) and *Taenia serrata*= *pisiformis* (Bloch, 1780) are found, although some investigators, including the present author, find only 16 chromosomes in the two latter species. Among the Nematotaeniidae, two races of *Baerietta desmognathi* (Douglas, 1957) have been studied, one race having 2n = 8 and the other 2n = 16 (Table 3). This difference may be an example of polyploidy but examination of a greater series of specimens would be necessary before any definite statement should be made. It would appear from the above records that the Cestoda do not show any completely definite taxonomic pattern of chromosomal numbers above the species level. Perhaps such evidence would be forthcoming following a broader sampling among the Cestodaria and the Cestoda. We believe, on other grounds, that the Cyclophyllidea are probably the most specialized of the Cestoda, but study of chromosome numbers, structure, or behavior, has not as yet seemingly substantiated such a conclusion.

Karyology represents a conspicuous gap in the phylogenetic evaluation of the Cestoda and of other flatworms, despite the fact that chromosome structure and gene location are of evolutionary relevance. Cytogenetic features, alone or in concert with other modern character-based approaches, might provide information not only on phylogeny but also on systematic interrelationships within the target group. Unfortunately, only nine out of 16 eucestode orders and up to 2% or 115 known species have been studied karyologically. Most early cytogenetic studies have been exclusively focused on the number of chromosomes; 74 species (63.5%) have been studied for chromosome morphology.

Table 3. Summary of chromosomes and karyotype data of Cestoda (Tapeworms) (1907–Till Date).

Order/ Family	Number 2n [3n]	Morphology	References
I. SPATHEBOTHRIIDEA			
Acrobothriidae			
Cyathocephalus truncates (Pallas, 1781)	18	2m+2sm+5a	Petkeviciute (1996a)
II.DIPHYLLOBOTHRIIDEA			
Diphyllobothriidae			
Schistocephalus solidus (Muller, 1776)	12-16		Smyth (1946)
	18	5m+4a	Petkeviciute (1996b)
Diphyllobothrium dendriticum (Nitzsch, 1824)	18 (9–18)	7m+2sm	Wikgren & Gustafsson (1965)
Diphyllobothrium ditremum (Creplin, 1825) (=*Diphyllobothrium osmeri*)	18 (8–22)	7m + 2sm	Wikgren & Gustafsson(1965)
	18	7m + 2sm	Petkeviciute (1992)
Diphyllobothrium latum (Linnaeus, 1758)	18 (15–28)	7m + 2sm	Wikgren & Gustafsson (1965)
Diphyllobothrium ursi Rausch, 1954	18		Wolcott (1959)
Ligula intestinalis (Linnaeus, 1758)	18	6m +3sm	Petkeviciute (1992)

