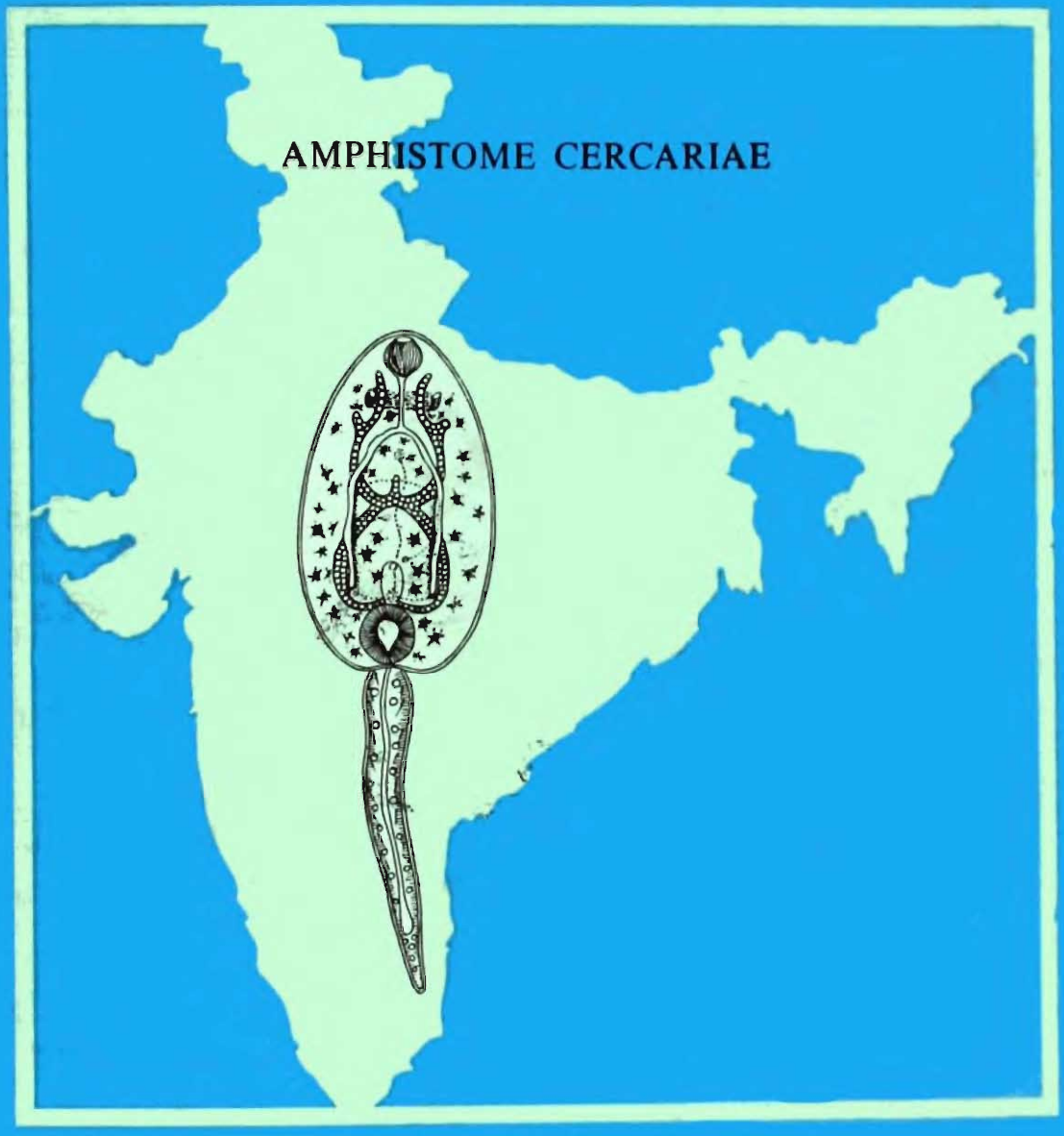
Fauna of India

LARVAL TREMATODES



R. P. MUKHERJEE

Amphistomes are digenetic trematodes infecting a variety of hosts including domesticated and wild animals and man. A number of amphistomes have been reported from India and majority of them have been recovered from the domesticated animals. Some of these amphistomes cause serious disease and mortality to our live-stock. Life histories of some of them have been elucidated. Besides the adult forms many amphistome cercariae have also been described from this country. This book contains the description of amphistome cercariae so far reported from India. The classification of these cercariae has been revised in the light of present knowledge of the group.

The book will be helpful both for students and research workers working in this important group of trematodes.

THE FAUNA OF INDIA

AND

THE ADJACENT COUNTRIES

LARVAL TREMATODES OF INDIA
PART 1—
AMPHISTOME CERCARIAE

By

R. P. MUKHERJEE

Zoological Survey of India, Calcutta

Edited by the Director, Zoological Survey of India

1986

Published : August, 1986

PRICE : *Inland :* **Rs. 60·00**
Foreign : **£ 6·50 $ 11·00**

PRINTED IN INDIA AT IMPRINTA, 243/2B, A. P. C. ROAD, CALCUTTA-6,
PRODUCED BY THE PUBLICATION DIVISION AND PUBLISHED BY
THE DIRECTOR, ZOOLOGICAL SURVEY OF INDIA, CALCUTTA

EDITOR'S PREFACE

R. T. Leiper, the then Head of Bilharzia Mission in Egypt and Middle East, drew the attention of Government of India to the possibility of the spread of Schistosomiasis in India through the heavily infected soldiers returning back after the First World War from Middle East and South Africa, the endemic focii of schistosome diseases. As such, the fear of the spread of human schistosomiasis in India started haunting the parasitologists and medical practitioners from the beginning of of this century. There were two possibilities to be looked into to confirm if the spread of the schistosome disease could become a menace in this country, firstly to search whether the intermediate mollusc hosts, reported in other coutries as vector for schistosomes could be found in India and secondly, to confirm whether the locally available snails were capable of harbouring the schistosome cercariae.

This marked the begining of the study of larval trematodes in India. Kemp and Gravely started their study on the larval trematodes of India and examined the different species of snails for the infection of larval trematodes. This work was further amplified and continued by Sewell, resulting in the publication of a monograph, *'Cercariae Indicae'* in the year 1922. Since the publication of this monograph, remarkable progress has been made in the study of larval trematodes in India and many new forms have been discovered. All these informations are scattered in Indian and foreign journals and at times the workers in the group face enormous difficulties in getting the relevant literature. In view of this and to bring the knowledge of the larval trematodes under one cover, it was decided by the Zoological Survey of India to bring out all relevant informations under the *"Fauna of India" series.*

The work was assigned to Dr. R. P. Mukherjee of this Department. The choice fell on him for his knowledge on the larval trematodes and for his outstanding contributions on the life history of trematodes.

This present issue is the first part and deals with the amphistome cercariae of India. The notariety of amphistome organisms causing amphistomiasis in domesticated animals and man are well known and it is hoped that this publication will be of immense value to the workers in the fields of medical and veterinary sciences.

Dr. B. S. Lamba
Jt. Director-in-Charge
Zoological Survey of India

August, 1986

Author's Preface

In comparison to the large number of adult trematodes that have been reported from India very little attention has been paid to explore their life cycles. During the past several decades the importance of helminthology to medical, veterinary and agricultural sciences has been increased as many of the helminth parasites infecting man, domesticated animals and agricultural crop cause serious diseases. Among the trematodes the amphistomes form a well defined group of parasites with considerable economic importance. They parasities from fishes to mammals and cause amphistomiasis in man and domesticated animals. The life histories of some of these parasites have been elucidated.

Since the publication of Sewell's (1922) work on the larval trematodes of India no attempt has been made to publish an upto date account of the larval trematodes that have been recorded from time to time. This part is the first of the series of the larval trematodes of India and deals with the larval stages of those amphistomes whose life histories have been worked out and the amphistome cercariae that have been recorded so far. Efforts have been made in this part to provide description in detail of each cercaria with keys at each step.

I am indebted to the Director, Zoological Survey of India, Calcutta, for providing necessary facilities. My thanks are also due to Shri Monoj Sengupta, Artist, for execution of the drawings and Shri R. C. Maity, typist, for typing out the manuscript.

Zoological Survey of India
Calcutta.

Dr. R. P. Mukherjee

CONTENTS

INTRODUCTION

Trematodes form an important group of helminth parasites because they parasities most of the vertebrates and many of them cause serious diseases to man and animals of economical importance. From early days man is concerned with the parasitic infections and diseases they cause. As a result the main thrust of parasitological research centred round the cure and prevention of diseases caused by various parasites. Very little attention has been given to the study of the life histories or to the larval trematodes. The survival of the trematodes depend upon the biotic factors of the aquatic environments and on the host-parasite relation. Most of the trematodes are so adopted to the parasitic mode of life that they are able to maintain themselves inside the host body as well as to the free living stages out side the body of the permanent host. The life cycles of most of the trematodes are simple and need one intermediate host whereas in some they need more than one intermediate host to complete the life-cycles. The hatching of the miracidia from eggs, the life span of miracidia and cercariae and the emergence of the cercariae from the infected snail hosts depend upon the various environmental factors. The success and the intensity of trematodes infection depend upon the density of the suceptible hosts on which the miracidia and cercariae develop. The miracidia after entering into a suitable molluscan intermediate host undergo the various stages of development and finally produce the cercariae. In comparison to the other larval stages of the life-cycle the cercaria is very well developed and possesses the structures for feeding, penetration, attachment, dispersal and structure for forming the cyst. Most of these structures help a cercaria to seek and to establish the infection in the final host. Some of these structural features of the cercaria disappear in the adult whereas the other characters persist even in the adult trematode. So in the life-cycle of a trematode the morphology of the cercaria plays an important role in its phylogeny than the other larval stages. There is variation in the morphology of the cercariae, some of the cercariae are simple whereas the structures are quite complicated in others.

The monostome cercariae possess only the oral sucker and the ventral sucker is absent. Among the distome cercariae the body of the amphistome cercariae is large with a muscular powerful tail. The ventral sucker in this type of cercariae is located at the posterior end of body. In the cystocercous cercariae the anterior part of the tail is enlarged to form a cavity in which the body can be retreated. The oral sucker of the gymnocephalous cercariae is without spines or stylet. The echinostome

cercariae like their adults are provided with collar and circle of spines at the anterior end. The oral sucker of the xiphidio cercariae is provided with a stout piercing stylet. Virgula organ may be present or absent in these cercariae. The tail in the furcocercous cercaria consists of a stem and two furcae. In microcercous the tail is short and stumpy and rhopalocercous cercaria the tail is wider than the body. In the lophocercous cercaria the body carries a fin fold and in the case of gasterostome cercaria the mouth is situated in the centre of the body. Similarly based on the morphology the other cercariae have been classified into various other groups and sub-groups. It is generally the practice to describe a cercaria as a species but in recent years it has been realised that it has little systematic value and the main idea of describing a cercaria as a species is to differentiate it with other cercariae. Some of the authors instead of nameing the cercariae used alphabet or roman numerals to classify the cercariae.

The body and tail of the cercariae may be smooth or provided with spines or hair like structures. In some cases the papillae may also be present particularly in the anterior region around the mouth. In some cercariae the body may be pigmented and the pigment may be localised in a particular area or scattered throughout the body. The body and tail of the cercariae are provided with longitudinal and circular muscles. The mouth is enclosed by an oral sucker which may be well developed, muscular and large or feebly developed and small. The oral sucker may be provided with stylet, virgula organ or oral pouch, which acts as a secretary glands or penetrating glands. The ventral sucker in case of distome cercariae is either located at the posterior end or at equatorial, pre or post-equatorial level of body.

The body of the cercariae may be provided with mucoid, cystogenous and penetration gland cells. The excretory system of the cercariae is very well developed and consists of flame cells, capillaries, collecting vessels, bladder and excretory pores. This system is of much taxonomic value for the classification of cercariae. The digestive system of the cercariae consists of mouth, prepharynx, muscular pharynx, oesophagus, oesophageal bulb and caeca. Out of these some structures may be absent in certain larvae. Some of the cercariae possess eyespots, body papillae or hair like projections on the tegument which act as sensory organs. The nervous system is very poorly developed in cercariae. The cerebral ganglia is located at the region of pharynx from which originates a number of nerve cords. The reproductive system of the cercariae is represented by genital rudiments. In some cases the rudiments are not well differentiated whereas in others they are differentiated into testes, ovary, uterus, vas-efferens, vas-deferens and genital pore.

The cercariae after emergence from the infected snail host disperse widely in search of the final or second intermediate hosts. For this purpose a cercaria develops a strong and powerful tail which generally acts as a locomotor organ. The structure of the tail shows a wide range of variations and this morphological variation is used in the taxonomy of the cercariae. In some the tail is absent or very small with the result that the cercaria moves in leech like manner, whereas in others the tail is very well developed with a long stem, furcae, finfolds and fin ribs which carries a cercaria to long distance. The cercariae after emerging from the snail host swim for some time and the duration of free swimming stage varies from species to species and it also depends upon the various environmental factors. A cercaria during the free swimming stage tries to reach its goal which may be an another intermediate host, a permanent host or to form a cyst. It has been proved that the vitality of the cercariae declined with the longer period of free swimming life. The cercariae may be positive of negative phototactic. Various environmental factors are responsible for the release of cercariae from the infected snails. Some factors like temperature, light, pH and nutrition play important role in the emergence of the cercariae. In comparison to the large number of adult trematodes that have been described from different parts of the world the life histories of a few have been studied so far.

India is very rich in helminth fauna and among them the trematodes form a major group. The adult trematodes infect the vertebrates from fishes to mammals and parasitise their various body organs. In some cases the infection is so high that they cause heavy mortality of the hosts. The animals of economic importance are equally affected by their infection with the result that India is not able to utilise the maximum of these animal resources. In some cases they not only damage the different body organs of the host and cause various diseases but also deprive the host from vitamins, minerals and trace elements thus interfering in their normal metabolism. Inspite of the richness of the trematode fauna no serious attempt has been made to elucidate their life histories. Every year new species of adult trematodes have been discovered from this country but efforts to explore the larval forms or to study the life-histories of these parasites have been practically overlooked.

The identity of the cercariae with adults can be made by morphological comparison of the two or by raising the adults from the cercariae by carefully controlled experiments. There is an inherent danger to correlate the identity of the cercariae with the adults on structural basis at least in those cases where they differ morphologically from the adults. Some cercariae which are quite different structurally than that of adults have been proved experimentally to be the larvae of the latter. The specific

identity can be established only when the adults are raised from the cercariae or the larvae are raised from their eggs experimentally.

The danger of spread of bilharziasis in India by the returning Indian troops from active service overseas during the first world war has been reported by a few helminthologists as early as 1916. So Sewell (1922) took up the study of the larval trematodes of India and published a monograph. Since the publication of Sewell's monograph no serious effort was made to explore further the larval trematodes of India. The life histories of some trematodes have been elucidated and few cercariae have been described after the publication of Sewell's monograph by various workers, but none of them have surveyed thoroughly even a particular zone or state.

AMPHISTOMES RECORDED FROM INDIA

Amphistomes form a major and important group of helminth parasites. A fairly large number of amphistomes have been recorded from this country, mostly from fishes, amphibians, reptiles and mammals. Various classifications have been proposed for this group of parasites but none of them is fully satisfactory with the result that inspite of great amount of work done, differentiation of some of the species is still remains a problem.

Amphistomes that were recovered from horses and elephants in India were probably first recorded by Cobbold (1875). Amphistomes of horses have long been known as 'Masuri' Cobbold (1875) reported three new amphistomes, *viz. Amphistoma collinsi*, *A. stanleyii* and *A. hawkesii* from horses. The same author in the year 1882 added another species *A. papillatum* from elephants. The first three species of Cobbold were later on transferred to the genus *Pseudodiscus* Sonsino (1895) and *P. stanleyii* was treated as synonym to *P. collinsi*. The fourth species of Cobbold was transferred to the genus *Pfenderis* errected by Stiles and Goldberger (1910) as *P. papillatus*.

Lewis and McConnel (1876) discovered a new species of amphistome from man in India and reported it as *Amphistomum hominis*. A new genus *Gastrodiscoides* was proposed by Leiper (1913) who transferred *A. hominis* in this genus and described it as *G. hominis*. Another species *G. hominis var. suis* was added into this genus by Verma (1954) which is now considered as synonym to type species. Based on the materials collected from the mules in Assam Looss (1907) described a new species as *Gastrodiscus secundus*.

Stiles and Goldberger (1910) made a valuable contribution on Indian amphistomes and their study was based on a large collection of amphis-

tomes from this country as well as from the other parts of the world. They have reported as many as five new species of amphistomes and described them as *Cotylophoron indicum*, *Paramphistomum cauliorchis*, *P. crassum*, *P. papillosum* and *P. indicum*. The first one was described by them from *Ovis aries* and the rest were from *Bos indicus*. The second, third and fourth species of the joint authors were later on transferred to the genus *Calicophoron* Nasmark (1937) as *C. cauliorchis*, *C. crassum* and *C. papillosum*. The validity of the species *C. crassum* was doubted by Nasmark (1937) and later on this species was treated as synonym of *C. calicophoron* (Fischoeder, 1901) Nasmark (1937) and the last species *P. indicum* of the joint authors was merged with *P. cervi* (Schrank, 1790) Fischoeder (1901). Fukui (1926) collected some aphistomes from an Indian elephant died in Japan and on study this proved to be a new species belonging to a new genus *Tagumaea* and he named it as *T heterocaeca* but later on this genus was merged with *Pfenderius* Stiles and Gold-berger (1910).

Bhalerao (1931) collected amphistomes from fresh water turtles and on study it proved to belong to a new genus *Stunkardia* and he named it as *S. dilymphosa*. Srivastava (1934) recovered amphistomes from frogs and considered it as a new variety of *Diplodiscus amphichrus* and named it as *D. amphichrus magnus*. Pande (1937) reported a new species of amphistome from frog and named it as *D. mehrai*, but his species and the variety described by Srivastava (1934) are considered now as synonym of *D. amphichrus* Tubangui (1938). Harshey (1934) reported three new species, *Cotylophoron ovatum*, *C. orientalis* and *C. elongatum*. Later on his first species was merged with *Ceylonocotyle scoliocoelium* (Fischoeder, 1904) Nasmark (1937) and the last two with *Cotylophoron indicum* Stiles and Goldberger (1910). Bhalerao (1935) reported a new species, *Pfenderius birmanicus* from elephant. Same author in the year 1937 errected a new genus *Neocladorchis* to accommodate his new species *N. poonaensis* collected from fish and reported three more new species viz. *Helostomatis sakrei* from fish, *Paramphistomum cuonum* from *Cuondukhunensis* and *P. maplestoni* from *Hyelaphus porcinus*. Srivastava (1938) reported a new species, *Gyliauchen ozakii* from fish and proposed two new genera, *Orientodiscus* and *Nicollodiscus*. The amphistomes of both these genera were collected from fishes. The first genus contained his two species, *O. lobatum* and *O. jumnai* whereas his second genus contained one species, *N. gangeticus*. Siddiqi (1965) added three new species to the genus *Orientodiscus* which were collected from the fresh water turtles. The three species described by him were *O. linguiformis*, *O. buckleyi* and *O. constrictus* but Mukherjee and Chauhan (1967) considered *O. constrictus* as the only valid species and the other two were synonimised with *O. lobatum* Srivastava (1938).

Johnson (1939) recovered a new amphistomes from an Indian cow and described it as *Paramphistomum magnum* but Yamaguti (1958) errected a new genus *Johnsonitrema* to accommodate this species and he named it as *J. magnum.* Thapar and Sinha (1945) errected a new genus *Olveria* with *O. indica* as type species. They obtained this parasite from the cattle. Tandon (1951) added a new species to this genus and described it as *O. bosi.* Tandon (1955) also described a new amphistome, *Paramphistomum spinicephalus,* from buffalo. Gupta (1951) reported the occurrence of *Paramphistomum bathycotyle* Fischoeder (1901) but his species is now considered as synonym to *Gignatocotyle explanatum* (Creplin, 1847) Nasmark (1937). The same author in the year 1958 reported two new species, *Cotylophoron madrasensis* and *Ceylonocotyle dawesi* both from domesticated ruminants. Thapar (1960) proposed a new genus *Caballeroia* with *C. indica* as type species and the parasites were collected from fish. Mukherjee (1963) reported two new species from domesticated ruminents and described them as *Cotylophoron bareilliensis* (Mukherjee, 1963) Mukherjee and Chauhan (1967) and *Ceylonocotyle nasmarki.* Gupta (1963) reported the occurrence of *Paramphistomum epiclitum* Fischoeder (1904) from animals in India. Dwivedi (1967) described a new genus *Kachugotrema* with a new species *K. amboinensis* but Mukherjee and Chauhan (1972) synonimysied the genus and species with *Orientodiscus* Srivastava (1938) and *O. lobatum* Srivastava (1938) respectively. Gupta and Gupta (1969) reported two new species *Cotylophoron chauhani* and *Ceylonocotyle narayani.*

Other workers who have studied and recorded the various known amphistomes, mostly from the domesticated animals, from various parts of India and made valuable contribution to our knowledge on the Indian amphistomes are Fischoeder (1901, 1903), Maplestone (1923), Bhalerao (1935), Moghe (1945), Tandon (1955), Thapar (1956) and Mukherjee (1960, 1962, 1963 and 1966).

It is evident from the above review that most of the amphistomes reported in India are from mammals, particularly from the domesticated animals, and only a few from fishes, amphibians and reptiles and none from birds.

GENERAL ACCOUNT OF AMPHISTOMES

The amphistomes are endoparasitic and usually parasitising the intestine, liver and bile duct. In living condition they are usually light redish, brownish or whitish in colour. They are elongated, conical or flat in shape. In some the body is divided into two parts. The oral sucker surrounding the mouth is located at the anterior end and the

large acetabulum is situated at the posterior end of body, The two suckers may be terminal or subterminal. The body is covered with thick or thin cuticle and it may be smooth or papillated. Some of the amphistomes are provided with ventral pouch which occupies almost the whole of ventral part of body and opens ventrally.

The muscles lie below the cuticle and the oral sucker, oesophagus, oesophageal bulb, acetabulum and genital atrium are highly muscular. The two suckers act as adhesive organs. Sometimes the oral sucker is provided with oral pouches similarly at times the acetabulum is provided with lip like organs or papillae.

The mouth opening is terminaly or subterminaly and it is followed by an oesophagus. The oesophagus may be short, moderately long or long. The oesophagus may be thin or thick. In some amphistomes the oesophagus is provided with an oesophageal bulb at the posterior end. The oesophagus may be straight or curved in the form of 'S' or 'J' The oesophagus at the posterior end bifurcates into two intestinal caeca which may be short or long. The caeca may be straight, wavy or form loops and end blindly. It may be divided into a swollen portion and a slender portion.

The amphistomes are hermaphroditic and there is a common genital pore, the opening of genital atrium, in which the terminal parts of male and female ducts open. The male reproductive organs consist of two testes but in some species only one testis may be present. They usually lie on the posterior or middle part of body and they may be entire, lobed, branched and varying in size. They are also vary in position and may be oblique, tandem, obliquely tandem or symmetrically opposite. Each testis gives off a fine vas-efferens, the two vas-efferens sooner or later join to form a common genital duct, the vas-deferens. This usually opens into the cirrus sac or into pars musculosa and ultimately opens to the exterior by genital pore. The anterior portion of vas-deferens may be divided into a swolen portion, the vesicula seminalis and pars prostatica and a muscular organ the cirrus. The female reproductive organ consists of an ovary which is usually situated anterior, posterior or between the two testes. It is usually round to oval in shape. From it originates the oviduct which is soon joined by the ducts of the vitelline glands. Near this union generally a small thin Laurer's canal opens which on the other hand opens to outside and the opening may be anterior or posterior to the excretory opening. There may be a small sac, receptaculum seminis, near the joining of the Laurer's canal and oviduct. Close to it also lies the shell glands which open into the dilated portion or the ootype of the oviduct. The ootype is connected with the usually coiled uterus. The uterus opens to the exterior and the opening

is located by the side of the male genital pore. Thus the male and the female ducts open into a common genital atrium which in turn opens outside through a genital pore. The genital pore is situated on the ventral side and lies at various levels. Some time the genital pore is situated on a pillar. In some forms the genital pore is surrounded by a genital sucker. Vitelline glands are either in small or in large follicles, lie usually on each side of the body and either restricted to small part or extended to greater length of body. They may be either extra or intercaecal.

In amphistomes there exist a longitudinal mesenchymatous system called the lymph vessels which are associated with the excretory system and other organs of the body by their branches and helping in the distribution of excretory and food substances. However, the function of these vessels is not yet definitely known. The lymphatic vessels may be one to three pairs. In the region of the excretory vessicles and around acetabulum the branches of the vessels are quite abundant. The main vessels give out branches to oesophagus, caeca, reproductive organs and the excretory vessicle and forming plexuses around them.

IMPORTANCE OF AMPHISTOMES

Amphistomes constitute an important and interesting group of trematodes because they are parasitising both cold and warm blooded animals including human beings. The damage caused by these parasites to fishes, amphibians, reptiles and birds is not yet known but the pathogenicity produced by various species of amphistomes to the live-stock and human beings have been reported by various workers from different parts of the world. Many cases of mortality of the animals of economical importance due to the attack of these parasites have been reported from many parts of India particularly from the low laying areas where the intermediate snail hosts are quite abundant. The wild animals are equally vurnalable to the attack of these parasites but the damage caused by them to the wild animals has not yet been worked out. The immature amphistomes are supposed to produce diseases in domesticated animals.

Only two species, viz, *Gastrodiscoides hominis* Leiper (1913) and *Watsonius watsoni* (Colyngham, 1904) Stiles and Goldberger (1910) are found to infect human beings. The infection of *G. hominis* in human being and pig is quite common in India. Various species belonging to different genera e.g. *Paramphistomum* Fischoeder (1901), Nasmark (1937), *Cotylophoron* Stiles and Goldberger (1910), *Ceylonocotyle* Nasmark (1937), *Gastrothylax* Poirier (1883), *Fischoederius* Stiles and Goldberger (1910), *Gastrodiscus* Leuckart (1877), *Pseudodiscus* Sonsino (1885), *Pfenderius*

Stiles and Goldberger (1910), *Homalogaster* Poirier (1883) and *Olveria* Thapar and Sinha (1945) are known to parasitise the domesticated animals of India. For a long time owing to the common occurrence in domesticated animals in India amphistomes were considered as harmless but recent investigations have proved that the Indian live-stock industry suffers much due to fatal enteritis caused by immature forms of various species of amphistomes. In the past the live-stock owners in this country knew the disease caused by the various species of these parasites and were under the impression that the disease was caused by eating the grass from the swampy areas. The disease caused by these parasites is known as amphistomiasis.

AMPHISTOMIASIS

The symptoms and pathogenicity produced by the amphistomes in human beings are severe diarrhoea and inflamation of the mucosa of duodenum, ileum, caecum and colon and may prove to be fatal.

Amphistomiasis in domesticated ruminants has been known from a very early date in India and in some parts it has been known as 'Pitto' and 'Gillar' Although the exact figure of loss due to amphistomiasis in live-stock in this country is not known but if compared with any other group of helminth parasites amphistomes will undoubtedly prove to be as one of the most important group in undermining the health of our domesticated animals and cause considerable monetary loss to the live-stock owners every year. The surveys conducted by various workers in India reveal that our domesticated animals carry a very heavy load of these parasites and they may cause great damage to the health of domesticated animals.

Though in the infected animals the effect of the amphistomes may not be quite distinct in the begining to attract the immediate attention but ultimately they cause the loss in the health and decrease the capacity of resistance to various diseases in animals. As reported by various workers the affected animals were often seen down and if raised would stagger and fall. The infected animals may also develop anaemia, debility, persistant diarrhoea, unthriftiness, oedema of the submaxilary space as in fascioliasis. The other symptoms that are associated with amphistomiasis are dung contained streaks of blood and usually with large number of immature amphistomes and mucous, the excreta is offensive in odour, the milk yeild decreases, the body temperature increases and the animals are less interested in food. The various pathological changes were also observed by different workers in the infected animals.

In Punjab the amphistomiasis has been known from very early date and the live-stock owners know that the disease is caused to the

animals by eating the grass called 'Khal' from the swampy areas. Probably Baldrey (1906) first studied the disease in sheep and while discussing 'Gillar' pointed out that clinically it resembles somewhat fascioliasis. He described the pathological lesions and collected the immature amphistomes from the infected animals. Walker in the same year while discussing 'Gillar' pointed out that the disease is practically confined to the low lying swampy areas. He also noted that the disease is common in the animals during the months of December, January and February. An outbreak of Amphistomiasis in Assam was reported by Pande (1935). He observed that 60% of the cattle in certain villages of Kamrup district was infected with immature amphistomes and stated that the disease started after the rains and alternate with the rinderpest with its occurrence. While describing this disease in sheep and goats at Sind, Haji (1935) was of the opinion that it was caused by the immature *Paramphistomum cervi*, Srivastava (1938) while describing the life history and pathogenicity of *Cotylophoron cotylophorum* stated that they were pathogenic so long as they were in duodenum and intestine but they became harmless on migrating to the rumen. Bawa (1939) reported the outbreak of immature amphistomiasis in sheep from Sind. The mortality in the infected animals was from 80% to 90%. He reported that the disease started during the rains and was common in the animals of lowlying areas. Maqsood (1944) reported a case of acute amphistomiasis in a cow. He recovered the amphistomes from the rumen and reticulum of the infected animals and identified them as *Paramphistomum cervi*. Bhalerao (1944) ascertained after examining the specimens collected from U. P., Sind, Bihar, Assam and Madras that the amphistomiasis in domesticated animals is due to the various species of immature amphistomes. Mudaliar (1945) reported fatal enteritis in goats due to immature amphistomes. The disease started in the months of February and March at Madras and 19 out of 40 goats died. He identified the worms recovered from the dead infected animals as *Cotylophoron cotylophorum* and *Fischoederius elongatus*. Moghe (1945) as a result of a survey conducted by him on the nature and incidence of helminth infection in cattle, goats and sheep in the Central Provinces and Berar and Central India pointed out that in goats the amphistome infection was the highest in all seasons and in winter as many as 76% animals were infected. He pointed out that 51% of sheep were infected with *Cotylophoron cotylophorum* and 75% of cattle were infected with *C. cotylophorum* 54% to 88% with *Gastrothylax crumenifer*. Srivastava (1948) infected a healthy goat with large number of encysted cercariae of *G. crumenifer* and observed that the experimental animal died after two months of infection due to amphistomiasis. Kuppuswamy (1948) reported heavy mortality among sheep and

goats in Bihar due to immature paramphistomes. The disease is known as 'Pitto' and 'Gillar' in Bihar. Iyer (1949) reported many deaths in a flock of seeep at Hosur cattle farm between December and March due to immature amphistomes. D'Souza (1949) reported fatal enterities in sheep, cattle and buffaloes at Hosur due to immature amphistomes. He identified those forms as *C. cotylophorum* and *G. crumenifer*. Ramakrishna (1950) reported an outbreak of acute amphistomiasis among cattle in Nellore district. Minett (1950) while discussing the cause of mortality in sheep and goats in India pointed out that in Bihar, Hosur and U. P. the death of the animals was due to immature amphistomes. His findings were based on his study of the cause of death in sheep and goats in the government farms. Based on a survey Thapar (1956) observed that buffaloes, cattle, sheep and goats were commonly infected with various species of amphistomes and they carry a very heavy load of these parasites. Sharma and Malik (1960) discussed the problem of amphistomiasis in cattle in Punjab. Mukherjee and Sharma (1962) reported the massive infection of a sheep with amphistomes and described the histopathology of the parasitised rumen. The average percentage of morbidity and mortality due to amphistomiasis was found to be 41.54 and 67.62 in sheep and 68.59 and 75.54 in goats respectively in U. P. by Katiyar and Varshney (1963). Sharma (1964) reported briefly the histopathological findings on gigantocotyliasis in buffaloes.

In recent years many papers have been published on the amphistomiasis of domesticated animals of India. In this country though there is no statistical data available to show the actual loss due to amphistomiasis but from the published accounts it is quite clear that the amphistomes are highly pathogenic to domesticated animals and causing great loss to stock owners. Only the immature forms are so far considered to cause the disease. Inspite of the enormous loss to domesticated animals with amphistomes no thorough investigation has yet been made to find out the incidence, distribution, pathogenicity, therapeutic and preventive measures. The knowledge of the life history is a pre requisite for the control of a parasite but the life histories of only a few amphistomes have been elucidated so far in India. So unless the amphistomes are studied in detail the amphistomiasis will continue to remain as a problem for conservation of animal health in India.

LIFE HISTORY IN GENERAL

In case the host is distributed widely in an area and even if the animals are parasitised the parasite may fail to establish and perish soon if the suitable intermediate snail host is not available in that area. A trematode parasite can survive and flurish only if both the final and

intermediate hosts are available in a given geographical area. Thus the survival of a trematode parasite depends largely on the distribution and survival of its intermediate host (s) on which it completes its life cycle.

The trematode parasites generally voide their eggs in the lumen of hosts which in turn passed out with the faeces of the hosts. The miracidia hatch out from the eggs which are deposited with the faeces of the host near some water source and start to swim actively in the water.

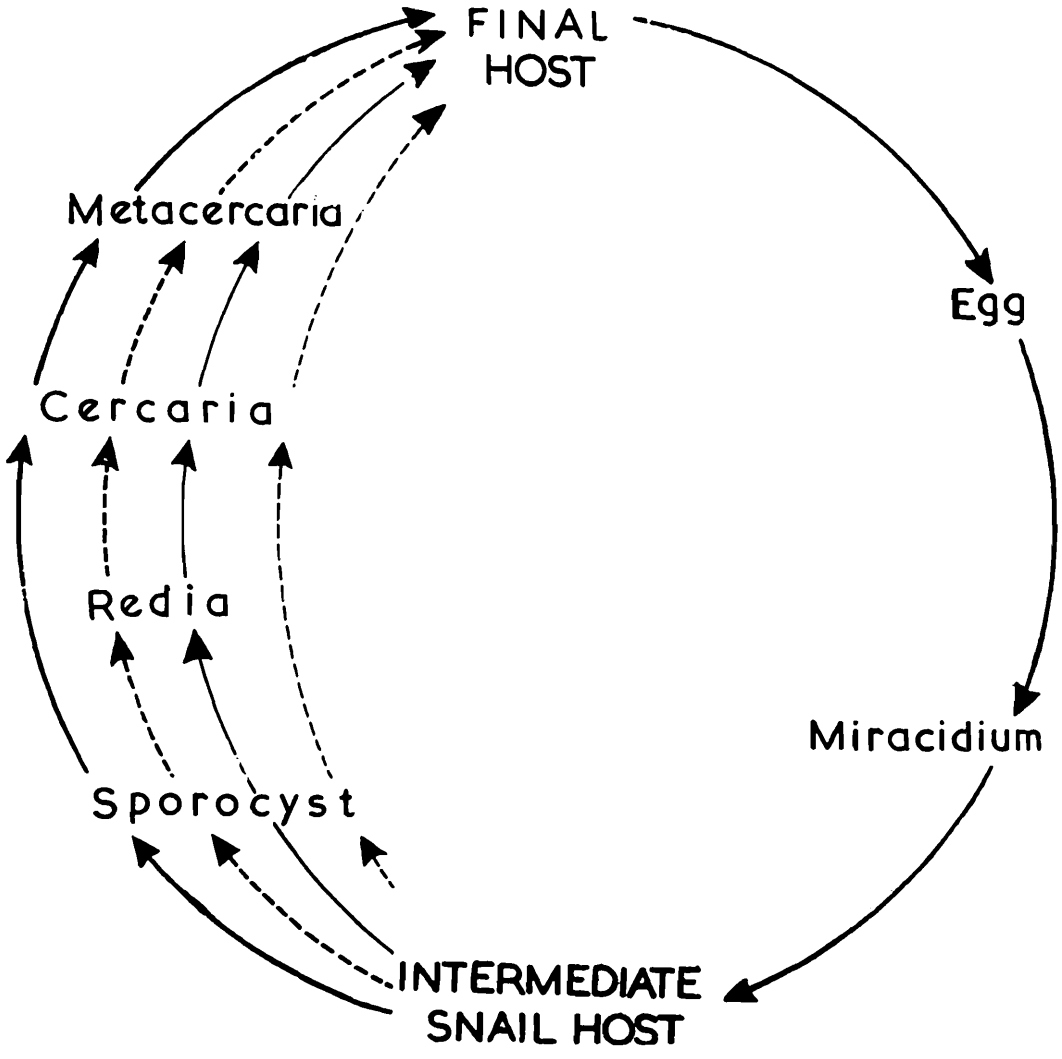
A miracidium is an elongated ovoid body and is covered with ciliated epidermal plates. The miracidium swims in the water actively with the help of body cilia. It is also provided with circular and longitudinal muscles, papillae, gut, penetrating glands, nerve mass, excretory system and germinal cells. Eye spots may be present or absent. A free swimming miracidium enters into a suitable intermediate snail host and after sheding its body cilia changes into as porocyst.

The sporocyst is an elongated body and contains germ cells and excretory system in the beginning and lodges itself in various body organs of the snail, such as digestive gland, gonads, mantle, lymph spaces surrounding the intestine, gill chambers, etc., and develops into a mature sporocyst. The mature sporocyst besides containing germ cells and excretory system may also contains the rediae.

The redia emerges from the sporocyst and has an elongated body. It may be provided with oral sucker, mouth, pharynx, oesophagus, blind sac like gut, birth pore, collar, locomotor appendages, excretory system, germ cells, cercariae and body pigment. The redia is able to move and shows body contraction and expansion. The germ cells of the redia give rise to cercariae.

The cercariae escape from redia and further development takes place inside the snail tissue. The fully developed cercaria emerges from the snail host and swims for some time in the water before it forms the cyst or enters into the final host. The structure of the cercaria is complex and is provided with a body but the trunk and tail may be present or absent. The body which is usually flat and elongated is provided with spines, stylet, suckers, pharynx, oesophagus, caeca, penetrating glands, excretory system, rudimentary reproductive organs, cystogenous cells, eye spots, body pigment, etc. Based on these characters the cercariae are variously classified. The cercaria penetrates and enters into the final host or may encysts on vegetation or in the tissue of the second intermediate host and forms the infective stage. Before the formation of cyst the cercaria shed its tail. Encysted cercaria is provided with thick cyst wall. The cyst wall helps the metacercaria to overcome the adverse climatic conditions and in this stage the metacercaria lies in dormant stage till it is picked up and ingested by the

final host. After entering the final host the wall of the metacercaria dissolves and excyst cercaria lodges into suitable part of the body of final host and attains maturity, Variations in this generalised life cycle in trematodes are well known. The different pattern which they follow are given in Fig. 1.



Fig, 1. Life cycle of digenetic trematodes in general

The study of the life cycle not only helps to understand the phylogenetic relationships between the closely related species of trematodes, but also helps to understand the host parasite relationships and enable us to eradicate the parasite finally.

LIFE HISTORY OF AMPHISTOMES

Studies on the life histories of amphistomes provide valuable information regarding systematics, pathogenicity, epidemiology, etc. of the parasites and help to control the diseases caused by them. The data

regarding the time taken by the miracidia to hatch from the eggs, prepatent period in the snail host, structure of the cercariae, longevity of the metacercariae and the time taken by the metacercariae to develop into the adult parasite in the final host are some of the important factors that can be known only from their life histories. So far the life cycle of only a few amphistomes, particularly those that are parasitising the domesticated animals in India, have been worked out.

The eggs of the amphistomes are whitish to transparent in colour, fairly large in size and oval in shape. The egg shell is uniform in thickness except at the posterior end. The acetabular end is provided with a small thickening which is assymetrical in position. The narrower anterior and is provided with an operculum. An egg contains distinct yolk cells and ovum. The ovum is more or less centrally situated. The eggs are passed out with the faeces of the host and further development of the ova take place outside the body of the host.

Freshly laid eggs contain ova in the early stages of segmentation. After the eggs are laid the embryos continue to develop and after some days the eggs contain fully developed miracidia. The rate of development of miracidia varies from species to species and depends upon the temperature. A fully developed miracidium shows antero-posterior movement inside the egg and it repeatedly hits the base of the operculum with its anterior end. A miracidium when fully develop escapes from the egg by throwing open the operculum.

The miracidium is of the non-ocellate type and is triangular in shape with body cilia, apical and other papillae, gut penetrating glands, nerve mass, subepithelium, etc. The miracidium swims actively in water with the help of body cilia. A miracidium is provided with 20 ciliated epidermal cells arranged in 4 tiers of 6, 8, 4 and 2 cells respectively. The nerve mass of the miracidium is spherical in shape. The excretory system contains a pair of flame cells which are connected with a pair of excretory ducts and the ducts finally open outside by separate excretory pores. The miracidium is also provided with a large apical gland and with one or two pairs of penetration glands. Besides this the larva also contains germinal balls and a number of circular and longitudinal muscle fibres. The miracidia when come in contact with a suitable intermediate snail host they penetrate into the body of the snail and transform into nonciliated sac like bodies or sporocysts.

The sporocysts are generally found in the mantle tissue, digestive gland, head or foot of the snail host. They may also occur in the body space surrounding the intestine either in free state or attached losely to the outer wall of the intestine by a mucoid substance. They are irregular, pyriform or oval in shape in the begining but when they mature they

become saccular. The young sporocyst contains the germinal balls with germinal cells and a pair of flame cells, like the miracidium, with their ducts. The germinal balls develop further and differentiated into the second generation of rediae and the germinal cells give rise to more germinal balls. Depending upon the temperature the sporocysts reach maturity in different times. Generally the sporocysts attain maturity in about 6-9 days during the summer months and 16-38 days during the winter months. A mature sporocyst contains developing rediae and the germinal balls. The rediae come out either by rupturing the anterior wall or by a terminal opening of the sporocyst. The rediae are produced by a sporocys till all the germinal elements are exhausted.

The rediae are liberated from the sporocysts in immature stage and continue to develop in the snail tissues. They lodged into the digestive gland, reproductive system, body space surrounding the intestine or into the mantle tissue of the host. After they come out from the sporocysts they generally take about 10-15 days to reach maturity under optimum conditions. They are elongated, sausage shaped and may or may not be provided with locomotor appendages and body pigment. The digestive system of a redia comprises of mouth, muscular pharynx, short oesophagus and rhabdocoel gut. On the posterior lateral side of the pharynx lies two groups of glandular cells or the salivary glands and probably form the part of the digestive system. The excretory system of redia forms by a set of three flame cells with their ducts which ultimately open out side through lateral excretory pores. A redia contains germinal balls, germinal cells and developing cercariae. Sometimes the mother rediae give rise to second generation of rediae and occasionally they give rise to rediae and cercariae both. The progeny of a redia is released through a birth pore of redia which is located at the anterior region near the level of gut.

The cercariae liberated in immature stage from the rediae and complete their development inside snail tissue before they emerge from the infected snail host. The cercariae take about 10-25 days, depending upon the temperature, to reach maturity. The mature cercariae are provided with a body and a powerful tail, circular and longitudinal muscles and the body may or may not be provided with pigment. The body is also provided with cystogenous cells and the anteriorly located acetabulum, like the adult parasite. Beside this the cercariae are also provided with digestive system, nervous system, eye spots, excretory system with refractile excretory granules, with or without oral pouches and the rudimentary reproductive system. The genital rudiments are arranged like the adult parasite and can be seen distinctly in the stained cercariae. Some of the characters of the cercariae are so distinct that it can be compared easily with that of the adult parasites whereas in other

ckaracters they show generic affinities. The mature cercariae are liberaled from the snail host from time to time into the water and swim actively by vigorous and continuous lashing movement of the powerful tail.

The cercariae remain active for a very short time and the free swimming period varies from a few minutes to a few hours. At the end of this period the cerariae attach themselves to a suitable object and contract to form globular bodies or metacercariae. The tail remains attach to the encysted metacercariae for some time and shows lashing movements but soon it seperates from the body and remains motile for a short period before it disintegrates. The encystation occurs on the grass blades, stems, leaves of the aquatic plants or on the surface of water. They may also encyst on the walls of the container in which the infected snails are kept. The cercariae prefer to encyst on the smooth surface with yellow or green colour and before encystation, they may come above the surface of water. A cercariae after encystation form a thick cyst wall which consists of three layers the outer unpigmented layer of mucopoly-saccharide, the inner opaque and brownish layer which forms the cyst wall proper and is essentially lipoid in nature and the third innermost layer which is formed by a colourless fluid secreted by the cercariae. The cercariae after encystment show rotational movement inside the cyst for some time and this movement is more on the anterior than the posterior part of body. Thus the encysted metacercariae need a period of maturation before they form the infective stage. The availability of the metacercariae depend upon the environmental conditions.

The metacercariae excyst in the small intestine when they are ingested by the final host. In the digestive system of the definitive host the excystment is effected by ruminal fluid, pepsin, hydrochloric acid, trypsin and the bile salts. The excysted metacercariae attach to the mucosa of the small intestine and then slowly migrate to the definite location. Time from the infection to the first appearence of the eggs in the faeces of the host varies from species to species of the parasite.