Order/ Family	Number 2n [3n]	Morphology	References
Spirometra erinaceieuropaei (Rudolphi, 1819) (= *Diphyllobothrium erinacei*)	[27]		Sasada (1978)
Spirometra mansonoides (Muller, 1935) (= *S. mansoni*)	[27]		Liu & He (1989)
III. CARYOPHYLLIDEA			
Balanotaeniidae			
Balanotaenia bancrofti Johnston, 1924	14		Grey (1979)
Capingentidae			
Capingens singularis Hunter, 1927	14		Grey (1979)
Caryophyllaeidae			
Hunterella nodulosa Mackiewicz *et* McCrae, 1962	14	3m + 1sm +3a	Mackiewicz & Jones (1969)
	14	3m + 4a	Grey (1979)
Archigetes sp. (=*appendiculatus*)	18		Motomura (1929)
Biacetabulum biloculoides Mackiewicz *et* McCrae, 1965	20		Grey (1979)
Caryophyllaeus laticeps (Pallas, 1781)	[30]		Grey (1979)
	20 [30]	10m	Petkeviciute & Kuperman (1992)
	20	10m	Bombarova *et al*. (2009)
Glaridacris laruei Lamont, 1921	16	3m + 1sm + 4a	Grey &Mackiewicz (1974), Grey (1979)
Glaridacris confusus Hunter, 1927	16		Grey (1979)
Glaridacris catostomi Cooper, 1920	20 [30]	8m + 2sm	Grey (1979), Grey & Mackiewicz (1980)
Glaridacris vogei Mackiewicz, 1976	20	8m + 1sm + 1a	Grey (1979)
Monobothrium hunter Mackiewicz, 1963	20	9m + 1a	Grey (1979)
Isoglaridacris folius Fredrickson *et* Ulmer, 1965	18	1m + 8a	Grey (1979)
Isoglaridacris jonesi Mackiewicz, 1972	18	2m + 7a	Grey (1979)
Isoglaridacris bulbocirrus Mackiewicz, 1965	18 [27]		Grey (1979)
Archigetes appendiculatus	18		Motomura (1929)
Lytocestidae			
Atractolytocestus huronensis Anthony, 1958	[24]	4m + 3a+ 1 minute	Jones & Mackiewicz (1969)
	[24]	4m + 3a + 1 minute	Kralova-Hromadova *et al*. (2010)
Caryoaustralus sprenti Mackiewicz *et* Blair, 1980	6		Grey (1979)
Khawia iowensis Calentine *et* Ulmer, 1961	16	5m + 3a	Grey (1979)
Khawia rossittensis (Szidat, 1937)	16		Grey (1979)
Khawia sinensis Hsu, 1935	16	3m + 5a	Petkeviciute (1998)
	16	3m + 5a	Mutafova & Nedeva (1999)
Khawia saurogobii Xi *et al*., 2008	16	3m + 5a	Orosova *et al*. (2010b)
Lytocestus indicus (Moghe, 1925)	16		Vijayaraghavan & Subramanyam (1977)
Caryophyllaeides fennica (Schneider, 1902)	20		Bombarova *et al*. (2009)
	20	10m	Orosova *et al*. (2010a)
Notolytocestus minor Johnston *et* Muirhead, 1950	12	6a	Grey (1979)
IV. TRYPANORHYNCHA			
Lacistorhynchidae			
Lacistorhynchus tenuis (Van Beneden, 1858)	16	8m or sm	Jones (1954)
V. BOTHRIOCEPHALIDEA			
Triaenophoridae			
Triaenophorus crassus Forel, 1868	18	7m + 1sm + 1a	Petkeviciute &Ieshko (1991)
Triaenophorus nodulosus (Pallas, 1781)	26	5m + 7sm + 1a	Petkeviciute & Ieshko (1991)
Bathybothrium rectangulum (Bloch, 1782)	18	8m + 1sm	Spakulova & Scholz (1999)
Eubothrium crassum (Bloch, 1779)	16	3m + 2sm + 3a	Petkeviciute & Bondarenko (2001)
Eubothrium rugosum (Batsch, 1786)	16	3m + 2sm + 3a	Petkeviciute & Kuperman (1991)
Eubothrium salvelini (Schrank, 1790)	16	2m + 3sm + 3a	Petkeviciute & Bondarenko (2001)
Bothricephalidae			
Bothriocephalus gregarious Renaud, Gabrion *et* Pasteur, 1983	14	4m + 3a	Petkeviciute (2003)
Bothriocephalus acheilognathi Yamaguti, 1934	14	6m + 1m-sm	Nedeva & Mutafova (1988)
Bothriocephalus claviceps (Goeze, 1782)	14	7m	Petkeviciute (2003)
Bothriocephalus scorpii Muller, 1776	12		Bazitov (1978)

Order/ Family	Number	Morphology	References
	12	5m + 1sm	Petkeviciute (2003)
Tetracampos ciliotheca Wedl, 1861 (=*Polyonchobothrium clarias* (Woodland, 1925))	12	4m + 2sm	Badawy and Noor El-Din (1998)
Bothriocephalus acheilognathi Yamaguti, 1934	14	6m + 1m-sm	Sofi & Ahmad (2014)
VI. TETRAPHYLLIDEA			
Phyllobothriidae			
Pelichnibothrium speciosum Monticelli, 1889	16	1m + 1sm + 6a	Petkeviciute & Regel (1993)
VII. PROTEOCEPHALIDEA			
Proteocephalidae			
Acanthotaenia sp. (= *A. multitesticulata*)	14		Vijayaraghavan & Subramanyam (1980a)
Glanitaenia			
(= *Proteocephalus*) *osculate* (Goeze, 1782)	18	1m + 3sm + 4a	Petkeviciute (2001a)
Proteocephalus longicollis (Zeder, 1800) (=*Proteocephalus exiguus*)	18	4m + 5sm	Hanzelova *et al.* (1995)
Proteocephalus macrocephalus (Creplin, 1815)	18	7m + 2sm	Scholz *et al.* (1997)
Proteocephalus percae (Muller, 1780)	18	6m + 1sm + 2a	Spakulova & Hanzelova(1992)
	18	2m + 7sm	Petkeviciute (1993)
VIII. NIPPOTAENIIDEA			
Nippotaeniidae			
Nippotaenia mogurndae Yamaguti et Miyata, 1940	28	7m + 7sm	Bombarova *et al.* (2005)
	28		Bombarova *et al*. (2009)
IX. CYCLOPHYLLIDEA			
Mesocestoididae			
Mesocestoides vogae Etges, 1991 (=*Mesocestoides corti*)	14	5m + 2sm	Raghunathan & Voge (1974)
Nematotaeniidae *Cylindrotaenia (= Baerietta) desmognathi* (Douglas, 1957)	8, 16		Douglas (1957)
Cylindrotaenia (= Baerietta) diana (Helfer, 1948)	28		Douglas (1963); diploid number assessed
Distoichometra bufonis Dickey, 1921 (=*Distoichometra kozloffi*)	16		Douglas (1963); diploid number assessed
Nematotaenia dispar (Goeze, 1782)	28		Vijayaraghavan & Subramanyam (1980b)
Anoplocephalidae			
Avitellina centripunctata (Rivolta, 1874)	8		Walton (1959)
Moniezia benedeni (Moniez, 1879) (=*Moniezia planissima*)	probably 12 or 14		Child (1907)
Moniezia expansa (Rudolphi, 1805)	probably 12 or 14		Child (1907)
Oochoristica sp.	10 small		Jones (1945)
Taeniidae			
Echinococcus multilocularis Leuckart, 1863	18		Lukashenko *et al*. (1965)
	18		Sakamoto *et al*. (1967)
	18	4sm + 5a	Rausch & Rausch (1981)
	18	1sm + 8sm-a	Mutafova & Svilenov (1985)
Echinococcus granulosus (Batsch, 1786)	18	1sm +8sm-a	Smyth (1962)
			Mutafova & Svilenov (1985)
Echinococcus vogeli Rausch *et* Bernstein, 1972	18		Rausch & Rausch (1981)
Taenia macrocystis (Diesing, 1850)	18		Rausch & Rausch (1981)
Taenia (= *Hydatigera*) *taeniaeformis* Batsch, 1786	16		Jones & Ciordia (1956)
Taenia rileyi Loewen, 1929	18		Rausch & Rausch (1981)
Taenia crassiceps (Zeder, 1800)	16	2m + 6a	Smith *et al*. (1972)
T. crassiceps (ORF strain)	14	1m + 6a	Smith *et al*. (1972)
Taenia pisiformis (Bloch, 1780)	20		Jones & Ciordia (1956)
	16		Walton (1959)
	18		Romanenko & Movsessian (1988)
Taenia hydatigena Pallas, 1766	18	7m + 1sm + 1a	Liu & He (1987b)

Order/ Family	Number	Morphology	References
	18		Rausch & Rausch (1981)
	20		Romanenko & Movsessian (1988)
	18 (12-22)		Movsessian & Margarian (1991)
Taenia saginata Goeze, 1782	16		Walton (1959)