EFFECTS OF PARASITISATION BY CERCARIAE ON SNAILS

In India the population of molluscs, the intermediate hosts of trematodes, generally builds up with the onset of monsoon when the rain water fills the various tanks and ditches and there is a rush of water in various rivers. However, the population of snails in a tank or in a river depends upon the ecological conditions. The percentage of infection in snails also depends upon the presence of infected final hosts and the intensity of infection in them. It is also believed that snails at certain ages are more susceptible to infection. Parasitisation by the larval

trematodes affect the behaviour and longevity of the snail. The activity and the longivity of an infected snail depends upon the intensity of infection, the parts infected and degree of damage caused by the infected larvae. The main seat of infection in molluscan hosts are the liver, pulmonary chamber, gills and gonads. In certain cases the shells of the infected snails are brittle. Generally the longevity of the infected snails are shorter than those of uninfected ones. It is well known that the rate of mortality of the infected snails is very high. During the studies of the life histories of certain amphistomes of domesticated animals high mortality among the infected snails under laboratory conditions was recorded by the author (Mukherjee, 1966) and in many cases the snails died before shedding the cercariae. Certain species of snails act as intermediate hosts for a number of trematode species whereas some others serve as intermediate host for a specific trematode species, while a few others are practically immune to their infection.

As a rule a single snail at a time is parasitised by a single species of trematode larvae but occasionally a snail may be parasitised by two trematode larvae and in such case the infected snail sheds the cercariae of both the trematodes. This type of infection is known as double infections. Usually those snails are involved in double infections which act as intermediate hosts of a number of trematodes.

CERCARIAE IN GENERAL

As stated earlier that it may not be possible to correlate the cercariae with their adults but they can be placed in the families on the basis of their characters. Some of the characters such as the nervous, excretory, digestive, genital systems, etc., are the characters that are common to both cercaria and adult whereas the characters like tail, body pigment, cystogenous cells, stylet, eye spots, penetrating glands, etc., are exclusively the cercarial characters. The cercariae are so highly specialised and variable in characters that it may not be possible to mention all the characters of all the groups here. However, some of the characters of different groups of cercariae have been given earlier. And attempt has been made here to mention some of the general characters that are commonly found in most of the cercariae.

The cercaria is generally provided with a body and a tail. The body of distome cercaria is provided with oral and ventral suckers. The oral sucker may be terminal or subterminal but the ventral sucker is variously placed. In majority of the cases the ventral sucker is located in middle of the body whereas in some cases it is shifted to the posterior end and form a suctorial disc or acetabulum. The suctorial disc may be strongly or poorly developed. In amphistome cercariae the acetabulum is very

strongly developed. The cercaria used the oral sucker for attachment whereas the ventral sucker or the acetabulum gives anchorage to the cercaria. A larva can crawl with the help of these two suckers. However, in some cases the oral sucker acts as a penetrating organ. In some larva the oral sucker is provided with distinct or rudimentary oral pouches. In monostome no ventral sucker or acetabulum is found in the cercaria but in some cases posterior pockets are present which may function as locomotor organs. The body of the cercaria is either smooth, provided with dermal glands or with spines. Spines when present are distributed throughout the body or restricted to some parts or organs of the body. Some of the cercariae are also provided with stylets at the anterior end. The arrangement, distribution and number of spines and stylets have great systematic value.

The body pigment of the cercaria when present is either distributed throughout the body or restricted to some parts of it and in cases it may be massed into definite lines. The body pigment may be brown or black in colour. In some cases the cercariae are provided with a pair of pigmented eye spots. The eye spots may be conical or irregular in shape and may or may not be provided with lenses. Some cercariae beside the eye spots are also provided with a condensed pigment spot over the brain mass and thus form a median eye.

Most of the cercariae contain cystogenous cells which are numerous and, contain oval or rounded cystogenous granules. These cells are situated beneath the integument and they may be large or small in size. The cystogenous granules are indifferent to dyes. These granules can dissolved in strong acids or bases. The secretion of these glands form the cyst of the cercariae. The method of encystment differs in different species. In some cases the cercariae encyst quickly after they are freed whereas in others there is a considerable lapse of time between their liberation and the formation of cysts. The cyst provides necessary protection to the cercaria to overcome the adverse conditions.

The phenomenon of encystment has been studied and described in detail by many workers. During the process of encystment the tail is either shaken off or remains attach with the body of the cercaria for a considerable period and shows lashing movements from side to side when finally it detaches from the body and disintigrate. Some cercariae does not form any cyst but enter the body of the host directly. A cercaria may or may not be provided with the salivary gland cells. When present the cells are few to many in numbers and contain granular protoplasma, nuclei and ducts and open into the penetrating organs. These cercariae with the help of the secretion of the cells and penetrating organs enter into the host body.

The pharynx when present is situated behind the oral sucker. In some cases it is rudimentary organ whereas in others it is well developed. The prepharynx may be present or absent and when present it may be short or long. The pharynx is followed by oesophagus. This structure may be present or absent in a cercaria and when present it may be long and well developed or may be short and poorly developed. Mostly the digestive system is triclad in character. The oesophagus may or may not bifurcate into two caeca. The oesophagus may be straight or curved and is provided with an oesophageal bulb at its bifurcation in some cercariae. In some cercariae the gut may be absent whereas in others it may be rhabdocoel type and still others the caeca may be short or long or may vary in their relative length.

The excretory system is the most delicate and important system in a cercaria. Many workers have studied the development of the excretory system in different species. The excretory system of a cercaria can be studied in detail only in the living forms and in the preserved forms it is impossible to trace out the whole of the excretory system. The excretory system mainly consists of main and subsidiary branches, flame cells, excretory bladder, excretory pore, etc. The excretory system of cercariae differ in their main and subsidiary branches ; number, arrangement and distribution of the flame cells ; size, shape, structure and opening of the excretory bladder. Based on these variations, different names have been proposed to different types of excretory system. The excretory system plays an important role in the systematic of the cercariae. In some forms the excretory system may be provided with excretory granules. The tail may also provided with caudal excretory canal and flame cells. Sewell (1922) on the basis of the excretory system has tried to show the line of evolution and relationships of various groups.

The central nervous system of a cercaria consists of two masses of ganglion and the dorsal commissure. The commissure is broad and flat. From the ganglion originate the various trunks which further divides into the finer branches.

The genital system is represented by rudimentary reproductive organs. The testes, ovary, genital pore are represented by mass of granular cells whereas uterus, vasa efferentia, vas deferens, vitelline ducts and vitellaria are represented by rows of cells. The arrangement of the reproductive organs in cercaria agrees more or less with that of the adult parasite.

The body of the cercaria may be provided with a tail at its posterior end. This tail may be long and muscular or it may be short and stumpy. It arises as a median protuberance from posterior end of body. The tail is generally provided with circular and longitudinal muscles and

these muscles are usually very well developed. In some cases the tail or part of it is forked and formed fork tail or furcocercaria. Besides, the excretory system the tail may be provided with spines, glands, fins and fin rays. The tail helps the cercaria in swimming and it remains attach with the body till the cercaria forms a cyst or penetrate into the host body.

AMPHISTOME CERCARIAE

In the earlier publications Mukherjee and Chauhan (1967, 1972) have dealt the adult amphistomes recorded from India. The importance and

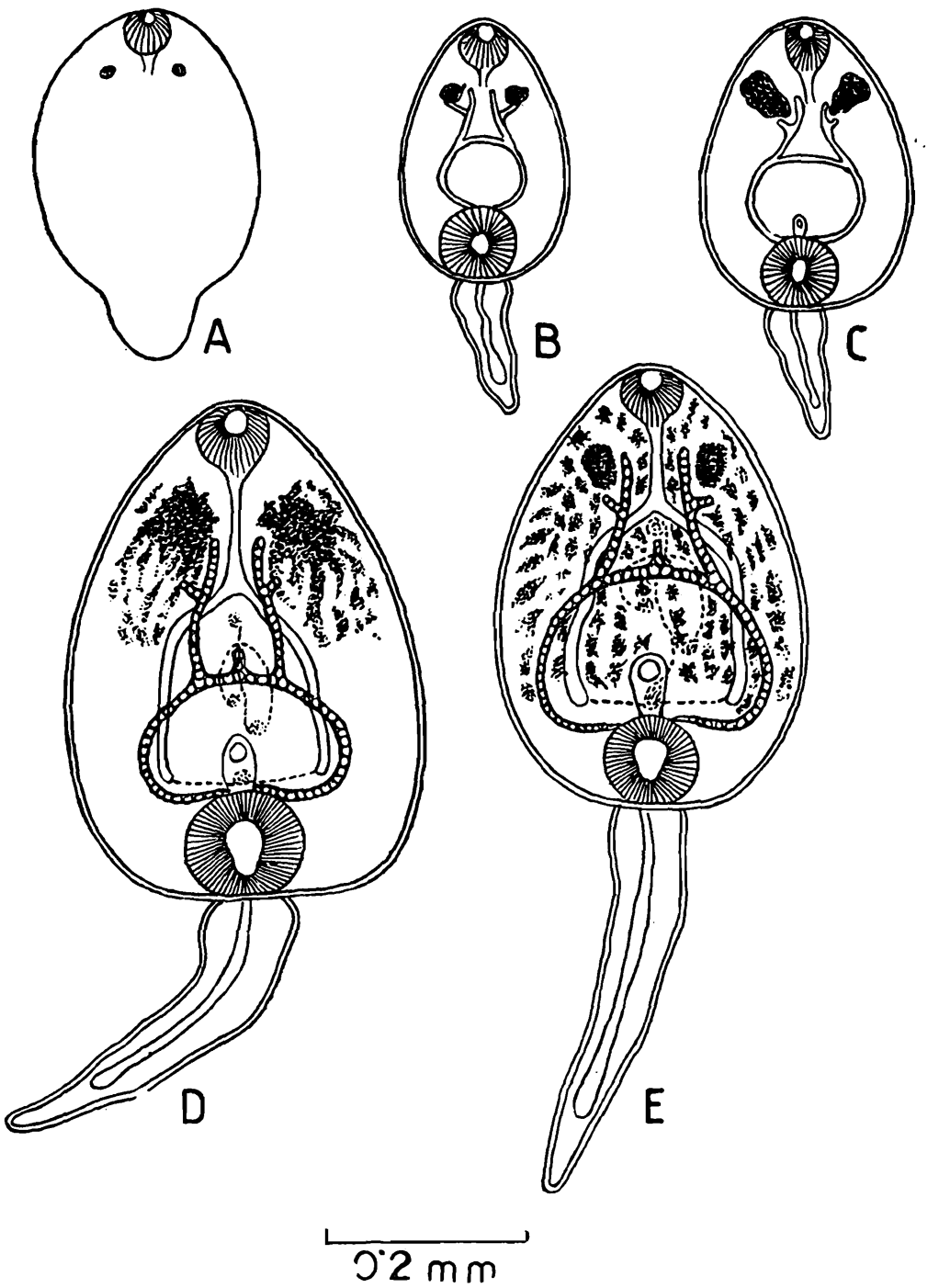


Fig. 2. (A-E) Developmental stages of amphistome cercaria (after Mukherjee, 1968).

the disease caused by these parasites to cattle, buffaloes, sheep and goats have been discussed in this part.

An amphistome cercaria is provided with a flat body and a powerful tail and can be distinguished from other cercariae by two suckers at either ends of the body. It is provided with cystogenous cells, eye spots, mouth, pharynx, oesophagus, caeca, excretory system and rudimentary reproductive organs. The body pigment and oesophageal bulb may be present or absent. The body pigment when present is variously arranged. The powerful muscular tail acts as a swimming organ and is provided with circular and longitudinal muscles and caudal excretory tube. At times it is also provided with spines. Cercaria emerges from redia in an immature stage and further development takes place inside the snail tissue (Fig. 2 A-E) and finally it emerges as a free swimming cercaria from the infected snail. The infection of amphistome cercaria in a snail shows seasonal fluctuation. Mukherjee (1966) studied the seasonal variations of amphistome cercarial infections in snails and demonstrated that the incidence shows variations from month to month.

Sewell (1922) was first to record the amphistome cercariae from India. In his monograph he has described four amphistome cercariae and grouped them into "Pigmentata" and "Diplocotylea" His classification is based on the characters of cercariae and rediae. Since then many amphistome cercariae have been reported and the life histories of some of the amphistomes of domesticated animals and man have been elucidated. With the increase of our knowledge on the amphistome cercariae it is difficult to place properly some of these larvae into the groups originally proposed by Sewell (1922). In the light of our present knowledge an attempt has been made in this part to reclassify the amphistome cercariae reported so far from India. The definitions of the two groups proposed by Sewell have been redefined, and four new groups "Indica", "Neopigmentata", "Pseudodiplocotylea" and "Neodiplocotylea" have been proposed to accommodate the different amphistome larvae. Key to each step and brief diagnosis of each cercaria have also been provided in this part.

Amphistome cercariae reported so far from this country fall into the groups "Pigmentata", "Diplocotylea", "Indica", "Neopigmentata" and "Neodiplocotylea" According to the classification proposed here the cercariae belonging to "Pseudodiplocotylea" group are characterised by the presence of locomotor appendages only in immature rediae. The cercariae of this category have not been reported so far from India as such have not been incorporated here. The main characters of all the groups on the basis of which they are classified have been incorporated in the key.

Some of the larvae are so inadequately described that it is not

possible to place them properly in any of the group proposed here. For example, two cercariae reported briefly, in form of abstract, by Peter (1958) have not been included here as they are not fully described. Kumar, Dutt and Jain (1968) were unable to trace the redia of *Cercaria helicorbis* reported by them. This cercaria has tentatively been placed in the Diplocotylea group till the redia is known. Singh (1970) while describing the life history of a new genus and a new species of amphistome parasite, *Srivastavaia indica*, found that *Indoplanorbis exustus* acts as its intermediate host. No comparison of its larva with any other known amphistome cercaria was made by him. This larva agrees in morphological details with *Cercaria lewerti* described by the same author and from the same host in the year 1957. So *Cercaria lewerti* is considered as the larva of *S. indica* and therefore, *S. indica* is treated as a synonym of *S. lewerti* (Singh, 1957) n. comb. Jain, Gupta and Sharma (1971) reported a cercaria from *Bulimus pulchellus* which they purported to be identical with *Cercariae indicae XXXII* Sewell, 1922. The cercaria described by them not only differs in the snail host that was recorded by Sewell but it differs morphologically and in certain body measurements with that of the description given by Sewell. It resembles much with cercaria of *Ceylonocotyle scoliocoelium* and whatever minor differences that have been noted with this cercaria are considered to be intraspecific variations. So the cercaria described by them is considered here as synonym of cercaria of *Ceylonocotyle scoliocoelium*. *Cercaria onkari* Jain, 1972 and *Cercaria chandrapali* Bansal and Jain, 1976 resemble *Cercaria mathurpurensis* Mukherjee, 1962, in all diagnostic characters such as the excretory system, distribution of body pigment, reproductive system, etc., as such they are considered as synonym of *C. mathurapurensis*. Anantaraman and Balasubramaniam (1949) were of the opinion that cercaria of *Gastrodiscus secundus* described by Peter and Mudaliar (1948) was the same as *Cercaria fraseri* described by Buckley (1939). The present author shares the opinion expressed by these two authors. Remarks of the other cercariae have been included along with their description.

Astrick marks against the name in the text indicate the authors who have described the life histories of the parasites. Unless otherwise stated all measurements are in millimeters.

MATERIAL AND METHODS

For study of larval trematodes infecting the aquatic snails it is necessary that the molluscs should be collected from all possible sources and washed thoroughly in running tap water, sorted, counted and then tubed separately in specimen tubes containing little of clean water. It

is necessary to examine them soon after collection. They should be exposed to sun light or against a glowing electric bulb and should be examined periodically for the discharge of cercariae. The snails which are found positive for cercarial infections should be separated and maintained in beakers, glass jars, small enamel basins or earthen pots with sufficient food and clean water. The water of the container should be changed daily. A detail record of the localities from where the snails were collected with dates, types and species of cercarial infections should be maintained.

The cercariae shed by the infected snails should be studied in alive condition after staining. The pattern of excretory system digestive system, body pigments, cystogenous cells, structure of the eye spots, etc., can be studied after staining them with suitable intra vitam stains like neutral red, brilliant cresyl blue, janus green, trypan blue, methylene blue, nile blue, gentian violet, etc. The arrangement of the genital rudiments, collar spines, muscular system, etc., can be studied after staining them with various stains like, acetic alum carmine, borax carmine, haematoxyline, etc. A better result can be obtained if a cercaria is flattened a little under the pressure of a cover slip before it is fixed in some fixative like hot Bouin's solution or hot 70% alcohol. The various developmental stages of cercaria, sporocyst and redia can be obtained by dissecting out the snail.

The study of the living cercaria offers details of its various developmental stages within the snail host, mode of locomotion, distribution of body pigments, excretory system and methods of encystment. The details of the excretory system of a cercaria can be best seen in a living material only as its finer structures such as flame cells, capillaries and excretory granules collapse after the death of the cercaria. Mukherjee (1980) discussed in detail the methods of collection and study of larval trematodes.

CLASSIFICATION OF AMPHISTOME CERCARIAE

As stated earlier the amphistome cercariae are much like that of the adults. The life histories of some of the amphistomes that are found in India have been elucidated. Where the life histories have been worked out it is easy to relate the cercariae with that of the adults. With the increase of our knowledge on the life histories of these parasites it will be possible in future to relate more and more the cercariae known to us with their adults. A cercaria can easily be placed in the family and even in the genus if the adult characters are present in it. For example on the basis of digestive, excretory and reproductive systems an amphistome cercaria can be placed in the family and in some cases even in the genus to which its adult belongs.

As mentioned earlier many of the structures that are developed in the cercariae may not be carried over to the adult forms and these characters are developed to suit the cercarial life and are purely larval characters. These characters are often used in classification of larval trematodes.

In this part the characters of the rediae and cercariae of the amphistomes that are reported so far from India are used to classify them. Such characters as presence or absence of locomotor appendages in redia ; presence or absence of second generation of redia ; presence or absence of body pigment and their distribution ; presence or absence of spines on the tail ; shape and structure of eye spots ; pattern of excretory, digestive and reproductive systems ; etc., in cercariae are used here to group the different amphistome cercariae,

Key to Groups

1.	Cercaria with oral diverticula	...	2.
	Cercaria without oral diverticula	...	5.
2.	Transverse excretory duct in cercaria present	...	*Indica.*
	Transverse excretory duct in cercaria absent	...	3.
3.	Locomotor appendages in redia present	...	4.
	Locomotor appendages in redia absent	...	*Neodiplocotylea.*
4.	Locomotor appendages in immature and mature redia present	...	*Diplocotylea.*
	Locomotor appendages present only in immature redia and mature redia without locomotor appendages	...	*Pseudodiplocotylea.*
5.	Transverse excretory duct in cercaria present	...	*Pigmentata.*
	Transverse excretory duct in cercaria absent	...	*Neopigmentata.*

I PIGMENTATA GROUP

Diagnosis (emended) : Oral diverticula in cercaria absent ; transverse excretory duct between two main canals in cercaria present ; locomotor appendages in redia absent.

Key to Indian Species

1.	Cercaria with conical eye and with clear lens	...	2.
	Cercaria without conical eye and without distinct lens	...	13.
2.	Caudal spines present ...		Cercaria of *Srivastavaia lewerti.*
	Caudal spines absent	...	3.
3.	Oesophagus with bulb	...	4.
	Oesophagus without bulb	...	8.

4. Transverse duct forms loop with main excretory duct ... 5.
   Transverse duct does not form loop with main excretory duct ... 6.
5. Main excretory duct with one lateral diverticulum ... Cercaria of *Ceylonocotyle scoliocoelium.*
   Main excretory duct with two lateral diverticula ... 7.
6. Transverse duct with median diverticulum ... Cercaria of *Cotylophoron cotylophorum*
   Transverse duct without median diverticulum ... *C. indicae XXXII.*
7. Main excretory ducts with three bends in the region of the caeca ... Cercaria of *Ceylonocotyle dicranocoelium*
   Main excretory duct with one bend in the region ... *C. kareillensis.*
8. Transverse duct with median duct ... 9.
   Transverse duct without median duct ... 12.
9. Main excretory duct with anterior lateral duct ... 10.
   Main excretory duct without anterior lateral duct ... Cercaria of *Fischoederius elongatus.*
10. Body pigment stellate shade ... Cercaria of *Cotylophoron indicum.*
    Body pigment without stellate shape ... 11.
11. Testes slightly diagonally tandem and distance between testes and ovary less ... *C. chauhani*
    Testes diagonally tandem and distance testes and ovary more ... Cercaria of *Gigantocotyle explanatum.*
12. Testes symmetrical, close and on two sides of ovary ... Cercaria of *Gastrothylax crumenifer.*
13. Anterior median diverticulum of transverse excretory canal distinct and not forming an inverted 'Y' and without second generation of redia. ... *C. indoplanorbis.*
    Anterior median diverticulum of transverse excretory canal not distinct and forming an inverted 'Y' and second generation of radia present ... *C. bhaleraoi.*

1. **Cercaria bhaleraoi** Mukherjee, 1960

(Fig. 3. A & B)

1960. *Cercaria bhaleraoi :* Mukherjee, *Proc. Indian Sci. Cong.*, 47 : 439.

Diagnosis : Body pigment in form of small dots distributed all over body, body measures 0.365-0.765 × 0.226-0.417 ; tail measures 0.278-0.469 × 0.034-0.086 ; eye spots in form of black patches ; oral sucker measures

0.038-0.057 × 0.038-0.057 ; acetabulum measures 0.076-0.130 × 0.069-0.107 ; oesophagus measures 0.038-0.115 in length ; caeca slightly convoluted ; main excretory ducts wlth small lateral diverticula, transverse duct with short median diverticulum, forms an inverted 'Y' with transverse duct, excretory granules in groups ; rudimentary reproductive organs represented by genital pore, ovary, diagonally tandem testes, uterus, vasaefferentia, vasdeferens, yolk glands and ducts.