	20	10a	Jones & Wyant (1957)
Paruterinidae			
Anonchotaenia sp.	16	1m + 7	Jones (1945)
Anonchotaenia globate (Von Linstow, 1879)	12	2m + 1a + 3	Jones (1945)
Francobona (= *Rhabdometra*) *similis* (Ransom, 1909)	12	2m + 1a + 3?	Jones (1945)
Dipylidiidae			
Dipylidium caninum	10		Jones (1945)
(Linnaeus, 1758)	16	4m-sm+ 1a + 3?	Bovt (1973)
	16	4m + 1sm + 3a	Liu & He (1988)
	16	4sm + 6	Margarian (1989)
Davaineidae	20		
Cotugnia meggitti Yamaguti, 1935			Gupta & Greval (1971)
Davainea proglottina (Davaine, 1860)	18	probably 9a	Jones (1951)
Raillietina echinobothrida (Megnin, 1880)	18	6m +1sm + 2?	Margarian (1989)
Raillietina tetragona (Molin, 1858)	18		Margarian (1989)
Skrjabinia caucasica Petrochenko *et* Kireev, 1966	16	4m + 4sm	Margarian (1989)
Dilepididae			
Anomotaenia bacilligera (Krabbe, 1869)	16	6m + 2m-sm	Petkeviciute *et al.* (2006)
Choanotaenia sp.	16	7sm + 1a	Jones (1945)
Dilepis undula (Schrank, 1788)	18	4m + 3sm + 2a	Petkeviciute *et al.* (2006)
Liga brasiliensis (Parona, 1901)	14	6sm + 1a	Jones (1945)
Molluscotaenia crassiscolex (von Linstow, 1890)	12	5m + 1sm	Petkeviciute *et al.* (2006)
Hymenolepididae			
Anatinella spinulosa (Dubinina, 1953)	12		Petkeviciute & Regel (1994)
Aploparaksis sp.	12		Jones (1945)
Aploparaksis brachyphalos (Krabbe, 1869)	12		Petkeviciute & Regel (1994)
Aploparaksis filiformis Spasskii, 1963	12		Petkeviciute & Regel (1994)
Aploparaksis furcigera (Rudolphi, 1819)	12		Petkeviciute & Regel (1994)
Aploparaksis occidentalis Prudhoe *et* Manger, 1967	12		Petkeviciute & Regel (1994)
Aploparaksis retroversa Spasskii et Gubanov, 1961	12		Petkeviciute & Regel (1994)
Cryptocotylepis (=*Hymenolepis*) *anthocephalus* (van Gundy, 1935)	12	1sm + 1a + 4?	Jones (1945)
Dicranotaenia fallax (Krabbe, 1869)	12		Petkeviciute & Regel (1994)
Diorchis ralli Jones, 1944	10	2m + 1a + 2?	Jones (1945)
Fimbriaria sp.	10		Petkeviciute (2002)
Hymenolepis citelli McLeod, 1933	12	6a	Ward *et al.* (1981)
Hymenolepis diminuta (Rudolphi, 1819)	12		Jones (1945)
	12	6a	Kisner (1957)
	12		Douglas (1962)
	12	2m + 3sm + 1a	Liu & He (1987a)
	12	1m-sm + 5a	Mutafova & Gergova (1994)
Microsomacanthus spasskii Tolkacheva, 1965	6	3m	Petkeviciute & Regel (1994)
Microsomacanthus spiralibursata (Czaplinski, 1956)	6	2m + 1m-sm	Petkeviciute & Regel (1994)
Passerilepis crenata (Goeze, 1782) (= *Hymenolepis serpentulus sturni* = H. *serpentulus turdi*)	12	4m + 2?	Jones (1945)
Protogynella blarinae Jones, 1943	10		Jones (1945)
Pseudodiorchis (= *Diorchis*) *reynoldsi* (Jones, 1944)	10	1sm + 4a	Jones (1945)
Retinometra giranensis (Sugimoto, 1934)	12		Petkeviciute & Regel (1994)
Rodentolepis erinacei (Gmelin, 1790)	12	6a	Mutafova & Gergova (1994)
Rodentolepis fraterna (Stiles, 1906)	10	1m + 4a	Jones (1945)
	12	6a	Jones & Ciordia (1955)
Rodentolepis microstoma (Dujardin, 1845)	12	6a	Hossain & Jones (1963)
	12	6a	Proffitt & Jones (1969)
Rodentolepis myoxi (Rudolphi, 1819)	12	3m + 3sm	Casanova *et al.* (2000)

Order/ Family	Number	Morphology	References
Rodentolepis nana (Siebold, 1852)	12	1m-sm + 5a	Jones & Ciordia (1955)
	12	1m + 5a	Mutafova & Gergova (1994)
	12	6a	Goldschmidt *et al*. (2006)
Rodentolepis straminea (Goeze, 1782)	12	2m + 2sm + 2a	Spakulova & Casanova (1998)
Sobolevicanthus Mastigopraedita (Polk, 1942)	12	1m + 1a-sm +4a	Petkeviciute & Regel (1999)
Sobolevicanthus spasskii Kornyushin, 1969	12	1m + 1a-sm +4a	Petkeviciute & Regel (1999)
Wardium fryei Mayhew, 1925	12	6a	Bondarenko & Petkeviciute (1998)
Wardium retracta (Von Linstow, 1905)	12		Petkeviciute & Regel (1994)
Dioecocestidae Gyrocoelia pagollae Cable *et* Meyers, 1956	12		Coil (1972)
Shipleya inermis Fuhrmann, 1908	8		Coil (1970)
	8	2sm + 2a	Rausch & Rausch (1990)

Sm = sub-metacentric; a =acrocentric; m =metacentric.

Chromosomes of Nematoda

Examination of over 87 species of nematodes, together with later observations by other workers gives available data on 1 genus and 1 species of the Desmadoridae, 1 genus and 4 species of the Rhabditidae, 2 genus and 8 species of the Rhabdiasidae, 3 genus and 5 species of the Strongyloididae, 9 genera and 24 species or subspecies of the Ascaridae, 1 genus and 3 species of the Anisakidae, 1 genus and 1 species of the Kathlaniidae, 2 genera and 2 species of the Oxyuridae, 2 genera and 6 species of the Heterakidae, 3 genera and 5 species of the Strongylidae, 1 genus and 1 species of the Heligmosomidae, 2 genera and 2 species of the Trichostrongylidae, 3 genera and 4 species of the Metastrongylidae, 1 genus and 1 species of the Onchocercidae 1 genus and 1 species of the Diplogastridae 1 genus and 1 species of the Camallanidae, 1 genus and 1 species of the Rhabdochonidae, 1 genus and 1 species of the Acuariidae, 2 genera and 2 species of the Spiruridae, 3 genera and 3 species of the Physalopteridae, 1 genus and 1 species of the Setariidae, 1 genus and 1 species of the Cosmocercidae, 1 genus and 1 species of the Spirocercidae, 1 genus and 1 species of the Parasitaphelenchidae, 1 genus and 1 species of the Gordiidae, 1 genus and 1 species of the Chordodidae, 1 genus and 4 species of the Trichinellidae and 1 genus and 1 species of the Trichosomoididae (Table 4). Over one-half of these forms show a somatic number of chromosomes greater than the number present in the zygote or in the "stem" cells of the embryo, and supports the postulation that the germ-cell-number is composed of compound chromosomes in many instances. Some authors, however, interpret this phenomenon as indicative of fragmentation during the formation of the somatic chromosomes (in *Parascaris equorum* (Walton 1924)) the diploid number may be 2 or 4 or 6 depending upon the variety being studied, and the somatic number of chromosomes may amount to rather high figures). “Diminution” or the loss of chromatic material is known to occur in at least 9 species of nematodes, as well as occurring in other phyla such as the Protozoa, the Arthropoda, and the Chordata. This loss has been interpreted as an attempt to stabilize the embryonic environment of the "stem" or "germ-track" cells during development (Ubisch, 1943). It is known that DNA is released from the nucleus at this time and such more-or-less universal release of nuclear chemicals may on occasion have a physical manifestation (particulates). Such a release may also be associated in some manner with the so-called "chromosome fragmentation" noted in some somatic cells. Lin, 1954, suggests a comparison of this elimination of chromatic material (heterochromatin is mainly DNA) from the collective germ-cell chromosomes to the macronuclear phenomena noted in so many protozoa. Examination for the presence or absence of recognizable "sex chromosomes" (heterochromosome) has afforded records indicating that 37 species of nematodes rather definitely show the presence of an "X" chromosome-sometimes appearing as a complex of 2 or more members in certain species-and in 6 species the presence of a "Y" chromosome (however in only one species, *Contracaecum incurvum*, has subsequent work substantiated the presence of such a "Y" element). Jeffrey and Haertl's 1938 objection to interpreting apparently unpaired and lagging chromosomes as being heterochromosomes has not held up in the light of more investigations (Nigon & Robert, 1952; Lin, 1954). Heterochromosomes may appear in forms in which the sperm acts only as a stimulating agent (true fertilization never taking place) and also in parthenogenetic species (Nigon & Roman, 1952, in *Strongyloides ratti*). From the taxonomic standpoint, the number and behavior of the chromatic elements seem to have a great deal of uniformity within species of a single genus, and even among species of closely related genera, and therefore may be of some significance. In the first place the so-called "diminution" phenomenon is found only in members of the Ascaridata (Nematoda), primarily among the Ascaridae. Secondly, the number of the so-called "X"-bodies is greater than 1 only in the Ascari data ("X" may be composed of 1, 2, 5, 6, or 8 units). The presence of an undoubted "Y"-body is reported only from the Ascaridata (*Contracaecum incurvum* Good-rich, 1916). Thirdly, there is a certain consistency of total chromosome numbers in various groups. The Strongyloididae have the reduced number of 3; the Rhabdiasidae all show the haploid number of 6; the Rhabditidae as a rule have n = 7, although one form has n = 9; 11 of the 12 species of the Strongylata show n = 6 (one has n = 8); the Heterakidae seem to group around n = 5, and the Oxyuridae around n = 4 (occasionally 8). Most of these groups are quite homogeneous and the similarity of chromosome numbers could be expected; on the other hand, the Ascaridata are much more heterogeneous in composition and the wide variation in chromosome numbers should equally be expected. These variations as found within a closely knit group have been interpreted as examples of fragmentation or duplication of one or more chromosomes (aneuploidy) rather than as cases of duplication of sets of chromosomes (polyploidy). The closely related Nematomorpha show a somewhat similar situation in that members of the genus *Gordius* show n= 2 or n = 4. *Paragordius*, however, has n = 7; a situation not in keeping with the interpretation of close relationships being indicated by the number of chromosomes present.

When one turns to the Platyhelminthes, one finds a somewhat similar picture, although this phylum is far less homogeneous than the Nematoda, with such variant groups as the non-parasitic Turbellaria and the parasitic Trematoda and Cestoda.

Table 4. Chromosome Number of Nematoda from 1886 Till Date.

Family Species	No. and Morphology of Chromosomes	Reference
	COSMOCERCIDAE	
Cosmocerca kashmirensis Fotedar, 1959	2n=16	Fotedar *et al*. (1973)
	TRICHINELLIDAE	
Trichinella nelsoni	2n=6 (female) 2n=5 (male)	Mutafova & Komandarev (1976)
Trichinella spiralis	2n=6	Thomas (1965)
Trichinella spiralis	2n=6 (female) 2n=5 (male)	Mutafova *et al.* (1982)
Trichinella pseudospiralis	2n=6 (female) 2n=5 (male)	Mutafova *et al.* (1982)
Trichinella nativa	2n=6 (female) 2n= 5 (male)	Mutafova *et al.* (1982)