Redia with two generations of rediae ; first generation redia measures

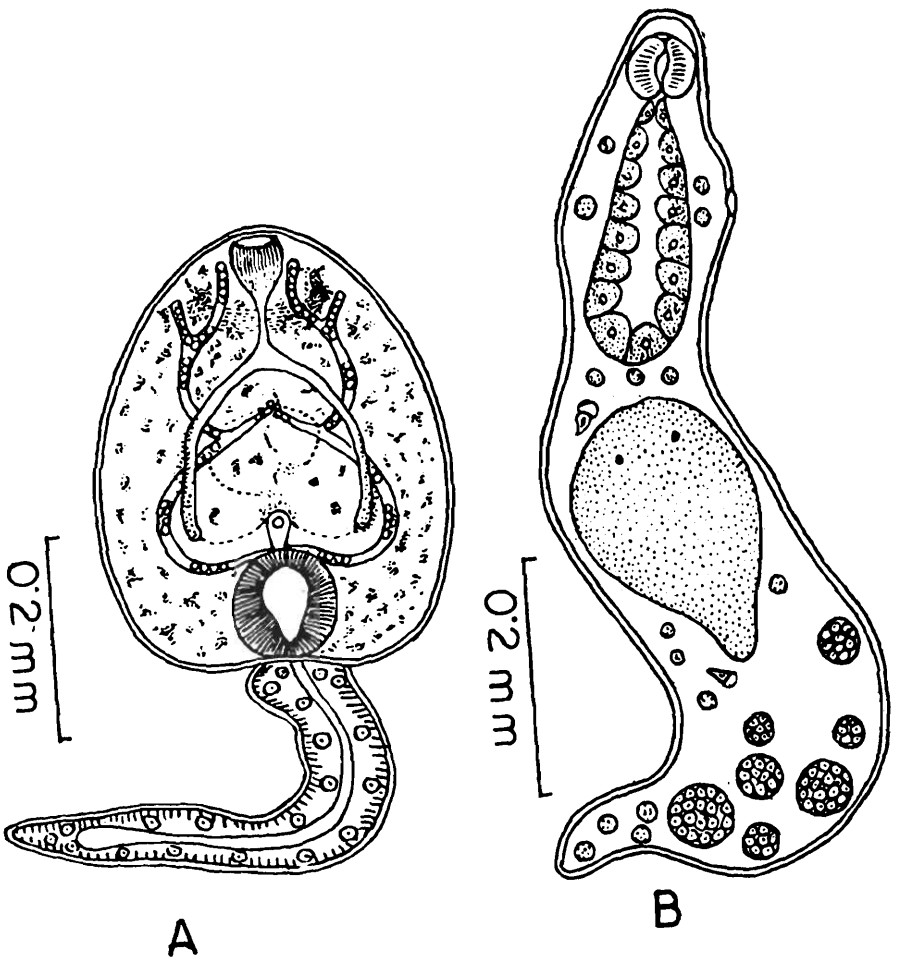


Fig. 3A. *Cercaria bhaleraoi* Mukherjee, 1960 (after Mukherjee, 1960).
B. Redia of *C. bhaleraoi* Mukherjee, 1960 (After Mukherjee, 1960).

0.695-1.04 × 0.121-0.156 ; second generation of redia measures 0.921-1.32 × 0.139-0.173 ; gut lined with large cells ; three pairs of flame cells present.

Metacercaria measures 0.365-0.434 in diameter ; cyst wall measures 0.034-0.052 in thickness.

Snail host : *Indoplanorbis exustus*

Locality : Bareilly

Life history of *Ceylonocotyle dicranocoelium* (Fischoeder, 1901) Nasmark, 1937.

Egg : The eggs are light grey in colour, oval in shape and 0.137-0.150 × 0.074-0.085 in size. The anterior end of the egg is narrow than the posterior and at the posterior end the egg shell has a small asymmetrical thickening. The ovum of the freshly voided egg shows early segmintation. The operculum is 0.025 in diameter.

Miracidium : The miracidia hatch out from the eggs in 9 to 10 days in the months of May and June, 12 days in August and 14 days in September. There was not much change in the ovum during the first three days of development. The ovum on the fourth day of development measures 0.025-0.034 × 0.024-0.032. On the seventh day the ovum measures 0.058-0.074 × 0.026-0.052. On the tenth day it measures 0.087-0.119 × 0.041-0.049. The embryo grows rapidly from the eleventh to thirteenth day of development. On the thirteenth day it measures 0.122-0.149 × 0.043-0.060. At this stage most of the body structures of the miracidium are developed. The miracidium is fully developed on the fourteenth day of development. The posterior portion of the fully developed miracidium is bent inside within the egg due to its greater length. The miracidium makes continuous antero-posterior movement inside the egg. The miracidium emerges by throwing open the operculum. The miracidium is pyriform in shape and measures 0.114-0.140 × 0.041-0.050. The epithelial cells are twenty in numbers and arranged in four transverse tiers. They are arranged in the ratio of 6:8:4:2=20. The average length of the first, second, third and fourth tiers of cells is 0.022, 0.044, 0.034 and 0.021 respectively. The shape of these cells is the same as found in other amphistome miracidia. These cells are covered with cilia. The body is provided with papillae, flask-shaped gut, two pairs of penetrating glands which are lying on either side of the gut, central nerve mass, a pair of flame cells with their ducts and germinal cells. The miracidium swims actively in water for six to eight hours. Its activity gradually slows down with the time and it settles down to the bottom of the container before death.

Sporocyst : The young sporocysts are formed in the tissue surrounding the intestine, digestive gland or in the mantle tissue. The young sporocysts measure 0.10-0.11 × 0.057-0.060 and are smooth and rounded in shape. In the central cavity of the sporocyst 4 to 9 germinal cells are present. The excretory system is represented by a pair of flame cells with their ducts. The body of the sporocyst exhibits slow movements of contraction and expansion. The sporocyst mature in the liver of the snail host in 8 to 10 days after infection. The mature sporocyst measures 0.170-0.178×0.057-0.061. The body wall of the sporocyst varied in thickness and is light greyish in colour. Anterior half of the body cavity of

the sporocyst is occupied by the rediae whereas the posterior half is occupied by the germ balls.

Redia : The young rediae emerge from the sporocyst after 12 days from the date of infection of snails by miracidia. The young redia measures 0.33-0.45 × 0.07 All the structures of a mature redia are present in a young redia except the birth pore. The young redia contains germ balls of various sizes and possesses a well developed muscular pharynx, short oesophagus, gut and the excretory system. The rediae develep in the gonads, digestive gland or in the mantle tissue of the snail. The rediae are without locomotor appendages. The rediae containing the developing cercariae are found after 17th day of development of rediae after the infection with miracidia. Fully mature redia is 0.64 × 0.07 in size. The elongated redia is provided with thick cuticle which is transparent and slightly greyish in colour. The digestive system consists of well developed pharynx, small oesophagus and well developed gut. The salivary glands are situated on either side of the gut. The birth pore is situated at the level of the gut. The excretory system consists of three pairs of flame cells and duct. A redia contains a number of developing cercariae and germ balls. These immature cercariae develop further into the snail tissue after the liberation from the rediae.

2. Cercaria of **Ceylonocotyle dicranocoelium** Jain, 1977

(Fig. 4. A-C)

1977. Cercaria of *Ceylonocotyle dicranocoelium* : Jain, *Zool. Anz.*, 199 (3/4) : 286-300.

Diagnosis : Brown body pigment in patches distributed over entire body, pigment patches connected by means of fine strings ; body in fixed condition measures 0.613-0.68 × 0.40-0.43 ; tail in fixed condition measures 0.60-0.82 × 0.098-0.120 ; eye spots conical, cone of eye measures 0.045-0.052 × 0.027-0.035 ; oral sucker measures 0.112-0.118 × 0.077-0.088 ; thick mascular oesophagus measures 0.116, oesophagus with distinct oesophageal bulb, the bulb measures 0.06 × 0.04 ; caeca follow a straight course, terminate just in front of acetabulum ; acetabulum muscular, measures 0.071 × 0.092 in fixed condition, in living cercaria it measures 0.093-0.114 × 0.105-0.126 ; dumb-bell shaped nerve mass situated between two conical eyes ; excretory bladder in front of acetabulum, main excretory trunks forming a cone-like out growth and three bends which cover the caeca, main trunks connected by an arch shaped median cross-connection in middle of body near caecal bifurcation, median diverticulum absent, excretory trunks on each side after giving out small outward branch at level of eye spot runs anteriorly between the oesophagus and eye spot,

descending canals without refractile granules, caudal canal with small bladder at its posterior end ; rudimentary reproductive system represented by ovary, tandem testes, uterus, genital pore, vasaefferentia, vasdeferens, extra caecal vitelline glands.

Cercariae encyst on vegetations and walls of the container ; metacercaria spherical, measures 0.53-0.58 in diameter.

Snail host : *Bulimus pulchellus*

Locality : Bareilly.

Life history of *Ceylonocotyle scoliocoelium* (Fischoeder, 1904) Nasmark, 1937.

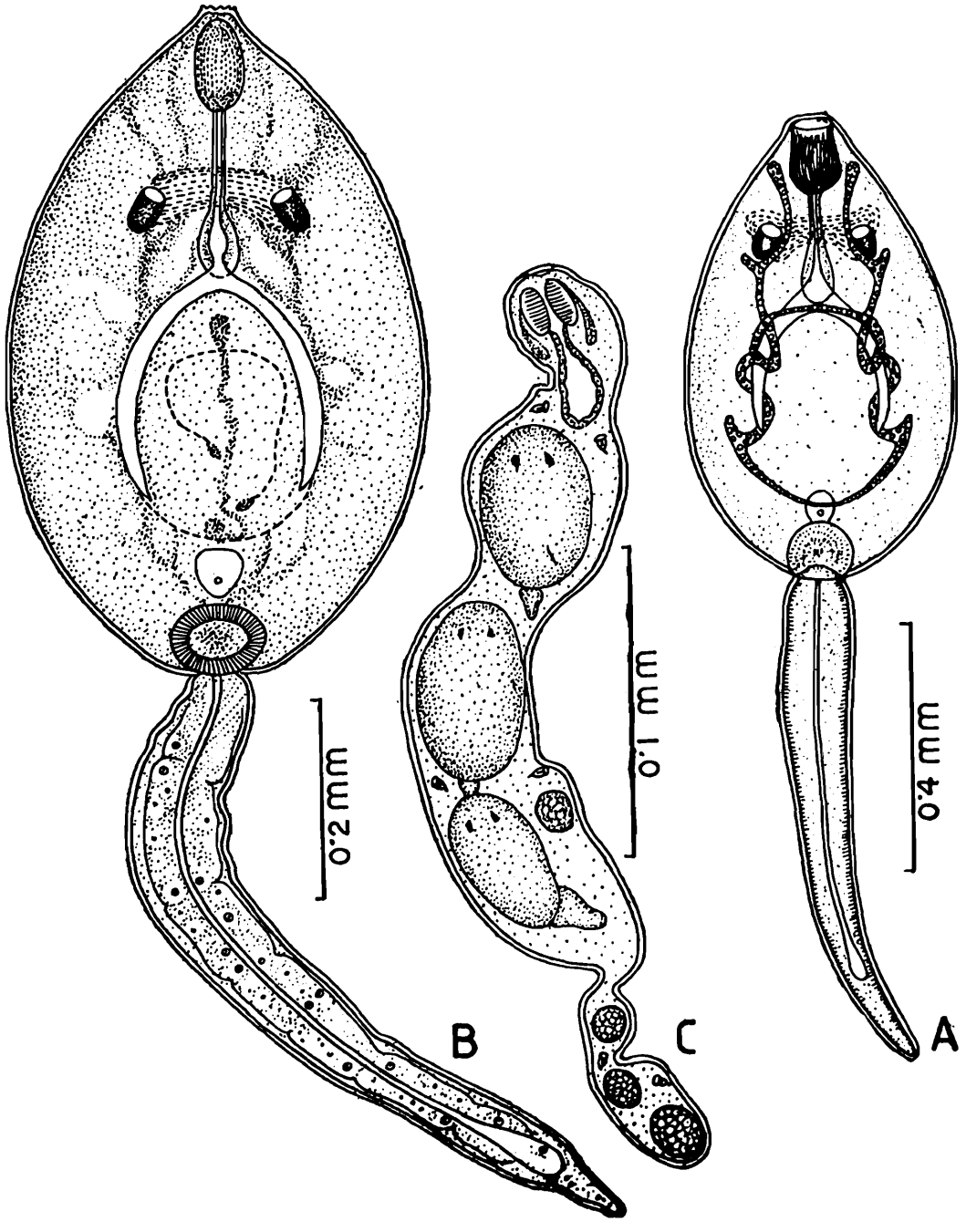


Fig. 4(A-C). Cercaria of *Ceylonocotyle dicranocoelium* (After Jain, 1977).

Egg : The egg of the parasite is yellowish brown in colour. Egg shell is uniform in thickness, except a slight asymmetrical thickening at the posterior end. The anterior narrower end is provided with a distinct operculum. The unsegmented ovum is surrounded by yolk cells when laid. Egg measures 0.122-0-174 × 0.069-0.087. Diameter of the operculum is 0.015-0.027. The ovum measures 0.015-0.031 in diameter when freshly laid.

Miracidium : In freshly laid egg the ovum is surrounded by vitelline cells. Ovum increases in size during the first three days from 0.011-0.023 × 0.011-0.023 to 0.035-0.073 × 0.026-0.042. Size of the developing embryo continues to increase from three to seven days. Embryo at end of seventh day measures 0.046-0.062 × 0.034-0.053 and the thickening of the walls of the embryo indicates the development of epidermal cells. Vitelline mass starts to break down to form large cells which fill a good portion of the egg. Embryo increases in size between seventh to tenth day. It measures 0.053-0.134 × 0.046-0.057 at the end of the tenth day. The epidermal cells, body cilia, gut and apical papilla become quite distinct on the tenth day of development of the embryo. The larva shows frequent body movements and during the movement the miracidium hits the base of the operculum with its apical papilla. Fully developed miracidium is pushed to one side of the egg and lies closely applied to inner wall of the egg shell. At this stage large almost exhausted vitelline cells are located between miracidium and the inner wall of egg shell and due to large size of the miracidium its posterior end is tugged inside. Fully developed miracidium shows frequent anterio-posterior movement. The time required by miracidium to hatch is influenced by temperature. At laboratory temperature the miracidium takes 11 to 12 days to hatch, except during severe winter months when it takes 18 to 20 days. It takes only 9 to 13 days to hatch when the eggs are kept at 32°C to 35°C in an incubator. At high temperature during May and June the number of emergence of miracidia decrease to a great extent. The miracidium generally removes the operculum completely out of the egg in the process of liberation but at times it remains attach to one end of the egg shell. Miracidium remains active for 7 to 9 hours at laboratory temperature in summer months but in winter month it remains active even upto 20 hours. The larva which is postive phototropic usally swims in straight lines and also shows vertical and horizontal movents. In active stage it appears to be long and narrow but it also changes its shape rapidly while swimming. The miracidium shows greatest width at the anterior fourth of body in active stage. In fixed condition the miracidium measures 0.104-0.139 × 0.052-0.069. Epithelial cells, twenty in numbers, are arranged in four transverse tiers. First tier consists of 6 triangular cells

which measures 0.023-0.038 in length. Second tier of 8 cells are longer than broader and measures 0.038-0.065 in length. Four cells of the third tier are also rectangular in shape like those of the second tier but they are shorter than the cells of the second tier. These cells measures 0.035-0.054 in length. Two cells of the fourth tier cover the postsrior blunt end of miracidium and are triangular in shape and measure 0 023-0.038 in length. The epithelial cells are arranged in the ratio of 6:8:4:2 20. The body of the miracidium is covered with cilia. The miracidium is provided with a flask shaped gut, a pair of penetrating gland, rounded, nerve mass, number of papillae, excretory system consists of two flame cells, germ cells and germ balls.

Sporocyst : Mature sporocyst is an elongated body and shows contraction and expansion after a short period of resting. The thin outer cuticle which forms the wall of the sporocyst is transparent. The two ends of the sporocyst are rounded and the body contains germ balls and rediae. The excretory system is similar to that of the miracidium. In normal condition the sporocyst measures 0.173 x 0.053 and in contracted condition it measures 0.105 x 0.076.

Redia : Two ends of the redia are rounded and the posterior blunt end tapers gradually. Anterior end is broader than posterior and is provided with five to six papillae. The redia is also provided with mouth, pharynx, oesophagus, well developed gut, birth pore, excretory system, germ balls and developing cercariae. Immature redia measures 0,37-0.829 x 0.123-0.194 and the mature redia measures 0.458-0.847 x 0.194-0.299. Pharynx in immature redia measures 0.023-0.038 x 0.026-0.038 and it measures 0.03-0.53 x 0.026-0.053 in mature redia. The mouth opening is surrounded by papillae and it is followed by a muscular pharynx. Three pairs of flame cells, anterior, median and posterior, are present. Rediae are set free from the sporocysts into the snail tissue after 11 to 12 days of infection in the month of October.

3. Cercaria of **Ceylonocotyle scoliocoelium** Mukherjee, 1960*

(= *Cercaria bulimusi* Peter and Srivastava, 1955)

(*Cercariae Indicae XXXII* Jain and Sharma, 1971)

(Fig. 5. A & B)

1955. *Cercaria bulimusi* : Peter & Srivastava, *Proc. Indian Sci. Cong.*, 42 : 353.

1960. Cercaria of *Ceylonocotyle scoliocoelium* : Mukherjee, *Proc. Indian Sci. Cong.*, 47 : 348-349.

1971. Redescription of *Carcariae indicae XXXII* Sewell, 1922 an amphistome cercaria from the snail *Bulimus Pulchellus* (Benson) : Jain, Gupta & Sharma, *Acta Parasit. Polon*, XIX (21) : 251-256.

1975. Cercaria of *Ceylonocotyle scoliocoelium* : Mukherjee *Dr. B. S. Chauhan Comm.*, vol., 251-266.

Diagnosis : Brown body pigment distributed uniformly over the whole body ; body in fixed condition measures 0.566-0.806 x 0.274-0.377 ; tail in fixed condition measures 0.360-0.651 x 0.069-0.103 ; eye spots conical, cone of eye measures 0.019-0.034 x 0.019-0.03 ; oral sucker measures

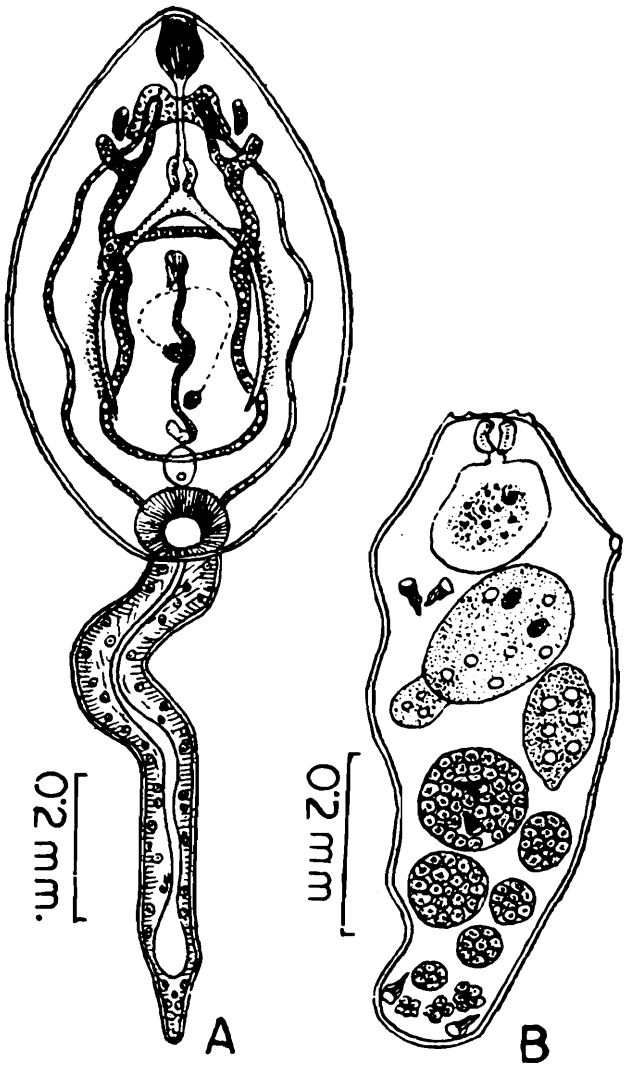


Fig. 5A. Cercaria of *Ceylonocotyle scoliocoelium* (After Peter and Srivastava, 1960).
B. Redia of *C. scoliocoelium* (After Peter and Srivastava, 1960).

0.076-0.113 x 0.038-0.065 ; narrow oesophagus measures 0.115-0.211 in length, oesophagus with distinct muscular oesophageal bulb ; caeca terminate blindly anterior to acetabulum ; acetabulum measures 0.076-0.099 x 0.072-0.096 ; main excretory trunks give off small blind lateral diverticula near the eye spots. Cross excretory canal arched, forms loop with main excretory canals on either side, loops may or may not enclose caeca, median diverticulum absent, caudal excretory duct terminates blindly in form of a small bladder ; rudimentary reproductive system represented by

ovary, tandem testes, genital pore at post bifurcal zone of oesophagus, uterus, vasaefferentia vasdeferens, vitellaria in extraceacal field.

Cercariae encyst on grass blades, plant leaves and walls of the container ; metacercaria measures 0.282-0.352 in diameter. The cyst wall measures 0.017-0.052 in thickness.

Snail host : *Digoniostome pulchella (= Bithynia pulchella = Bulimus pulchellus)*

Locality : Bareilly.

4. **Cercaria chauhani** Pandey and Jain, 1971

(Fig. 6. A & B)

1971. *Cercaria chauhani* : Pandey & Jain, *Proc. Zool. Soc. Calcutta*, 24 : 29-32.

Diagnosis : Body pigment in form of small granules distributed all over body ; body measures 0.40-0.85 x 0.25-0.48 in living and 0.32-0.72 x 0.20-0.40 in fixed conditions ; tail measures 0.82-0.94 in living and 0.71-0.83 in fixed conditions ; eye-spot cone shaped ; oral sucker measures 0.04-0.05 x 0.04-0.06 in living and 0.03-0.04 x 0.03-0.05 in fixed conditions ; elongate pear shape gland present near oral sucker ; oesophagus elongate, measures 0.05-0.07 in fixed specimens ; caeca extend posteriorly upto level of acetabulum ; transverse excretory canal with small median diverticulum, anterolateral diverticulum of main excretory canal present, main excretory canal, transverse duct and lateral diverticula filled with excretory granules ; testes diagonally tandem, genital pore behind caecal bifurcation.

Redia measures 0.40-0.70 x 0.04-0.06 in living and 0.31-0.60 x 0.02-0.03 in fixed conditions ; pharynx measures 0.01-0.02 ; salivary glands present ; gut extends upto anterior fourth of body ; three pairs of flame cells present ; 4-7 germ balls and 1-2 developing cercariae present ; birth pore at level of pharynx.

Snail host : *Indoplanorbis exustus*

Locality : Lucknow.