Family Species	No. and Morphology of Chromosomes	Reference
Trichinella nelsoni	2n=6 (female) 2n= 5 (male)	Mutafova *et al.* (1982)
	ASCARIDIDAE	
Ascaris lumbricoides (=suis)	2n=48	Homedes (1933)
Neoascaris vitulorum	2n=18	Homedes (1933)
Ophidascaris filaria	2n=14	Walton (1959)
Parascaris equorum, var. 1	2n=18	Li (1937)
Parascaris equorum, var. 2	2n=12	Li (1934)
Parascaris equorum, var. 3	2n=6	Walton (1924)
Parascaris equorum, var. 4	2n=4	Walton (1924)
Parascaris equorum, var. 5	2n=2	Walton (1924)
Toxacara cati	2n=18	Walton (1924)
Toxacara canis	2n=36	Walton (1924)
Toxacara vulpis	2n=24	Walton (1924)
Toxoscaris leonina	2n=40	Mutafova (1995)
Baylisascaris transfuga	2n=36	Mutafova (1995)
Hexametra sp.	2n=22	Mutafova (1995)
Toxocara canis	2n=22	Mutafova (1995)
Toxocara cati	2n=22	Mutafova (1995)
Ascaridia galli	2n=10	Mutafova (1995)
Ascaridia compare	2n=10	Mutafova (1995)
Ascaridia dissimilis	2n=10	Mutafova (1995)
Ascaris suum	2n=48	Mutafova (1975)
Ascaridia galli Schrank, 1788	2n = 10 (Female) 2n=9 (Male)	Mutafova (1976)
Ascaridia dissimilis (Vigueras, 1931)	2n=10 (Female) 2n=9 (Male)	Mutafova (1976)
Ascaris megalocephala	2n=4	Merlin *et al.* (2003)
Ascaris lumbricoides var. *suum*	2n=24	Merlin *et al.* (2003)
	SPIROCERCIDAE	
Mastophorus muris	2n=8+XX/XO	Spakulova *et al.* (2000)
	STRONGYLOIDIDAE	
Strongyloides ratti	2n=5 (Male) 2n=6 (Female)	Harvey & Viney (2001)
Strongyloides ratti	2n=6	Nignon & Roman (1952)
Strongyloides papillosus	2n=6	Chang & Graham (1957)
Strongyloides stercoralis	2n=5 (Male) 2n=6 (Female)	Harvey & Viney (2001)
	DIPLOGASTRIDAE	
Pristionchus pacificus	2n=12	Mitreva *et al.* (2005)
	ONCHOCERCIDAE	
Brugia malayi	2n=10	Mitreva *et al.* (2005)
	PARASITAPHELENCHIDAE	
Bursaphelenchus xylophilus	2n=12	Hasengawa *et al.* (2006)
	DESMADORIDAE	
Spirina parasitifera	2n=14	Cobb (1928)
	RHABDITIDAE	
Rhabditis aspera	2n=14	Walton (1940)
Rhabditis monhysterii	2n=14	Nignon (1949)
Rhabditis pellio	2n=14	Walton (1940)
Rhabditis aberrans	2n=18	Kruger (1913); Walton (1940)
Caenorhabditis elagans	2n=12	Mitreva *et al.* (2005)
Caenorhabditis briggsae	2n=12	Mitreva *et al.* (2005)
Caenorhabditis remanei	2n=12	Mitreva *et al.* (2005)
Caenorhabditis japonica	2n=12	Mitreva *et al.* (2005)
	RHABDIASIDAE	
Rhabdias briggsiae	2n=12	Nignon & Dougherty (1949)
Rhabdias bufonis	2n=12	Schleip (1911)
Rhabdias elegans	2n=12	Nignon & Dougherty (1949)
Rhabdias filleborni	2n=12	Dreyfus (1937)