5. Cercaria of **Cotylophoron cotylophorum** Srivastava, 1939*.

(Fig. 7A & B)

1939. Cercaria of *Cotylophoron cotylphorum* : Srivastava, *Indian J. Vet. Sci. Anim. Husb.*, 8 : 381-385.

1950. Cercaria of *Cotylophoron cotylphorum* : Sinha, *Indian J. Vet. Sci. Anim. Husb.*, 20 : 1-11.

Diagnosis : Circular muscle fibres around base of oesophagus febly developed ; caeca arch shape ; cross excretory duct present, main excretory ducts with antero-lateral diverticula.

Redia sausage shape ; measuring 0.28-0.72 x 0.14-0.16 ; mouth, pharynx, oesophagus, rhabdocoel gut, three pairs of flame cells present ; daughter redia present in some cases.

Metacercaria hemispherical in shape ; deep gray in colour.

Snail host : *Indoplanorbis exustus.*

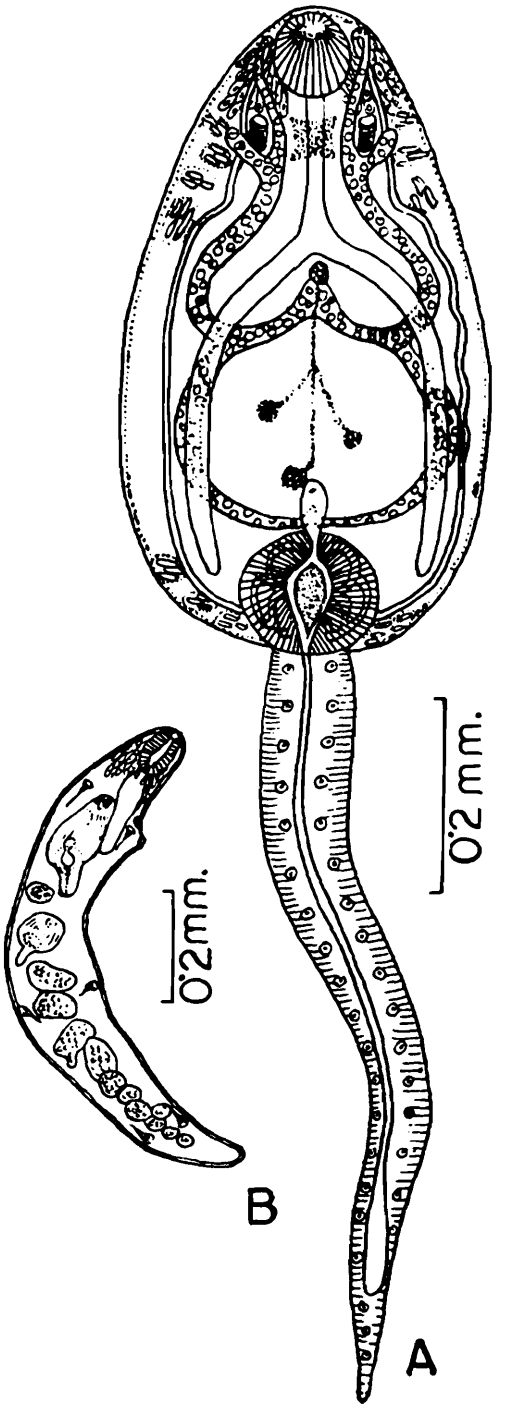


Fig. 6A. *Cercaria chauhani* Pandey and Jain, 1971 (After Pandey and Jain, 1971).
B. Redia of *Cercaria chauhani* Pandey and Jain, 1971
(After Pandey and Jain, 1971).

Remarks : The description of cercaria is so inadequate that it is difficult to differentiate it with *Cercariae indicae XXVI* Sewell, 1922. The cercaria resembles closely with *Cercaria indicae XXVI* insted of *Cercariae indicae XXIX* as mentioned by Srivastava (1939). Only further studies on the life history of *Cotylophoron cotylophorum* Stiles and Goldgerger, 1910 can established the identity of this cercaria. Sinha (1950) further worked out the life history of this parasite and described the cercaria, redia and metacercaria as follows :

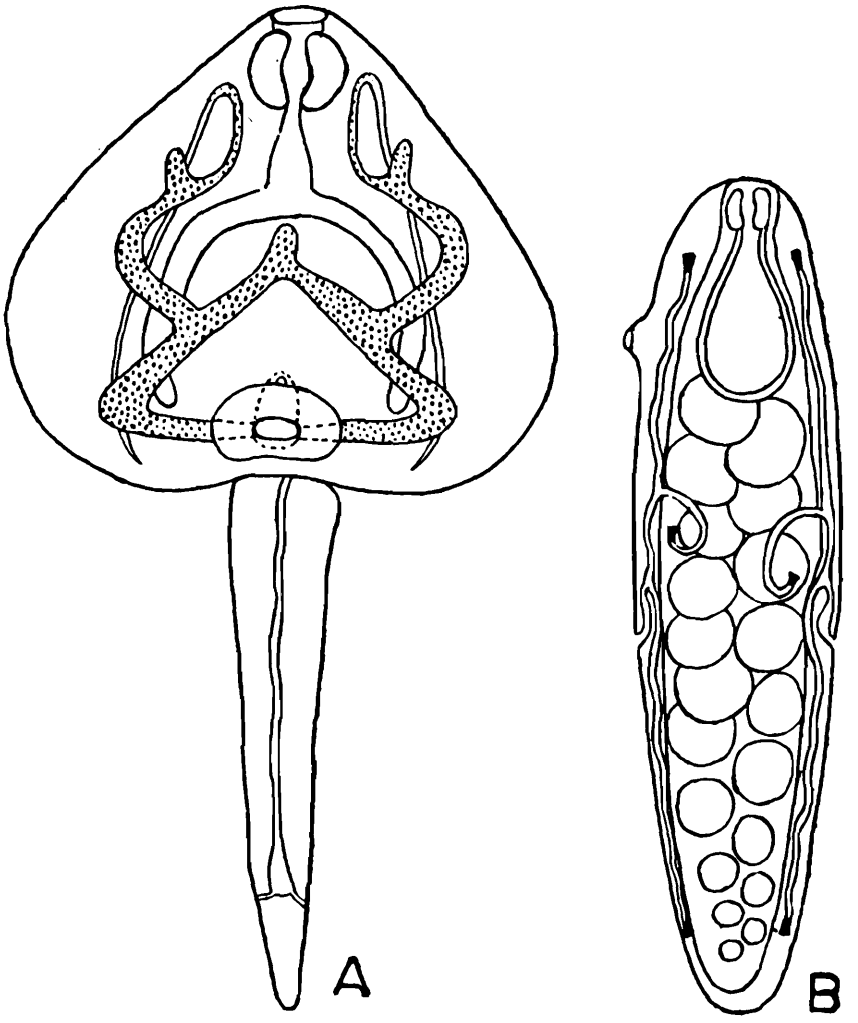


Fig. 7A. Cercaria of *Cotylophoron cotylophorum* (After Srivastava, 1939).
B. Redia of *Cotylophoron cotylophorum* (After Srivastava, 1939).

Entire body of cercaria particularly anterior third thickly pigmented ; body measures 0.45-0.47 in length and 0.14-0.15 in breadth in living condition, it measures 0.32-0.43 in length and 0.27-0.30 in breadth in fixed condition ; tail measures 0.61-0.67 in living condition and 0.46-0.51 in fixed condition ; eye spots conical, oral sucker oval, terminal ; acetabulum oval, broader than long ; oesophagus bifurcates behind eye spots ; caeca terminate in front of acetabulum ; excretory system consists of excretory vesicle, main ducts, transverse duct and median duct, excretory granules present, caudal excretory duct swells up to form a small bladder and

lateral ducts ; reproductive organs represented by two groups of cells, connected by a single cord of cells, posterior cell mass represents ovary and testes, anterior cell mass represents genital pore and genital sucker, cord represents uterus and vasdeferens.

Redia sausage shape ; measures 0.56-0.62 in length and 0.13-0.15 in breadth ; mouth, muscular pharynx, sac like gut presant ; excretory pore in middle of body ; three pairs of flame cells present with flame cell formula 2 (2+1). Redia contains 10-17 developing cercariae.

Metacercaria flat on ventral side and round above ; dorsal surface dome-shaped.

Host : *Indoplanorbis exustus*

Locality : Lucknow.

Life history of *Cotylophoron indicum* Stiles and Goldberger, 1910.

Egg : The oval shape egg is provided with an operculum on the narrower end and a small asymmetrical thickening on the broad posterior end. In the freshly laid egg the ovum is situated in the middle or a little anterior to it and the ovum is surrounded by lightly packed yolk cells. The egg measures 0.121-0.156 × 0.069-0.086 (0.146 × 0.075).

Miracidium : The size of the ovum when the egg is freshly laid is 0.015-0.023 × 0.015-0.023 with an average size of 0.019 × 0.019. At the end of the third day of development the ovum measures 0.019-0.061 × 0.019-0.042 with an average size of 0.039 × 0.033. The size of the embryo increases at the end of the third day and it increases greatly in size from three to seven days of development. The embryo at the end of the seventh day measures 0.038-0.108 × 0.031-0.054 with an average size of 0.056 × 0.039. At the end of the seventh day of development the apical papilla and the four pairs of epidermal plates are quite distinctly developed. The smallest and the largest embryos at the end of this period measure 0.038-0.038 and 0.107-0.049 respectively. Some of the embryos attain maxium size and most of the embryos attain the maximum breadth during the end of the seventh day. At the end of the tenth day the embryo measures 0.054-0.096 × 0.031-0.058 with an average size of 0.066 × 0.43. At the end of the tenth day the miracidium shows antero-posterior movement. From the tenth day the larva growing very fast at room temperature and the miracidium measures 0.065-0.135 × 0.038-0.061 with an average size of 0.104 × 0.049 at the end of the 12th day of development. The miracidium grows considerably in length than breadth during this period. The flask shaped gut, beating of the body cilia and the flame cells of the excretory system are quite aparent during this period. The vitelline cells decrease in number but increase

considerably in size and pushed the fully developed larva to one side of the egg. The miracidium emerges from the egg in a few minutes to several hours after it shows active movements within the egg. The apical papilla of the miracidium keeps on knocking continuously at the base of the operculum and finally throws it open. The miracidium hatches out at any time of the day but mostly it comes out in the morning when the container is put against a source of light for some time. During winter months the miracidium takes 17 to 20 days to hatch at laboratory temperature but it takes 10 to 15 days when put in the incubator at 32°C to 35°C. The free living miracidium is an active swimmer and swims in straight lines or in zig-zag course. It remains active for 6 to 7 hours after which the normal activity decreases considerably and it dies and disintegrates. The larva is positive phototrophic. The miracidium measures 0.121-0.191 × 0.065-0.086 with an average size of 0.159 × 0.071. The body is provided with papillae and the body is covered with 20 epithelial cells which are arranged in the four transverse tiers. The cells are arranged in the ratio of 6:8:4:2. The cells of the first, second, third and fourth tiers measure 0.033, 0.051, 0.039 and 0.028 in length respectively. The epithelial cells are provided wtth cilia. The conical flask shaped gut of the miracidium occupies the anterior fourth of the body length and it opens at the base of the apical papilla. A pair of small flask shaped penetrating glands is located on either side of the gut. The central nerve mass is situated at the base of the gut and appears as fibrous mass. The excretory system of the miracidium consists of two flame cells and the much coiled excretory tubes. The compactly arranged germ cells are extended from the middle to the posterior part of the body. The cells are mostly rounded in shape and each is provided with granular contents and a nucleus.

Sporocyst : The miracidium on entering in the intermediate snail host looses the cilia, gut, penetrating glands and papillae and changes into a sporocyst. The sporocyst retains the excretory system and germ cells of the miracidium. The mature sporocyst measures 0.102 × 0.066. The cuticle is thin and both the ends are rounded. The body cavity encloses the germ balls and the rediae. In the month of October the redia comes out of the sporocyst in 6 to 7 days time at room temperature. Further development of the redia takes place inside the snail tissue.

Redia : Usually one generation of redia is found but the first generation of redia may also contains second generation of rediae and at times it may contain both rediae and cercariae. The first generation of redia measures 0.834-0.956 × 0.191-0.208 with an average size of 0.895 × 0.199. The second generation of redia when present measures 0.313-0.347 × 0.069-0.086 with an average size of 0.33 × 0.078 while still inside the

mother redia. The size of the second generation of redia after emerging from the mother redia measures 0.834 × 0.226. The redia which contains both second generation of rediae and cercariae measures 0.747 × 0.208. The redia also contains pharynx, gut three pairs of flame cells and their ducts, birth pore and germ balls and germ cells.

6. Cercaria of **Cotylophoron indicum** Mukherjee, 1960*

(= *Cercariae indicae XXVI* Sewell 1922)

(Fig. 8. A & B)

1922. *Cercariae indicae XXVI* : Sewell, *Indian J. Med. Res.* (Supl.)., 10 : 69-74.

1960. Cercaria of *Cotylophoron indicum* : Mukherjee, *Proc. Indian Sci. Cong.*, 47 : 349.

1968. Studies on life history of *Cotylophoron indicum* Stile and Goldberger, 1910 an amphistomatous parasite of ruminats in India. Mukherjee, *J. Zool. Soc. India*, 20 (1&2) : 105-122.

Diagnosis : Body pigment diffuse with concentrated stellate markings of black pigments on dorsal side ; body measures 0.58 × 0.31 ; tail measures 0.702 × 0.105 ; eye spots conical ; oral sucker round, 0.079 in diameter ; acetabulum twice the size of oral sucker ; oesophagus 1/11th of body length which dilates a little near its bifurcation ; caeca long, wavy ; transverse excretory canal with antero-median canal, main excretory canals with anterolateral diverticula near the eye spots ; rudiments of genital organs represented by ovary, diagonally tandem testis, genital pore, uterus, vasaefferentia, vasdeferens.

Cercaria readily encysts on grass blades or on walls of continer ; metacercaria dome shape, measures 0.261-0.313 in diameter.

Snail host : *Indoplanorbis exustus*

Localities : Calcutta, Madras, Calicut, Sitapur, Bareilly.

Remarks : Chatterjee (1931) reported *Cercariae indicae XXVI* Sewell, 1922 from Rangoon and by feeding experiments with this cercaria he obtained the adults of *Paramphistomum* sp. Rao and Ayyar (1932) by feeding experiment of a cercaria which was similar to *Cercariae indicae XXVI* recovered few immature flukes which they identified as *Paramphistomum cervi* (Zeder, 1790) Fischoeder 1901. Pande (1935) believed that *Cercariae indicae XXVI* could possible be develop into *P. cervi.* Mudaliar (1945) pointed out the similarity of this larva with *Cotylophoron cotylophorum* (Fischoeder, 1901) Stiles and Goldbergen 1910 and this contention was supported by Bhalerao (1945) after studying the morphology of the

larva. Anantaraman and Balasubramaniam (1949) after infecting a calf and a piglet with a mixture of *Cercariae fraseri* Bucklay, 1939 and *Cercariae indicae XXVI* Sewell 1922 recovered *C. cotylophorum* from the infected calf. The experiment conducted by Mukherjee (1960) proved *Cercariae indicae XXVI* as the larval form of *Cotylophoron indicum* Stiles and Goldberger (1910).

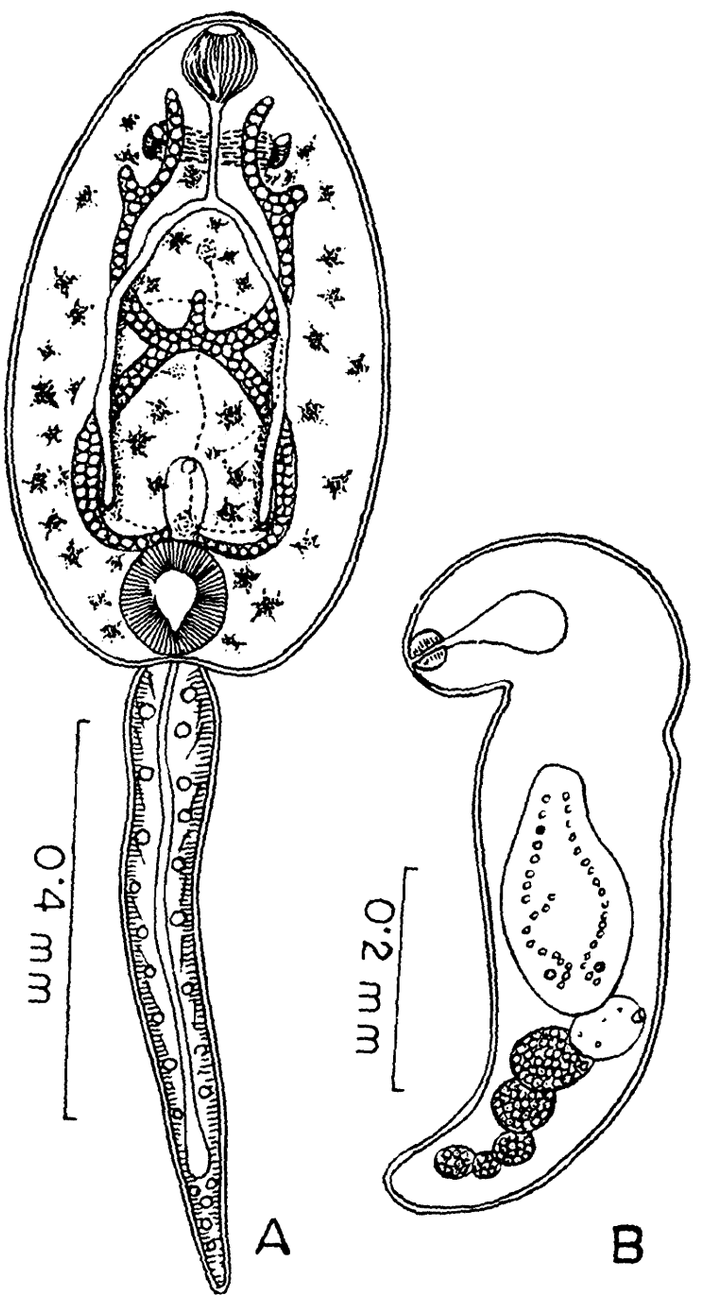


Fig. 8A. Cercaria of *Cotylophoron indicum* (After Mukherjee, 1960).

B. Redia of *Cotylophoron indicum* (After Mukherjee, 1960).

Life history of *Fischoederius elongatus* (Poirer, 1883) Stiles and Goldberger, 1910

Egg : The eggs are whitish in colour and oval in shape. The egg shells are uniform in thickness except at the posterior end which has a small asymmetrical thickening. The anterior end of each egg is provided with a distinct operculum. The eggs measure 0.128-0.160 × 0.064-0.096 with an average size of 0.139 × 0.081.

Miracidium : The freshly laid egg contains a large ovum which is usually located in the middle of the egg and is surrounded by yolk cells. The ovum reached to 8 to 16 cells stage when the egg is laid. The size of the ovum on the first day is 0.012-0.048 × 0.012-0.036 with an average size of 0.033 × 0.028. The second day the ovum measures 0.024-0.064 × 0.020-0.040 with an average size of 0.044 × 0.036. On the third day the ovum measures 0.044-0.072 × 0.040-0.060 with an average size of 0.060 × 0.047 and some of the embryos attain maximum breadth. On the fourth day the embryo measures 0.064-0.120 × 0.048-0.072 with an average size of 0.082 × 0.057. Some embryos show the thickening of the body on the fourth day of development and these thickening indicate the development of epithelial cells. The apical papilla develops during this period of development of the miracidium. Some of the embryos attain maximum size on the fifth day of development and they measure 0.100-0.132 × 0.116-0.120 with an average size of 0.120-0.060. By this time the epithelial cells, gut and apical papilla become quite distinct and the yolk cells are decreased in number. The body cilia also develop during this period of development and the miracidium shows regular body and gut movements. The embryo measures 0.112-0.168 × 0.056-0.068 with an average size of 0.140 × 0.061. At this stage the yolk cells decrease in number but they increase in size and remain closely pressed against the miracidium. The miracidium shows antero-posterior movement and hits the base of the operculum. The miracidium is fully developed on the seventh day and measures 0.128-0.172 × 0.050-0.068 with an average size of 0.155 × 0.062. The miracidium is now quite active and shows frequent body and ciliary movements and the germinal cells are well developed. The miracidium start hatching from the seventh day of development but the majority of the miracidia hatch out on the eighth day of development and almost all of them come out by the tenth day of development. The miracidia generally emerge in the morning and swim actively. They usually swim in straight lines and rotate their body along the long axis. They are positive phototropic and remain active from 12 to 14 hours under laboratory temperature. The body cilia of the miracidia beat rapidly while swimming and active larvae appear pyriform in shape. The greatest

width of the miracidium is noticed in the anterior fourth of the body. The miracidium measures 0.112-0.208 × 0.044-0.088 with an average size of 0.169 × 0.063 when killed. The anterior tip of the miracidium is provided with a conical apical papilla. Like the miracidium of other amphistomes the present larva is also provided with twenty epithelial cells which are arranged in four transverse rows. The first tier consists of six cells which cover the anterior part of the body of the larva. These cells measure 0.024-0.044(0.036) in length. The second tier consists of eight cells and these cells measure 0.040-0.064(0.053) in length. The third tier has four cells which are 0.032-0.056(0.044) in length. The fourth or the last tier consists of only two cells and these cells measure 0.028-0.044(0.034) in length. These four rows of cells are arranged in the ratio 6:8:4:2=20. The conical gut of the miracidium occupies the anterior part of body. The tapering neck of the gut opens at the base of the apical papilla. The gut is provided with two nuclei and is filled with granular liquid. Two pairs of penetrating glands are observed on either side of the gut. They also contain granular liquid and open at the base of the apical papilla. Each gland is provided with a nucleus. The nervous system consists of an oblong mass and is placed near the posterior end of the gut. The miracidium is also provided with a number of papillae. The excretory system consists of flame cells and ducts. The miracidium also contains the germ balls of different sizes.

7. Cercaria of **Fischoederius elongatus** Rao and Ayyar, 1932*

(=*Cercariae indicae XXIX* Sewell, 1922)

(Fig. 9)

1922. *Cercariae indicae XXIX* : Sewell, *Indian J. Med. Res. (Supl.)*., 10 : 74-78.

1932. Cercaria of *Fischoederius elongatus* : Rao and Ayyar, *Indian J. Vet. Sci. Anim. Husb.*, 2 : 402-405.

Diagnosis : Body pigmented ; body measures 0.252-0.770 × 0.154-0.308 ; tail measures 0.378-0.700 × 0.056-0.098 ; eye spots conical ; mouth opening papillonated ; oral sucker measures 0.09 × 0.06 ; acetabulum broader than long, measures 0.098 × 0.148 ; oesophagus 1/4th of body length ; caeca short terminate a little posterior to half of body-length, oesophagus and caeca contain rectangular granules ; main excretory canal with antero-median diverticulum ; rudimentary reproductive organs represented by ovary, testes diagonally tandom and placed on anterior and posterior to ovary, genital pore prebifurcal, uterus. vasaefferentia, vasdeferens.

Redia elongate in shape ; anterior end bluntly rounded ; containing

few developing cercariae or daughter rediae ; body measures 0.8×0.105 ; mouth small, terminal ; pharynx well developed, diameter of pharynx 0.053 ; narrow gut ; oval stomach ; mass of pyriform granular cells present ; three pairs of flame cells and suspended excretory granules present.

Metacercaria hemispherical in shape ; measures 0.3 in diameter ; cyst wall measures 0.02 in thickness.

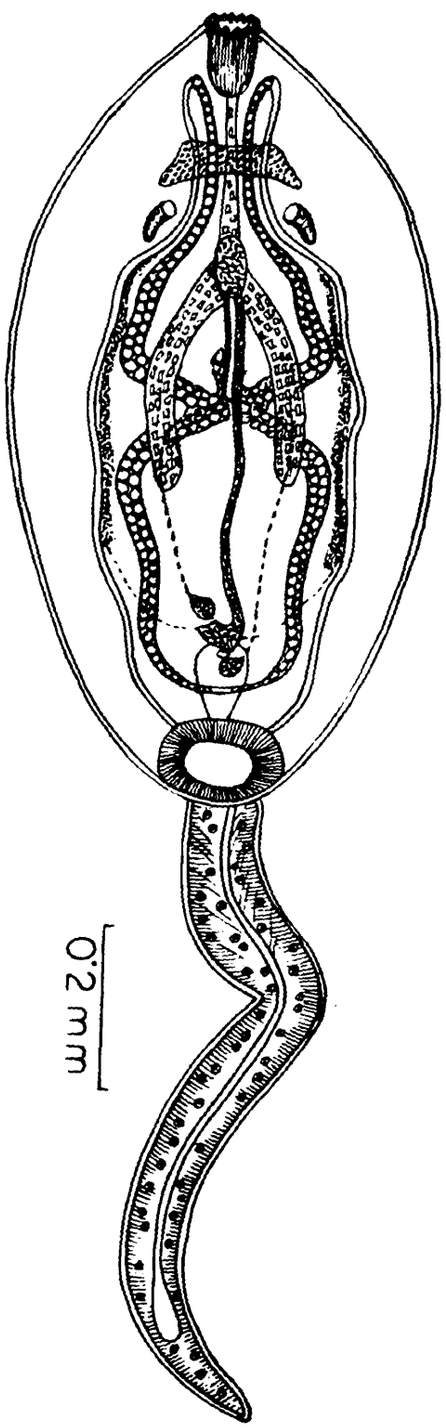


Fig. 9. Cercaria of *Fischoederius elongatus* (After Peter and Srivastava, 1960).

Snail hosts : *Lymnaea acuminata, L. luteola f. succinea, Gyraulus euphraticus.*

Localities : Calcutta, Malabar, Madras, Hydrabad; Bareilly.

Remarks : Vaidyanathan (1941) and Mukherjee (1966) by feeding experiments of the *Cercariae indicae XXIX* Sewell, 1922 confirmed the findings of Rao and Ayyar, 1932.

Life history of *Gastrothylax crumenifer* (Creplin, 1847)

Egg : The oval shape egg is uniform in appearance and is provided with an operculum at its narrower end. The broad posterior end is provided with an asymmetrical projection. The freshly laid egg measures 0.102-0.142 × 0.064-0.073 with an average size of 0.123 × 0.067. The freshly laid egg contains granular yolk cells and the ovum at various stages of developement. The ovum is situated in the middle or slightly anterior to the opercular end.

Miracidium : On the second day of development the embryo forms a mass of cells and on the third day the embryo takes the shape of an irregular mass of cells and the smallest embryo measures 0.032 × 0.03 while the largest embryo measures 0.045 × 0.037. On the fourth day of development the embryo assumes a shape of a compact mass of cells which is oval in shape and the ciliary epithelial layer of the body also develops. On the fourth day the smallest embryo measures 0.044 × 0.035 while the largest measures 0.058 × 0.041 and by this time the yolk cells surrounding the embryo divide further. On the fifth day the largest embryo measures 0.062 × 0.028. On the sixth day the largest embryo measures 0.082 × 0.039 while the smallest measures 0.054 × 0.038. The gut and the excretory system also develop by the sixth day of development. On the seventh day of development embryo shows the movement and the smallest embryo measures 0.06 × 0.043 while the largest measures 0.093 × 0.045. On the eighth day the embryo increases in size and the smallest measures 0.063 × 0.045 while the largest measures 0.098 × 0.045. The gut, nerve mass, excretory system and germ cells are quite distinct during the eighth day of development. By the ninth day the embryo is fully developed and the egg is fully occupied by the miracidium in length wise. The penetrating glands, germ cells and germ balls are fully developed. The fully developed miracidium measures 0.116 × 0.047 and shows frequent body movements and the miracidium comes out on the tenth day. The rate of development of the miracidium depends upon

temperature and light. The temperature from 85°F to 90°F is most suited for the development of the miracidium. The miracidium takes about one to three minutes to come out of the egg after pushing of the operculum. The miracidia generally emerge in large numbers during the early hours of the morning. Soon after the emergence the miracidia become very active. The miracidium remains active for four to six hours. The pyriform miracidium in fixed condition measures 0.108-0.146 $\times$ 0.033-0.036 with an average of 0.126 $\times$ 0.035. The ciliated epithelial cells, 20 in numbers, arrange in four transverse rows in the ratio of 6:8:4:2. The cells of the third tier are the broadest and the cells of the fourth tier are the smallest. Each cell is provided with a large, elongated rod-like nucleus placed at its posterior end and lying in transverse direction The gut of the miracidium is flask shaped with rounded nuclei and it measures 0.036-0.062 $\times$ 0.020-0.028. Two pairs of penetration glands are present. Each gland is elongated, uni-nucleate and the content is granuler in nature and opening to the base of the head papillae. The nervous system of the miracidium is an irregular mass of nervous tissue which is lying above the primitive gut. The germ balls are compact, oval and elongated mass of cells lying almost in the middle of the body. The germ ball measures 0.025-0.051 $\times$ 0.016-0.020. The germ cells are rounded with large rounded nuclei. The excretory system consists of a pair of flame cells with their ducts.

Sporocyst : The miracidium on entering into the snail host transforms into a sporocyst. After 48 hours of infection to the snail with miracidia the sporocyst measures 0.12 x 0.097 and the sporocyst increases in size during this period from five to seven hours of infection. The sporocyst shows slow movements of contraction and expansion. The eight days old sporocyst shows redia and germ balls. It reaches the advance stage of development and measures 0.238 $\times$ 0.150 and at one end an obliquely transverse opening is developed for the embergence of the rediae. The sporocyst becomes mature by the tenth or eleventh day and it starts to liberate the rediae in the snail tissue. The mature sporocyst measures 0.378 $\times$ 0.125 and the tapering end bears the transverse opening. The body wall of the sporocyst is greyish coloured, transparent and of varying thickness. The body wall is beset with shining granules. The excretory system consists of flame cells and their ducts. The mature sporocyst contains rediae of various sizes and germ balls.

Redia : The rediae start to come out of the sporocysts from 10-11 days. A redia contains a muscular pharynx, a short oesophagus, a long saccular gut, three pairs of flame cells with their ducts, salivary glands, birth pore and germ balls and germ cells. After liberation the redia

remains either in the mantle cavity or to the gonads and liver of the snail host. A redia matures in 21-25 days and it starts to liberate the cercariae. The mature redia measures 0.56-1.03×0.17-0.02. The pharynx measures 0.05-0.08 in diameter and the gut is 0.11-0.2 long. A redia contains upto 19 developing cercariae.

8. Cercaria of **Gastrothylax crumenifer** Tandon, 1957*
(= *Cercaria chungathi* Peter and Srivastava, 1955)
(Fig. 10 A & B)

1955. *Cercaria chungathi* : Peter and Srivastava, *Proc. Indian Sci. Cong.*, 42 : 353.

1957. Cercaria of *Gastrothylax crumenifer* : Tandon, *Zeit. fur. Wissen Zool.*, 160(1/2) : 39-71.

Diagnosis : Body heavily pigmented ; body measures 0.55-0.715 ×0.32-0.44 ; tail measures 0.528-0.63×0.11-0.132 ; eye spots cone shaped, measures 0.06-0.068×0.04-0.05 ; oral sucker measures 0.095—0.115×0.07-0.075 ; long tubular oesophagus measures 0.09-0.16 in length ; long caeca reaching anterior to acetabulum ; main excretory duct with transverse connection ; rudimentary reproductive organs represented by ovary, testes on either side of ovary, prebifurcal genital pore, uterus, vasaefferentia, vasdeferens.

Cercaria encyst on walls of container or on leaves ; metacercaria measures 0.355 in diameter.

Snail host : *Gyraulus convexiusculus*

Localities : Lucknow, Bareilly.

Life history of *Gigantocotyle explanatum*
(Creplin, 1847) Nasmark, 1937.

Egg : The anterior narrower end of the oval egg is provided with an operculum which articulates with the egg shell like a cap. The colourless egg shell is uniform in thickness except at the posterior end which has a small asymmetrical thickening. The freshly laid egg measures 0.123-0.149×0.073-0.084 with an average size of 0.134×0.079. The ovum is located at the middle of the egg and is surrounded by the yolk cells. The ovum at this stage measures 0.026-0.042 in diameter with an average diameter of 0.036. The yolk cells are light yellowish-green in colour.

Miracidium : During the first three days the ovum increases in size slightly from 0.038-0.054×0.038-0.042 to 0.042-0.081×0.038-0.058. The increase in average size is from 0.045×0.039 to 0.058×0.042. Embryo at the end of seventh day measures 0.057-0.115×0.046-0.053 with an

average size of 0.085×0.049. Although some of the embryos attain maximum width by the seventh day but their various body organs are not yet developed. Between the seven and tenth days the rate of development of the embryo is much rapid and the embryo increases more in

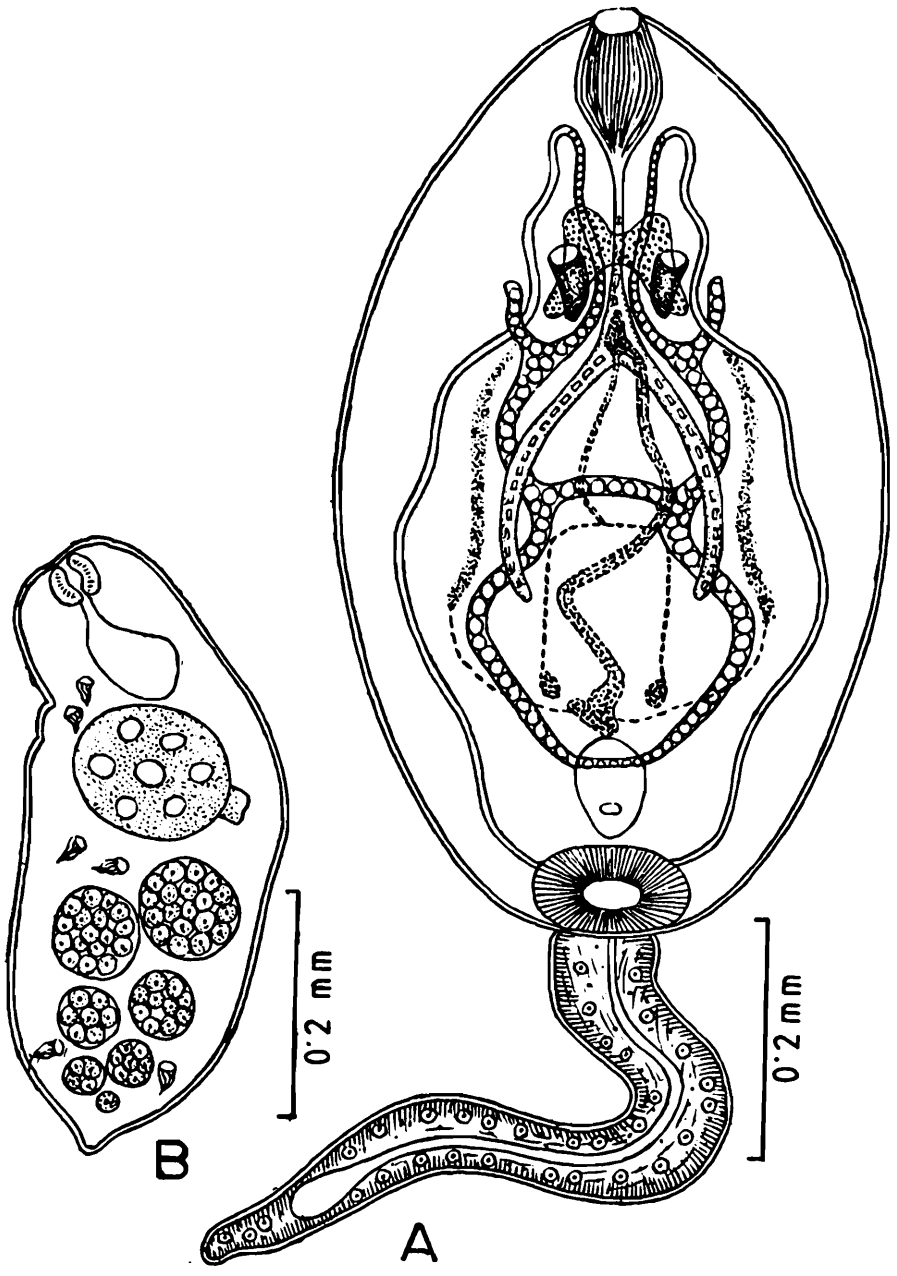


Fig. 10A. Cercaria of *Gastrothylax crumenifer*, (After Peter and Srivastava, 1966).
B. Redia of *Gastrothylax crumenifer* (After Peter and Srivastava, 1966).

length than breadth and it measures 0.058-0.135×0.046-0.058 with an average size 0.105 × 0.059 at the end of tenth day. On the eight day of development the epidermal cells and cilia of the larva are quite apparent. The larva also shows the development of apical papilla. The larva also starts to move inside the egg-shell wnich gradually increases with further development of the larva. By ninth day the body cilia, germinal cells, nervous tissue and gut are quite distinct. Vitelline cells are decreased

in number but increase in size with the result that the larva is pushed to one side of the egg. On the eleventh day the miracidium shows regular movements at short intervals and hits the base of the operculum with its apical papilla. Posterior part of the body of the larva is bent inside due to its length being greater than that of the egg. From July to October miracidium takes 11 to 12 days to hatch whereas during November to February it takes 19 to 21 days. At 32°C to 35°C the miracidium takes 8 to 15 days to hatch. It hatches out after a long and continous active movements which some times last more than a day. Miracidium gradually comes out of the egg after throwing open the operculum. Majority of the larvae found to hatch out in forenoon but a small percentage of hatching takes place at all time. The miracidium swims actively and it usually moves in straight lines and remains quite active for 7 to 11 hours after hatching. The active miracidium is pyriform in shape and the greatest width is observed across the anterior fourth of the body and measures 0.115-0.169 × 0.058-0.073 with an average size of 0.135 × 0.063. Epithelial cells are twenty in numbers and are arranged in four transverse tiers. They are arranged in the ratio of 6:8:4:2 = 20. The cells of the first, second, third and fourth tiers are about 0.021, 0.045, 0.034 and 0.027 in length respectively. The elongated nuclei of these cells are located near posterior border of the cells, except in the last row in which they are situated anteriorly. The nuclei of the sub-epithelium are also slightly elongated in shape and dlstributed irregularly. The flask shaped gut tapers anteriorly and opens near the tip of the apical papilla and posteriorly it extends upto the nerve mass. It also contains coarsely granular material and posteriorly located nuclei. A pair of penetrating glands is situated one on each side of the gut. These glands open at the base of apical papilla and unclei of these glands are situated near the posterior ends. The rounded nerve mass is located behind the gut. The miracidium also possesses number of papillae. Excretory system consists of flame cells and their ducts. Two flame cells are situated a little anterior to middle of body. The excretory tubes open to outside through excretory pores which are located between third and fourth rows of cells. Germ cells are situated behind the gut and occupying the greater part of the body of the miracidium.

Sporocyst : The sporocyst of four days old is small, rounded or slightly elongated and shows little mobility. It contains at this stage 4 to 8 germ balls. The sporocyst measures 0.224 × 0.13. The maximum number of germ balls found in a sporocyst is 11. The epithelium of the sporocyst is thin with large nuclei, At the posterior end of the sporcyst are present 3 to 5 large cells with 0.011 in diameter. These

represent the germ cells of the sporocyst. The wall of the sporocyst consists of thin cuticle with numerous cells and the large cells measure 0.012-0.013 and the smaller cells measure 0.009-0.01 in diameter. The nuclei are large and promient but with poorly developed muscle layers. The wall is 0.002 in thickness. On the sixth day of development the sporocyst showed a more advanced stage of development as some of the germ balls started to differentiate into rediae. The wall of the six day old sporocyst is considerably thickened and measures 0.015-0.016 in thickness. The rediae escape from the sporocyst through a pore which lies at one end of the sporocyst.

Redia : The mature redia is provided with mouth, pharynx, short oesophagus, well developed gut, body pigments, birth pore, excretory system, germ balls and developing cercariae. Anterior end of the redia is provided with papillae. Young redia measures 0.347-0.643 × 0.191-0.347 with an average size of 0.509 × 0.248 and the mature redia measures 0.617-0.917 × 0.194-0.352 with an average size of 0.768 × 0.284. The redia is provided with black pigment which is dense on the lateral sides and diffuse in the centre. The globular pharynx in mature redia measures 0.028-0.038 × 0.026-0.038 with an average size of 0.031 × 0.031. The gut is small and is lined by cells with prominent nuclei. Excretory system is provided with three pairs of flame cells and their ducts. The birth pore of the redia is situated at a level posterior to gut termination and about 0.251 from the anterior end of body in mature redia whereas it is located about 0.17 from anterior end of body in immature form. Mature redia encloses a large number of germ balls together with cercariae at different stages of development. A mature redia contains one to three cercariae.

9. Cercaria of **Gigantocotyle explanatum** Singh, 1958*

(= *Cercaria gyraulusi* Peter and Srivastava, 1955.
= Cercaria of *Gigantocotyle bathycotyle* Jain, 1978*)

(Fig. 11 A & B)

1958. Cercaria of *Gigantocotyle explanatum* : Singh, *J. Parasit.*, 44 (2) : 210-224.

1960. Amphistome cercariae in India : Peter and Srivastava, *Indian J. Helm.*, 12(1) : 51-73.

1978. Studies on amphistomes V. On the life history and validity of *Gigantocotyle bathycotyle* (Fischoeder, 1901) Näsmark, 1937 - an amphistomen in the bile ducts of bovines : Jain, *Zool. Anz. Jena.* 200 (3/4) : 185-218.

Diagnosis : Body pigment diffuse ; body measures 0.496 x 0.341 ; tail measures 0.62 x 0.062 ; eye spots conical ; margin of mouth opening with papillae ; oral sucker about 0.062 in diameter ; acetabulum 0.155 in

diameter ; oesophagus long ; caeca long ; main excretory ducts with anteriolateral diverticula near eye spots, transverse canal with antero-median diverticulum ; rudimentary reproductive organs represented by ovary, diagonally placed testes, genital pore, uterus, vasaefferentia, vasdeferens, vitellaria.

Cercaria encyst readily on leaves or on walls of container ; metacercaria measures 0.2-0.23 in diameter.

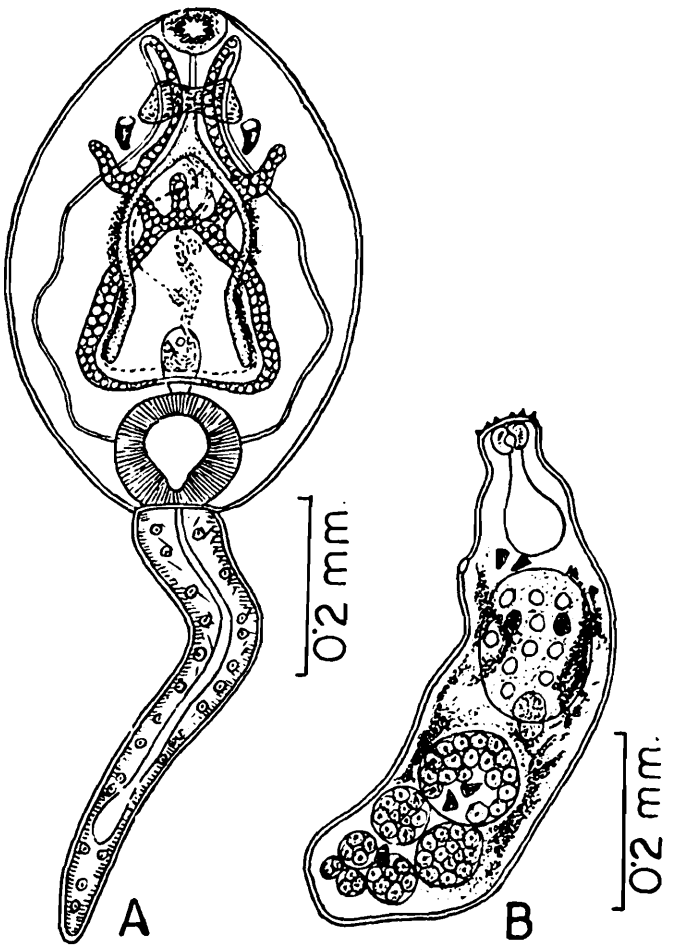


Fig. 11A. Cercaria of *Gigantocotyle explanatum* (After Peter and Srivastava, 1966).
B. Redia of *Gigantocotyle explanatum* (After Peter and Srivastava, 1966).

Snail host : *Gyraulus convexiusculus*

Localities : Lucknow, Bareilly.

Mukherjee and Srivastava (1960, 1981) and Mukherjee (1962) also reported the life history of this parasite and found that *G. convexiusculus* acts as its intermediate host.

Jain (1978) redescribed the life history of an amphistome which he considered as *Gigantocotyle bathycotyle* but description of the life history and the illustrations confirm that he was dealing with *Gigantocotyle explanatum.*

10. Cercariae indicae *XXXII* Sewell, 1922

(Fig. 12)

1922. *Cercariae indicae XXXII* : Sewell, *Indian J. Med. Res.* (Suppl.), 10 : 79-80.