Family Species	No. and Morphology of Chromosomes	Reference
ANISAKIDAE		
Contracaecum clavatum	2n=24	Walton (1940)
Contracaecum incurvum	2n=42	Goodrich (1916)
Contracaecum spiculigerum	2n=10	Walton (1924)
KATHLANIIDAE		
Cruzia tentaculata	2n=12	Walton (1924)
HETERAKIDAE		
Ascaridia galli	2n=10	Walton (1940)
Heterakis dispar	2n=10	Gulick (1911); Walton (1940)
Heterakis gallinae	2n=10	Gulick (1911); Walton (1940)
Heterakis papillosa	2n=10	Gulick (1911); Walton (1940)
Heterakis sp?	2n=10	Walton (1924)
Heterakis spumosa	2n=12	Walton (1924)
Heterakis gallinarum	2n=10	Mutafova (1995)
OXYURIDAE		
Passalurus ambiguus	2n=8	Meves (1920)
Syphacia obvelata	2n=16	Walton (1924)
TRICHOSOMOIDIDAE		
Trichosomoides crassicauda	2n=8	Walton (1924)
HELIGMOSOMIDAE		
Nematospira turgida	2n=12	Walton (1924)
STRONGYLIDAE		
Cyclostomum tetracanthum	2n=12	Walton (1940)
Strongylus edentatus	2n=12	Kultz (1913); Walton (1940)
Strongylus equinum	2n=12	Kultz (1913); Walton (1940)
Strongylus vulgaris	2n=12	Kultz (1913); Walton (1940)
Stephanurus dentatus	2n=12	Tromba & Steele (1957)
METASTRONGYLIDAE		
Dictyocaulus filaria	2n=12	Struckmann (1905); Walton (1940)
Dictyocaulus viviparous	2n=12	Walton (1940)
Filaroides mustelarum	2n=16	Carnoy (1886); Walton (1940)
Metastrongylus elongatus	2n=12	Gulick (1911); Walton (1940)
TRICHOSTRONGYLIDAE		
Haemonchus contortus	2n=12	Bremner (1955)
Trichostrongylus tenuis	2n=12	Gulick (1911); Walton (1940)
Haemonchus contortus	2n=12	Mitreva *et al.* (2005)
ACUARIIDAE		
Dispharynx spiralis	2n=12	Walton (1924)
CAMALLANIDAE		
Camallanus lacustris	2n=12	Walton (1940)
PHYSALOPTERIDAE		
Physaloptera turgida	2n=10	Walton (1924)
Proleptus robustus	2n=16	Carnoy (1886); Walton (1940)
Physaloptera clausa	2n=10	Mutafova (1995)
RHABDOCHONIDAE		
Cystidicola farionis	2n=12	Mulsow (1912)
SPIRURIDAE		
Protospirura muris	2n=10	Walton (1924)
Spirura talpae	2n=16	Carnoy (1886); Walton (1940)
SETARIIDAE		
Setaria equina	2n=12	Meves (1915)
GORDIIDAE		
Gordius (all spp?)	2n=4, 8	SvAbenik (1909); Meyer (1913); Muhldorf (1914); Vejdovsky (1912); Camerano (1890)
CHORDODIDAE		
Paragordius varius	2n=14	Montgomery (1904)

Chromosomes of Acanthocephala

Turning to the Acanthocephala, we again find very few records of the examination of the chromosomal components of the various species. Apparently only 5 species belonging to 3 genera have been studied: *Macracanthorhynchus hirudinaceous* (Noe, 1914); of the Archiacanthocephala, and *Echinorhynchus* (*acus*, *haeruca*, and *polymorphus*) (Hamann, 1891) and *Pomphorhynchus proteus* (Von Voss 1910) of the Palaeacanthocephala. In *Macracanthorynchus* the diploid number is 6, and strong evidence seems to indicate that the male is heterogametic and that an X-Y pair of heterochromosomes is present. In the female the 2X condition seems to be present (Jones & Ward, 1950). Earlier reports of other than 6 chromosomes being characteristic of this species may be due to faulty technique or to misidentification of the worms. *Pomphorhynchus* seems to have 8 somatic chromosomes while the 3 *Echinorhynchus* species show 16 (Table 5). This definite ratio relationship between members of the Echinorhynchidae may or may not be of phylogenetic importance, but definitely does support the separation of *Pomphorhynchus* from *Echinorhynchus*, a separation which some authorities have questioned on purely morphological grounds. It is interesting to note that in the only genus in which more than one species has been studied there is a common chromosome number. Similar examples may appear in other genera, with a broader sampling. Such constancy would not be surprising in view of the known constancy of nuclear numbers among certain of the Acanthocephala. No evidence of the presence of recognizable heterochromosomes among the Palaeacanthocephala has been presented as far as can be determined. It would seem, on the basis of the evidence at hand, that while constancy in chromosome numbers may seem to occur within a genus, far too few records are available for making any general statement. The finding of heteromorphic conditions in one species of the Acanthocephala should encourage search for similar phenomena in other members of the phylum. As far as the actual chromosome numbers are concerned, one can only say that the low numbers reported are in accord with the high specialization of the Phylum, but do not give recognizable clues as to possible relationships, either within groups above the species level, or as to possible derivation from other phyla.

Table 5. Chromosome number of Acanthocephala from 1891 Till Date.