Diagnosis : Body pigment sparsely present ; body measures 0.404-0.509 x 0.333-0.351 ; tail measures 0.579 x 0.088 ; eye spots conical with clear lenses ; oral sucker measures 0.118 x 0.071 ; acetabulum measures 0.087-0.153 in diameter ; oesophagus 0.193 long with well marked thick sphincter muscle at posterior end ; caeca wide, short ; lateral diverticula of main excretory ducts present near eye spots, transverse excretory duct present.

Redia measures 0.702-0.842 x 0.228-0.263 ; oral sucker 0.036 in diameter.

Snail host : *Aminicolar travancorica*

Locality : Malabar.

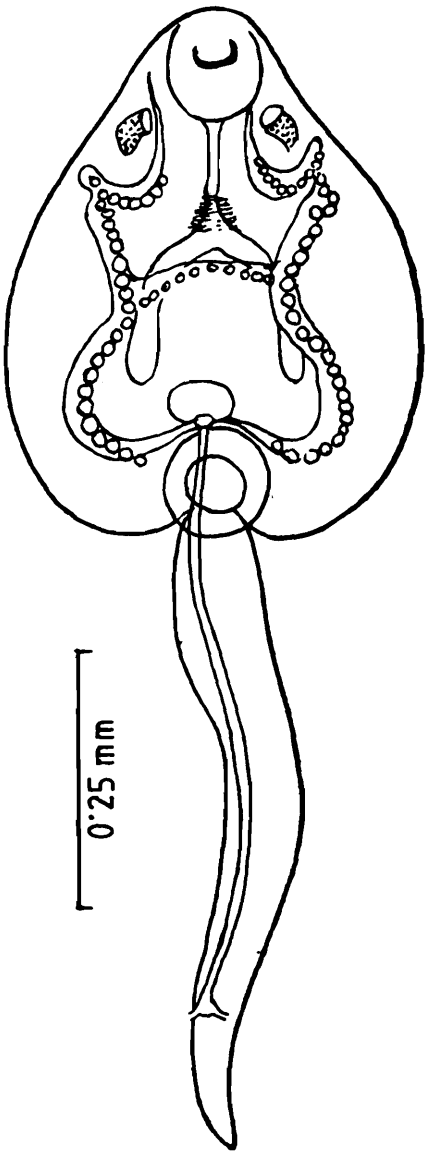


Fig. 12. *Cercaria indicae* XXXII Sewell, 1922 (After Sewell, 1922).

11. **Cercaria indoplanorbisi** Peter and Srivastava, 1955 (Fig. 13 A & B)

1955. *Cercaria indoplanorbisi* : Peter and Srivastava, *Proc. Indian Sci. Cong.*, 42 : 353.

1960. *Cercaria indoplanorbisi* : Peter and Srivastava, *Indian J. Helm.*, 12 : 60-62.

Diagnosis : Body pigment diffuse with irregular patches in anterior half ; body measures 0.229-0.480 x 0.165-0.293 ; tail measures 0.448-0.709 x 0.048-0.080 ; eye spots large, irregular, with no clear lenses ; oral sucker

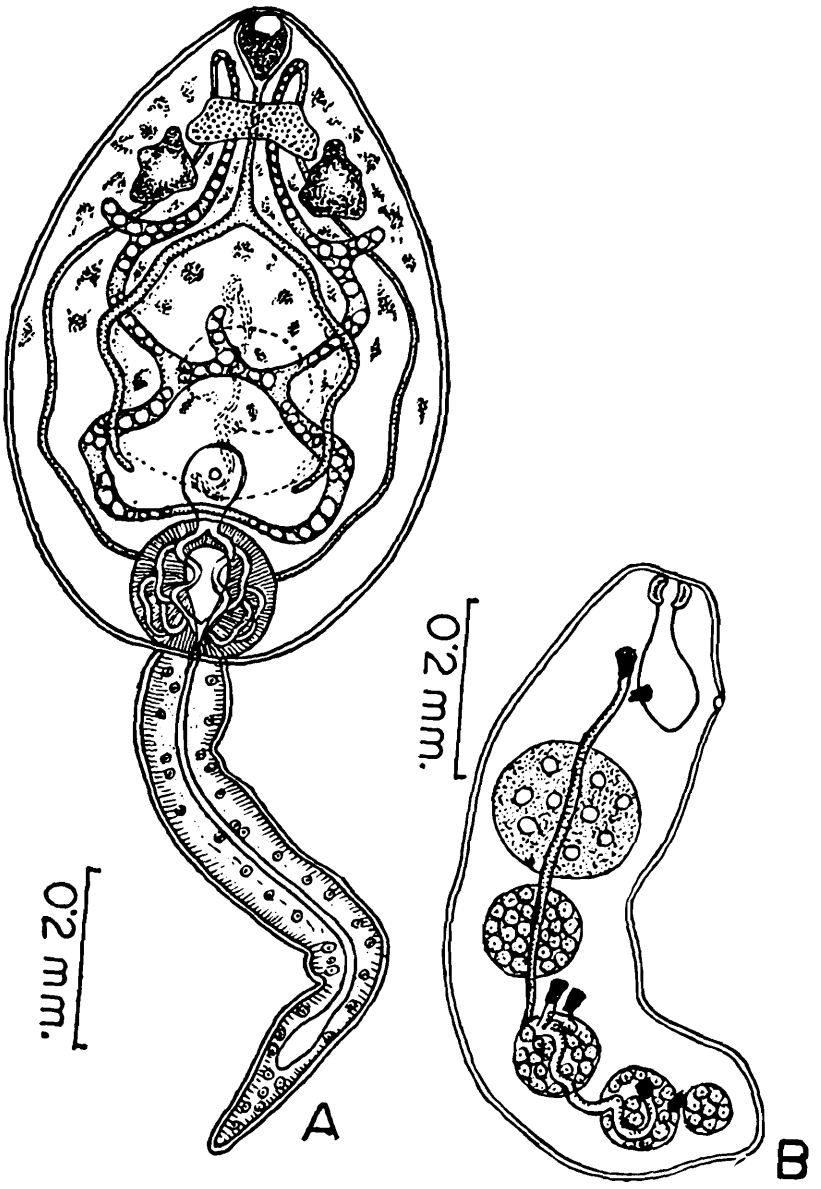


Fig. 13A. *Cercaria indoplanorbis* Peter and Srivastava, 1955 (After Peter and Srivastava, 1960).

B. Redia of *Cercaria indoplanorbis* Peter and Srivastava, 1955 (After Peter and Srivastava, 1960).

measures 0.065 ; acetabulum measures 0.150 ; oesophagus 1/5th body length ; caeca undulated, 3/4th body length ; excretory ducts with antero-lateral diverticula, transverse excretory duct with anteromedian diverti-

culum, excretory granules leaving empty spaces at irregular intervals; rudiments of reproductive organs represented by genital pore, ovary, tandem testes, uterus, vasaefferentia, vasdeferens.

Redia measures 0.844 x 0.180 ; oral sucker 1/19th of body length ; gut thick walled, empty ; birth pore anterior to gut termination.

Metacercaria measures 0.28 in diameter.

Snail host : *Indoplanorbis exustus*

Locality : Bareilly.

12. **Cercaria kareilliensis** Mukherjee, 1972

(Fig. 14 A & B)

1972. *Cercaria kareilliensis* : Mukherjee, *Sci. & Cult.*, 38 : 418-420.

Diagnosis : Body pigmentation diffuse with tendency to form small patches ; body measures 0.6 x 0.4 ; tail measures 0.5 x 0.1 ; eye spots conical with lenses, measure 0.025 x 0.022 ; mouth opening papilonated ; oral sucker measures 0.07 x 0.06 ; acetabulum measures 0.07 in diameter;

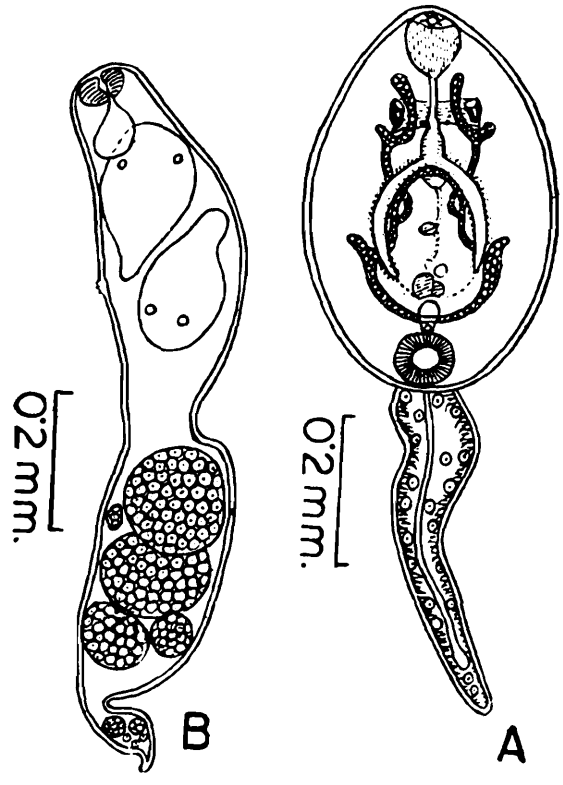


Fig. 14A. *Cercaria kareilliensis* Mukherjee, 1972 (After Mukherjee, 1972).

B. Redia of *Cercaria kareilliensis* Mukherjee, 1972 (After Mukherjee, 1972)

oesophagus measures 0.1 x 0.01, oesophageal bulb measures 0.05 x 0.04 ; caeca arched ; main excretory canals with antero and postero-lateral

diverticula, transverse excretory duct arched shape, main canals with transverse excretory duct form loops on either side ; rudiments of reproductive organs represented by genital pore, ovary, obliquely tandem testes, uterus, vasaefferentia, vasdeferens, vitelline glands, vitelline ducts.

Redia measures 1.1 x 0.2 ; oral sucker measures 0.06 x 0.09.

Metacercaria measures 0.29 in diameter ; encysted cercaria measures 0.35 in diameter.

Snail host : *Digoniostoma pulchella* (= *Bulimus pulchella)*

Locality : Bareilly.

13. Cercaria of **Srivastavaia lewerti** (Singh, 1970*) n. comb. (= *Cercaria lewerti* Singh, 1957)

(Fig. 15 A & B.)

1957. *Cercaria lewrti* : Singh *Trans. American Micro. Soc.*, 76 : 366-370.
1970. Cercaria of *Srivastavia indica* : Singh, *H. D. Srivastava Comm. Vol.*, 117-126.

Diagnosis : Body pigment heavy on dorsal and ventral side, pigmented stellar areas joined by smaller dots ; body oval measures 0.684—0.865 × 0.447—0.485 ; tail measures 0.95-1.08 × 0.13—0.143, posterior end of the tail provided with small spines ; eye spots conical ; oral sucker 0.074—0.086 in diameter ; small muscular pharynx present ; oesophagus short ; intestinal caeca terminating anterior to acetabulum ; acetabulum 0.129—0.172 in diameter ; excretory bladder rounded, anterior to acetabulum, transverse excretory canal with median anterior duct, main excretory duct gives out anterior diverticula near eye spots, caudal excretory duct arises from excretory bladder dorsally giving rise to two narrow ducts at posterior end of tail which remain open during early life of cercaria ; reproductive organs represented by ovary, obliquely tandem testes, genital pore, uterus, rudiments of vitelline glands on ventral to caeca.

Redia with two generation of rediae ; mother redia measures 0.903—0.998 × 0.2—0.22 ; muscular pharynx measures 0.43 in diameter ; gut measures 0.194—0.22 long ; salivary glands three pairs ; excretory system with three flame cells on each side, two main excretory ducts present, one running anteriorly and other posteriorly ; mother redia with one or two daughter rediae ; measures 0.32—0.38 × 0.067—0.075 ; pharynx measures 0.034-0.039 in diameter ; birth pore present on a small papilla ; daughter radiae measure 1.1—1.52 × 0.17—0.3, with two or three developing cercariae.

Metacercaria forms on leaves or on walls of container.

Snail host : *Indoplanorbis exustus*

Locality : Lucknow.

II. NLOPIGMENTATA GROUP

Diagnosis : Oral diverticula in cercaria absent ; transverse duct between two main canals in cercaria absent ; locomotor appendages in redia present.

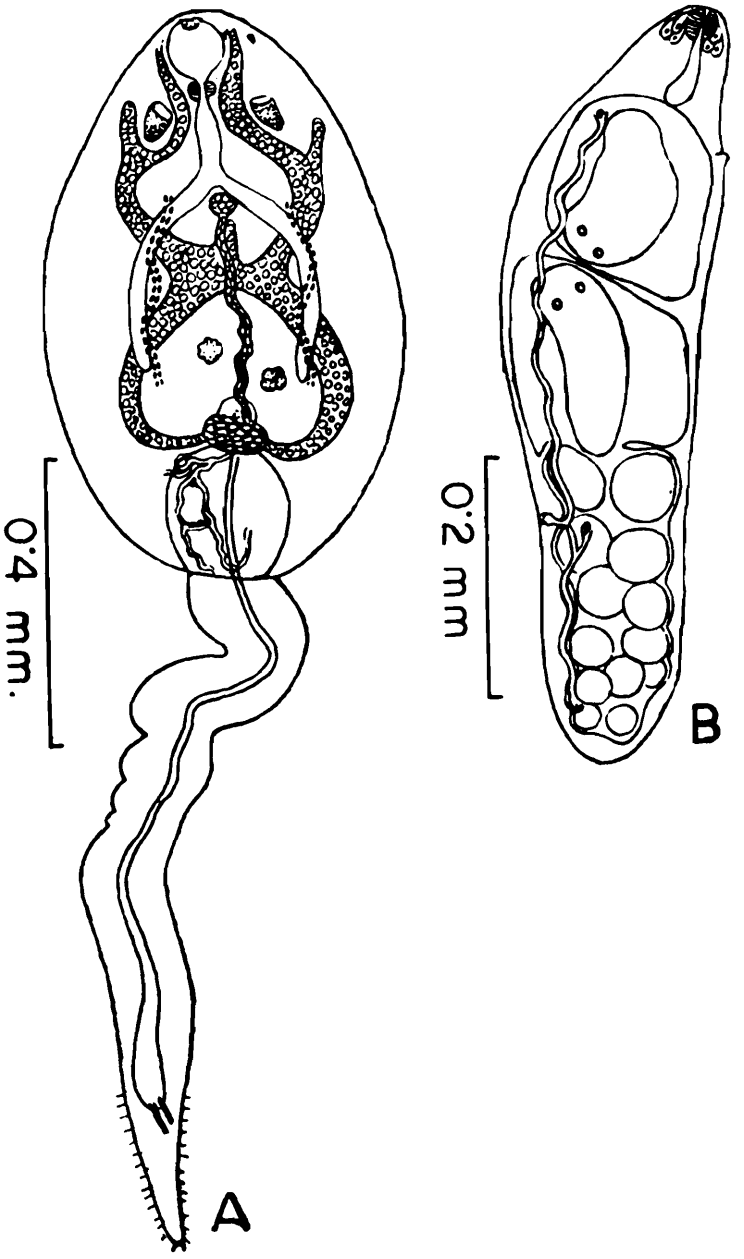


Fig. 15A. Cercaria of *Srivastavaia lewerti* (After Singh, 1957).
B. Redia of *Srivastavaia lewerti* (After Singh, 1957).

14. Cercaria sp. I Kerala Mohandas, 1976

(Fig. 16. A-C)

1976. Studies on the freshwater cercariae of Kerala V. Paramphistomatoid and Opisthorchioid cercariae : Mohandas, *Vest. Cs. Spol. Zool.*, XL (3) : 196-205.

Diagnosis : Body contracted and bent ventral while swimming, capable of leech like movement on the thin film of water ; body measures 400—690 × 225—400 μ ; pigmentation in irregular patches all over the body except in the region anterior to eye spots ; eye spots with lenses ; oral

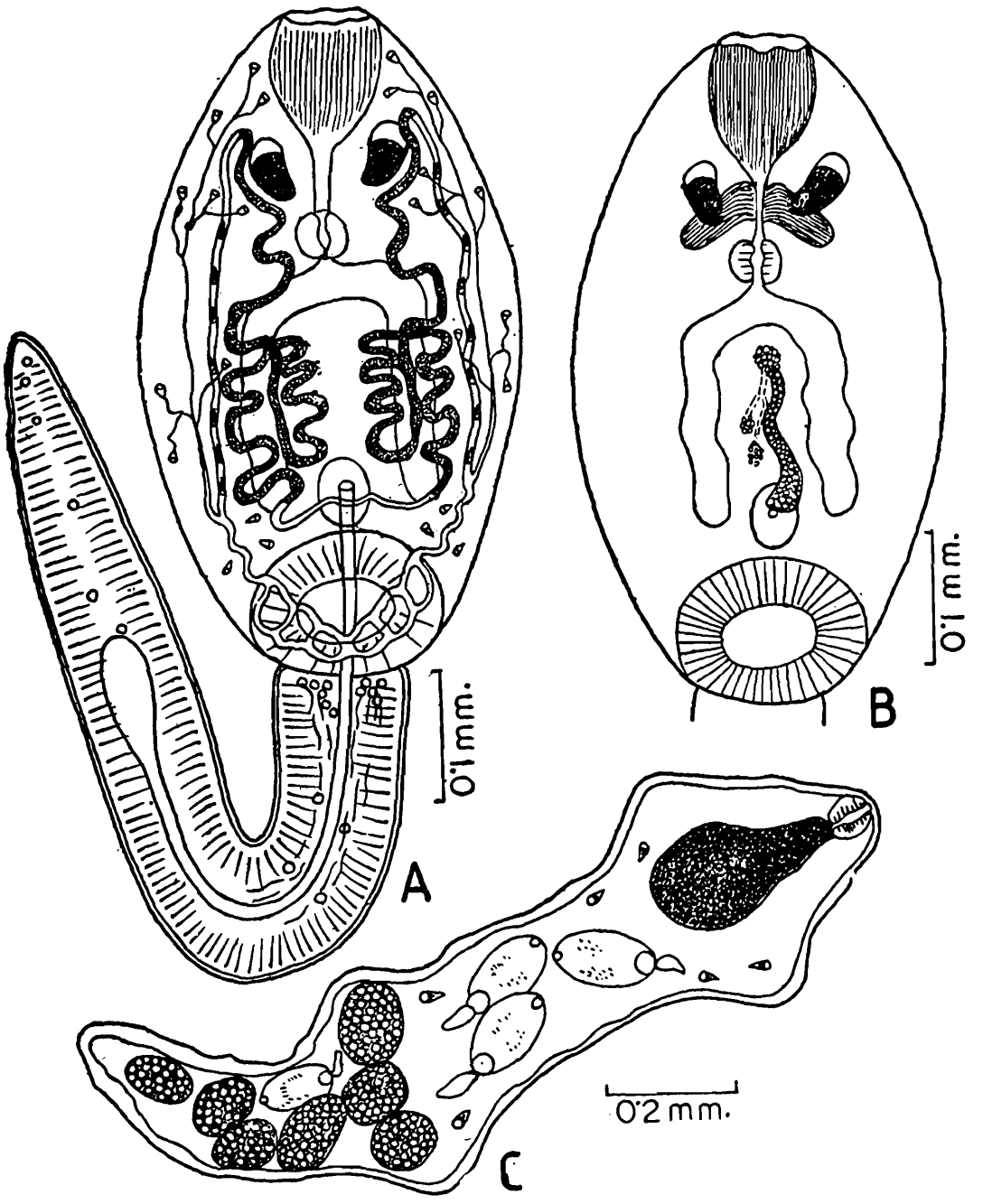


Fig. 16(A-B). *Cercaria sp. I kerala* Mohandas, 1976 (After Mohandas, 1976).
C. Redia of *Cercaria sp. I kerala* Mohandas, 1976 (After Mohandas, 1976).

sucker 90—125 × 75—110 μ ; acetabulum 125—170 × 100—125 μ ; tail measures 420—650 × 70—110 μ ; mouth terminal or sub-terminal ; oesophagus short ; oesophageal bulb measures 25—45 × 35 × 50 μ ; excretory bladder small and oval shaped, main excretory tubes highly coiled around caeca,

transeverse duct between two tubes absent, descending excretory ducts divide into anterior and posterior ducts at level of excretory bladder, flame cell formula 2(3+3+3+3), caudal excretory sac ends in a dilated sac ; rudimentary uterus runs a zig-zag course, testes tandem, genital pore post bifurcal.

Redia 1050-1910 μ long ; pharynx measures 50-75 μ ; two pairs of locomotor appendages present ; excretory system with three pairs of flame cells ; matured redia contains as many as 12 developing cercariae.

Cyst measures 400-430 μ and the cyst wall varies in thickness between 10-15 μ.

Snail host : *Indoplanorbis exustus*

Locality : Palghat, Aleppey and Trivandrum districts.

III. INDICA GROUP

Diagnosis : Oral diverticula in cercaria present ; transverse duct between two main canals in cercaria present ; locomotor appendages in redia absent.

KEY TO INDIAN SPECIES

1. Oesophagus in cercaria curved.....2.
   Oesophagus in cercaria not curved.....3.
2. Oesophagus curved forward at posterior end ;
   caeca coiled.....Cercaria of *Olveria indica.*
3. Oesophagus provided with muscular bulb at posterior end ;
   caeca not coiled.....Cercaria of *Gastrodiscoides hominis.*

Life history of *Gastrodiscoides hominis* (Lewis and McConnel, 1876) Leiper, 1913

Egg : Eggs measure 0.127-0.160 × 0.062-0.075 with an average size of 0.146 × 0.066. The abopercular end is generally thickened. In optical section about 24 vitelline cells can be seen. The distinct embryo which is in very early stage of development when the egg is laid occupies almost the central position and measures 40 × 30 μm. At laboratory temperature of 24°-33°C in the month of September the embryo attains the size of 84 × 47 μm, 124 × 47 μm, 140 × 47 μm and 145 × 47 μm in 4, 6, 7, and 8 days respectively. The miracidium is fully mature on the 9th day when the miracidium starts to hatch. The miracidium continues to hatch for 7 days. In the month of September-October at slightly lower temperature

the miracidium starts to hatch from 11 to 14 days. High temperature proves to be detrimental to the development of the miracidium. The miracidium needs 4 weeks in April-May and 3 weeks in July for maturing.