Family Species	No. and Morphology of Chromosomes	Reference
	OLIGACANTHORHYNCHIDAE	
Macracanthorhynchus hirudinaceus	2n=12	Noe (1914); Jones & Ward (1950)
Macracanthorhynchus hirudinaceus	2n=6	Robinson (1964)
	ECHINORHYNCHIDAE	
Pomphorhynchus proteus	2n=16	Von Voss (1910)
Echinorhynchus acus	2n=32	Hamann (1891)
Echinorhynchus haeruca	2n=32	Hamann (1891)
Echinorhynchus polymorphus	2n=32	Hamann (1891)
Echinorhynchus gadi Mueller, 1776	2n=16	Robinson (1965)
Echinorhynchus gadi	2n=16	Walton (1959)
Echinorhynchus truttae	2n=7/8	Parenti *et al.* (1965)
Acanthocephalus ranae (Schrank, 1788)	2n=16	Robinson (1965)
Acanthocephalus ranae	2n=8	John (1957)
	2n=16	Walton (1959)
Acanthocephalus lucii	2n=6 (2sm-m+1sm) 1st (X) 1m (Supernumerary B)	Spakulova *et al.* (2002)

Family Species	No. and Morphology of Chromosomes	Reference
	MONILIFORMIDAE	
Moniliformis dubius	2n=8 (female) 2n=7 (male)	Robinson (1965)
	POLYMORPHIDAE	
Polymorphus minutes (Goeze, 1782)	2n=16	Robinson (1965)
Polymorphus minutes	2n=16	Walton (1959)
	POMPHORHYNCHIDAE	
Pomphorhynchus laevis Mueller, 1776	2n=8	Robinson (1965)
Pomphorhynchus laevis	2n=7/8	Mutafova &Nedeva (1988); Fontana *et al.* (1993)
Pomphorhynchus laevis	2n=6+X	Bambarova *et al*. (2007)
Pomphorhynchus tereticollis	2n=6+X	Bambarova *et al*. (2007)
	RHADINORHYNCHIDAE	
Leptorhyncoides plagicephalus (Westrumb, 1821)	2n=14	Fontana *et al.* (1993)
Leptorhyncoides thecatus	2n=5/6	Bone (1974)

[a]TCL, total complement length.; [c] ?, uncertain value.; [b]m, metacentric chromosome; sm, submetacentric chromosome; a, acrocentric chromosome (*i.e*. telocentric and subtelocentric of Levan *et al*. (1964).

CONCLUSION

Although the turbellarians are not parasitic except for a few possible exceptions, they have been introduced into this paper because they do show the gradual reduction of the basic number of chromosomes from a large number of small chromosomes to a smaller number of larger units, not only within the group as a whole, but in some cases within races of the same species, and may possibly give hints as to the derivation of the Trematoda which do show a much greater conformity between the chromosome number and the taxonomic position as based on other criteria.

Studies of trematode material have been relatively numerous, and the results point definitely toward the desirability of continued efforts in this field of research. The discovery of the presence of heterochromosomes, particularly of the fact that some forms show the female as the heterogamic sex, is of especial interest and importance. Some definite taxonomic relationships are recognizable, but since in some cases they substantiate other types of evidence used in establishing phylogenetic position and in other cases the results seem to be contradictory, further observations are in order. Perhaps some of the apparent contradictions may be eliminated as our knowledge increases. Such definitely has been the case among the Turbellaria, as mentioned in the body of this paper. In the digenetic trematodes studied till to date, most variations in the chromosome numbers within a genus are seldom greater than + 1 or 2 bivalents. Thus the mechanism for an addition or deletion of the chromosome must operate at a low level or inefficient level in this group. This suggest that the differences in the have come about by a doubling of the whole sets of chromosome but by a gradual addition or losses. Each change which represents aneuploid condition becomes stabilized. When variation in the chromosome number exceeds 1 or 2 bivalents, it probably represents successive aneuploid conditions, each change followed by a period of stability in the new chromosome number.

Study of cestode material has been quite limited, and such few records as have been noted do not give any appreciable taxonomic clues, except perhaps to indicate that some present taxa are too heterogeneous to be of real validity. Many questions on the systematics of basal cestode groups still remain controversial and phylogenetic interrelationships of the groups remain only partially resolved (Kodedova *et al.*, 2000; Mackiewicz, 1981, 1982, 1994, 2003; Olson *et al.*, 2001, 2008; Waeschenbach *et al.*, 2007). Unfortunately, no cytogenetic information is available on the two most basal cestodarian lineages Gyrocotylidea and Amphilinidea, as well as for Haplobothriidea and Diphyllidea.

Study of the parasitic nematodes has given a considerable amount of valuable taxonomic information, and here again; the field is by no means exhausted. The cytologist has a broad field of endeavor in the study of parasitic forms. With the newer techniques and the newer optical equipment now available, new knowledge of the physiology, morphology and phylogenetic relationships of such parasitic forms as those discussed is just at the threshold of a whole vista of new concepts and new interpretations.

Study of the Acanthocephala gives clues as to relationships only at the species level, but such work as has been done promises interesting results.

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