Miracidium : The free swimming miracidium measures 0.116-0.142 × 0.035-0.049. The 20 epidermal cells are arranged in four tiers of 6,8,4 and 2 respectively. Each cell has an elongate nucleus which is without distinct nucleolus but possesses a small number of chromatin granules. The prominent apical papilla bears a number of short bristle like cilia. Beneath the cuticle lies about 48 nuclei which lack nucleolus but possess a number of scattered chromatin granules. Out of these 9 nuclei are middorsal and another 9 midventral. The rest of the nuclei, about 15 on each side, are distributed on the two sides of the body. These are spindle shaped and the two ends being drawn out into fibre like processes. Slightly ventral to and on either side to the first nucleus of the middorsal row lie two groups of small nuclei. A few subepithelial parenchymal cells with very small nuclei are also present. The coarsely granular apicel gland or gut is voluminous and is provided with four spherical nuclei, each with a distinct nucleolus and a few chromatin granules. The granular penetrating glands are two in numbers and one lies dorsal to the apical gland and the other ventral to it. They are about half the length of gut. The nuclei of these glands are nearly oval in shape with prominent nucleolus but no discernible chromatin granules. One of the nuclei is situated anteroventral to the first of the middorsal row of nuclei of muscle cells and the other anterodorsal to that of the midventral ones. The large nerve mass lies dorsal to the posterior of the gut. The excretory system consists of a pair of flame cells, one on each side, with their convoluted ducts ending at the excretory pores which are located laterally belween the third and fourth tiers of epidermal cells. The germinal elements consist of germinal balls and cells. The germinal balls located at the centre of the miracidium just posterior to the gut. The nuclei of the germinal cells have distinct nucleolus and a few chromatin granules.

Redia : The redia is found free in the digestive gland of the infected snail and is sausage shaped. The birth pore is located near the level of the saccular intestine. The redia measures 0.148-0.747 × 0.045-0.140. The pharynx measures 0.022-0.046 and the saccular intestine with oesophagus measure 0.042-0.164 × 0.027-0.044. The junction of the pharynx and oesophagus is surrounded by about 8 pairs of uninucleate elongated cells. The redia encloses germinal balls, germinal cells and developing cercariae. Some times a redia contains daughter rediae. The daughter rediae measures 0.166-0.206 × 0.076-0.082.

15. Cercaria of **Gastrodiscoides hominis** Dutt and Srivastava, 1966*

(All measurements are in microns)

(Fig. 17. A & B.)

1966. Cercaria of *Gastrodiscoides hominis :* Dutt and Srivastava, *J. Helm.*, XL (1/2) : 45-52.

Diagnosis : Body light brown in colour, pigment in flecks, distributed all over, more concentrated in anterior region near eye-spots ; body measures 403-865 × 192-310 ; tail longer than body, measures 468-923 × 59-94 ; eye spots with clear lenses, measure 21-42 × 18-36 ; mouth

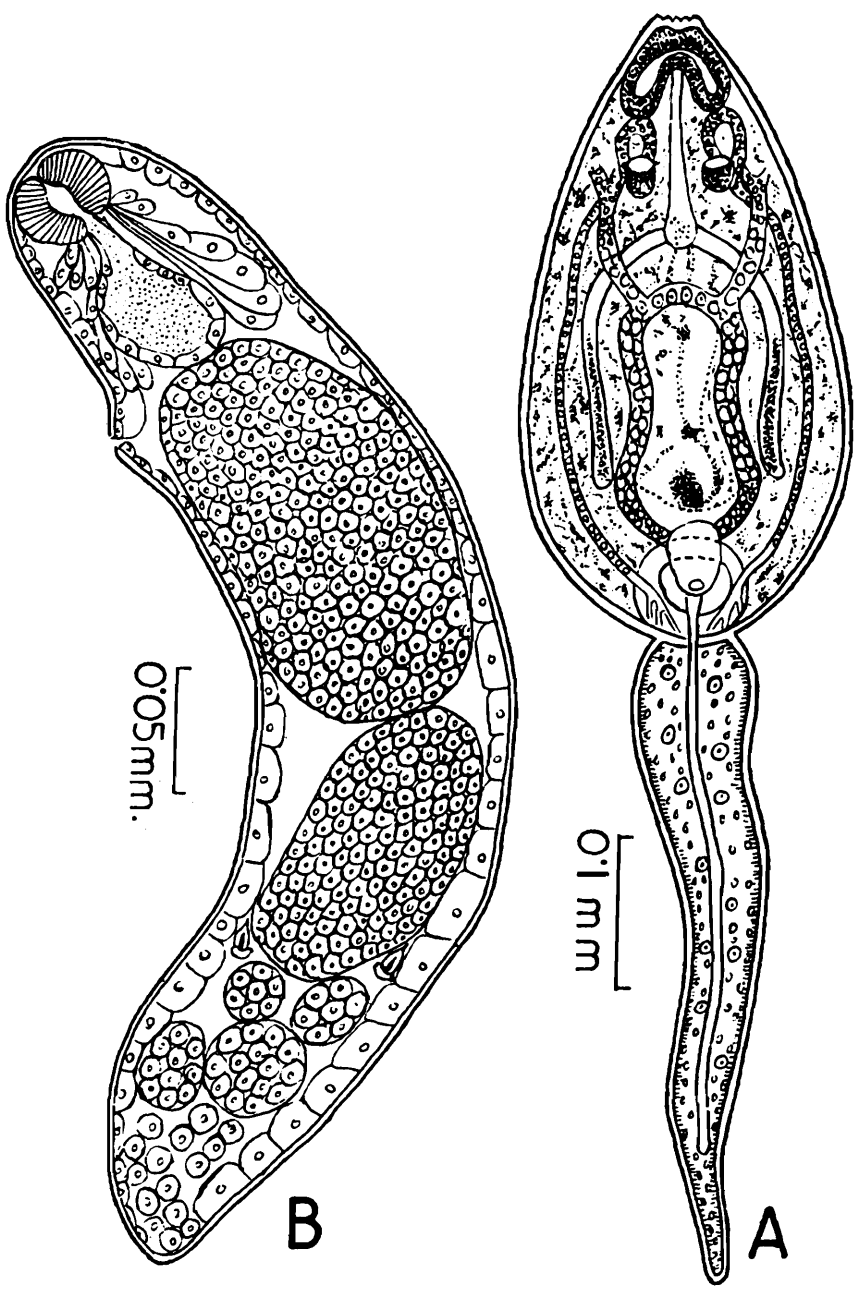


Fig. 17A. Cercaria of *Gastrodiscoides hominis* (After Dutt and Srivastava, 1966).

B. Redia of *Gastrodiscoides hominis* (After Dutt and Srivastava. 1966).

surrounded by number of small papillae ; oral sucker measures 31-47 × 22-40 ; acetabulum measures 67-140×67-115 ; oesophagus measures 97-174 long, provided with a muscular bulb at posterior end ; caeca measure 160-208 long ; main excretory trunks with antero-medially directed diverticula near eye-spots, main excretory trunks and transverse connection contain excretory granules ; rudiments of reproductive organs represented by ovary, vitelline glands, vitelline ducts, tandem testes, uterus, vasaefferentia, vasdeferens, genital pore.

Metacercaria hemispherical in shape ; measures 0.201-0.227 (0.216) in diameter ; cyst wall measures 0.014-0.035 (0.025) in thickness.

Snail host : *Helicorbis coenosus*

Locality : Bareilly.

Life history of *Olveria indica* Thapar and Sinha, 1945

Egg : The eggs are oval in shape and have colourless operculated shells. The eggs when deposited are yellowish brown in colour. In an average size the egg measures 0.13×0.015. The egg contains an ovum in unsegmented stage at the time of laying. Within 24 hours the cleavage starts and the ovum reached to 2-4 cell stage. Thereafter the ovum starts to divide quickly and within three days the embryo forms an irregular mass of cells which measures 1.5×0.5 in size. The embryo gradually increases in size and the yolk cells are used up. Between the embryo and the egg shell a fluid substance appears and the embryo shows slow movement of contraction and expansion. On the eight day of incubation differentiation of embryo takes place. The body cilia, cephalic glands and germ balls are developed. The embryo becomes active and shows considerable body movements. The miracidium strikes the operculum with its apical papilla and tries to make its way out of egg shell and finally the miracidium emerges by throwing open the operculum. While the embryo is still inside the egg a wave like current due to the constant beating of the body cilia from the anterior to the posterior end of body can be seen. The miracidium emerges from the egg in 8-14 days of incubation. It usually comes out during the early hours of the morning between 6-10 a.m. and swims actively in the water in a spiral motion after its emergence.

Miracidium : The mature miracidium is conical in shape with broad anterior end and narrow posterior end. The anterior end bears the head papilla. The two ends of the miracldium are tapering and it measures 0.145-0.225×0.054-0.068. The body is covered with plates that are arranged in four transverse rows and these plates carry the cilia. The

first or the anterior row consists of six plates, the second row consists of eight plates, the third row with four plates and the fourth row or the last plates consists of two plates only. Each plate carries the nucleus at the posterior end, except in the fourth row which carries the nucleus at the anterior end. The sub epithelium lies below the epidermal plates and consists of thin elongated oval cells. It multiplies actively and gives rise to germinal cells that migrate to the central cavity. Each germinal cell contains a prominent nucleus and granular cytoplasm. These cells unite to form germ ball which lies on the posterior third of body. Another germ ball lies in the middle third of body which consists of 13-17 germ cells. Occasionally some of the germ cells break off from the germinal mass and float in the central cavity of the miracidium. The primitive gut measures 0.05 in length. The two elongated flask shaped penetrating glands are located on either side of the gut and it opens at the base of the apical papilla. A pair of eye spots is situated in the region of the gut and beneath this lies the irregular nerve mass. The two flame cells, one on either side, in the middle region of body are located close to the body margin. These flame cells are provided with narrow ducts. These coiled tubes open posteriorly at the junction of the third and fourth row of epidermal plates.

Sporocyst : The miracidium after entering into the snail tissue first sheds its ciliated epidermal plates and cephalic glands but the flame cells, gut, eye spots and germinal cells are still persist. On the fourth day of development the sporocyst forms an oval sac-like body in the mantle cavity of the snail and it measures 0.175×0.118. It contains germinal cells which are arranged in masses of packed cells. Generally there are three such solid masses beside a few germinal cells. In some sporocysts, however, only two germ balls were seen with two flame cells on either side of the body. The germinal mass in young sporocyst consists of 10-15 cells, each with prominent nucleus. After about seven days the sporocyst increases in size and may attain 0.4×0.2 in size. The larger sporocyst contains besides germinal cell masses, young rediae also. The fifteen days old sporocyst contains as many as five germ masses and two immature rediae and it measures 0.4×0.24 in size. The thirty three days old sporocyst contains seven germ balls at various stages of devclopment, a few germ cells and two fairly well developed rediae and at this stage it measures 0.45×0.235. The sporocyst wall consists of thin cuticle with a layer of muscle fibres and sub-epithelial cells contain nuclei distributed over the surface of the sub-eipithelium.

Redia : The redia is an elongated body and measures 0.2-1.0 × 0.07-0.2 in size. The muscular pharynx measures 0.04 long and the

sac-like gut measures 0.07 long. The redia contains 8-15 germ balls of different sizes. The cells lining the intestine are large with prominent nuclei. The mouth followed by muscular pharynx and sac-like intestine. Excretory system consists of three pairs of flame cells. The birth pore is located at quarter of a distance from the anterior end. The redia contains well developed cercariae.

16. Cercaria of **Olveria indica** Thaper, 1961*
(Fig. 18 A & B)

1961. Cercaria of *Olveria indica* ; Thapar, *J. Helm, R, T. Leiper Suppl.*, 179-186.

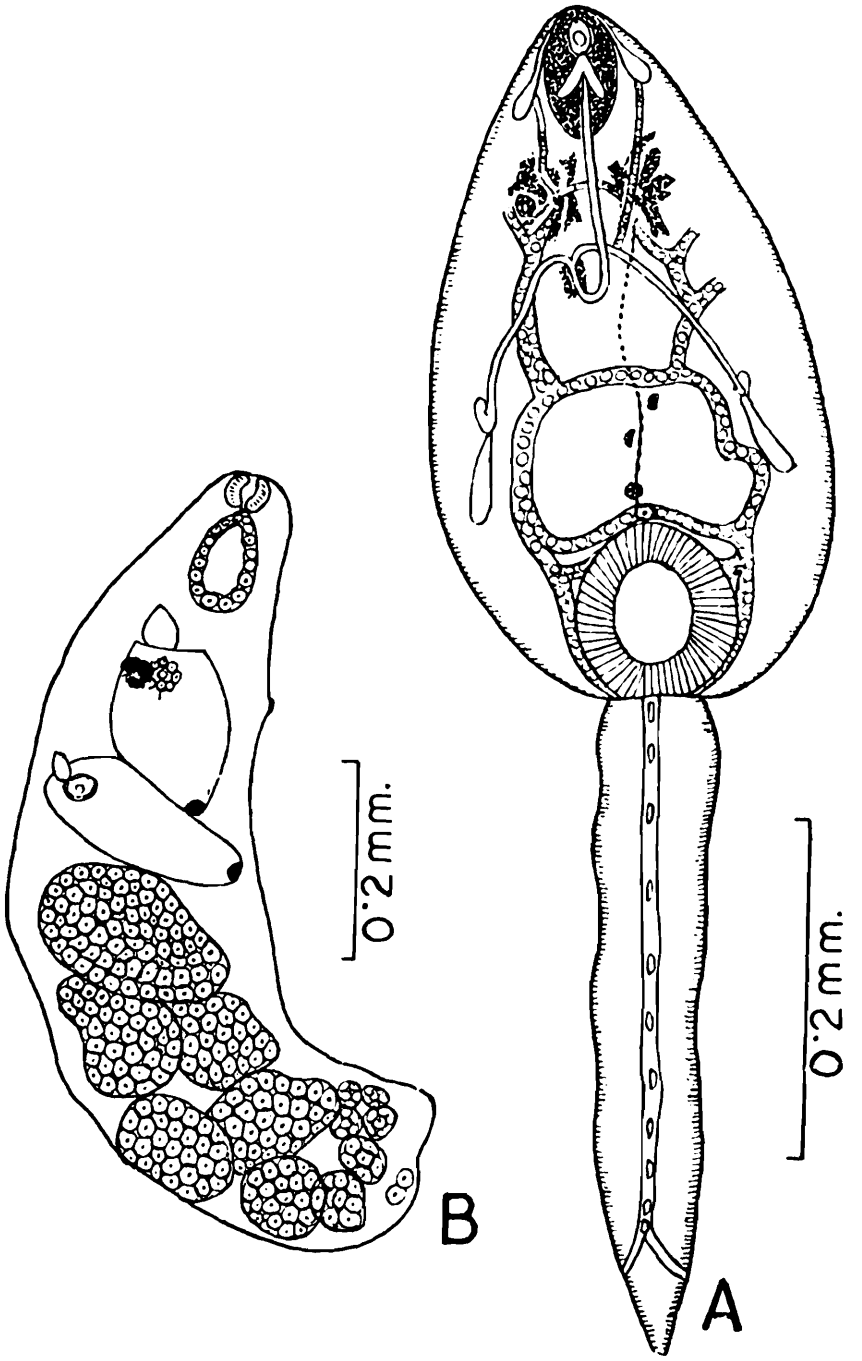


Fig. 18A. Cercaria of *Olveria indica* (After Thapar, 1961).
B. Redia of *Olveria indica* (After Thapar, 1961).

Diagnosis : Body deeply pigmented, pigments starts round eyes form long radiating strings ; body measures 0.41 × 0.21 ; tail measures 0.36 × 0.05 ; eye spots conical with clear lenses ; acetabulum measures 0.09 in diameter ; oral sucker measures 0.06 × 0.05, oral pouches present ; oesophagus measures 0.11, curved forward at posterior end ; caeca coiled ; main excretory canals with transverse connection, each canal with three narrow ducts in region of eye-spots ; rudiments of reproductive organs reperesented by ovary, obliquely tandem testes.

Metacercaria measures 0.2 in diameter.

Snail host : *Gyraulus convexiusculus*

Locality : Lucknow.

IV. NEODIPLOCOTYLEA GROUP

Diagnosis : Oral diverticula in cercaria present ; cross excretory duct between two main canals in cercaria absent ; locomotor appendages in redia absent.

KEY TO INDIAN SPECIES

1.	Caudal spines and papillae present		*C. fursolensis*
	Caudal spines and papillae absent		2
2.	Main excretory duct with anterior and posterior diverticula ...		*Cercaria of Pseudodiscus Collinsi*
	Main excretory duct with anterior diverticulum only ...		*Cercaria of Gastrodiscus secundus*

17. **Cercaria fursolensis** Singh and Malaki, 1963.

(Fig. 19 A & B)

1963. *Cercaria fursolensis* : Singh & Malaki, *Indian J. Helm.*, 15(1) : 54-69.

Diagnosis : Body measures 0.607-0.947 × 0.243-0.405 ; tail measures 0.899-1.119 × 0.089-0.137, a number of small rounded papillae with short spines present throughout length of tail ; oral sucker 0.097-0.162 in diameter, oral pouches present ; oesophageal bulb present ; caeca wide ; eye spots conical ; acetabulum measures 0.203-0.380 in diameter ; main excretory ducts follow an irregular wavy course, sixteen pairs of flame cells present ; rudiments of reproductive organs represented by ovary, single testis.

Redia measures 0.652-1.304 × 0.271-0.445 ; oral sucker measures 0.058-0.089 in diameter ; gut measures 0.081-0.178 in length ; two generation of redia present ; three flame cells present.

Snail host : *Gyraulus convexiusculus*

Locality : Bhowali

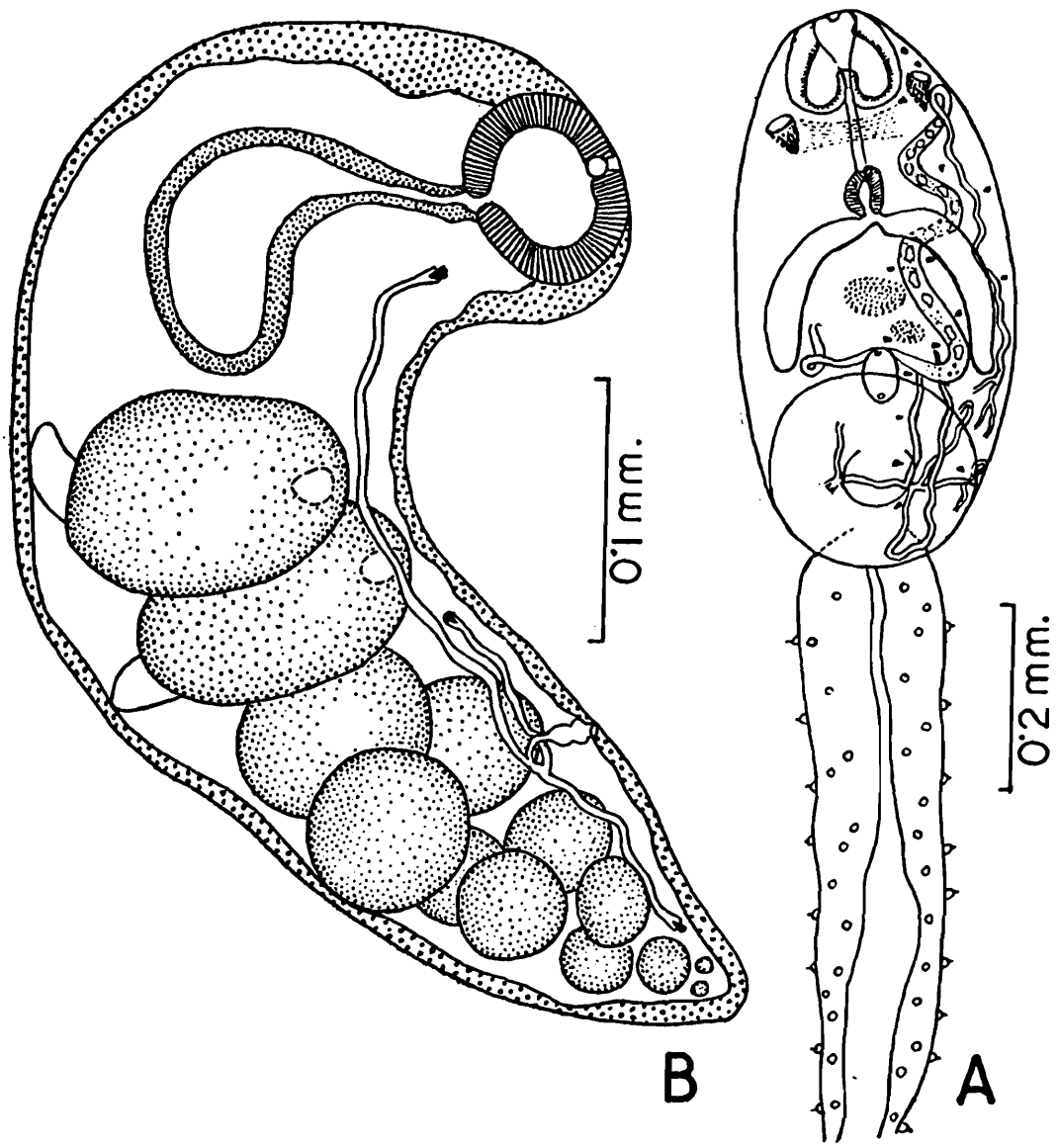


Fig. 19A. *Cercaria fursolensis* Singh and Malaki, 1963 (After Singh and Malaki, 1963).

B. Redia of *Cercaria fursolensis* Singh and Malaki, 1963 (After Singh and Malaki, 1963).

Life history of *Gastrodiscus secundus* Looss, 1907

Egg : Under a microscope the egg appears transparent with a brownish tinge towards the inner lining of the shell. The egg is oval in outline with anterior end narrower than posterior. The egg measures 0.119-0.191 × 0.087-0.118 with an average size of 0.158 × 0.100. The shell is smooth and transparent. The operculum is located at the anterior end and measures 0.03 in diameter. There is a projection at the posterior end of the shell which forms a button or hook-like structure or at times it

appears as a mere thickening. The shell varies in thickness at different regions. Vitelline mas occupies the whole of the shell cavity and it is composed of tightly packed cells which vary in number from 27 to 31. The ovum which lies embeded in the vitelline mass is very distinct and is located slightly anterior to the centre of the egg but it may be located to any other place also. The embryo measures 0.036 across and no cleavage is noticed when the egg is laid.

Miracidium : The egg which is about to be hatch contains a fully developed larva lying parallel to its long axis with its apical papilla directed towards the opercular end. The posterior part of the fully developed larva is flexed in order to accomodate itself within the shell cavity. The other part of the shell cavity is occupied by two or three large globules, the empty vitelline cells. The larva is periodically active and its movements consisting of a series of muscular contractions, thus the larva continuously trying to force open the operculum so that it can emerge out of the egg. These movements which last only for 30 to 90 seconds usually followed by a longer period of rest. Majority of the larvae come out of the eggs during the day, particularly in the morning hours but some come out during the night also. The minimum time required by the eggs to hatch during the monsoon season is 8 days and it takes a minimum period of 13 days during the winter months with an average of 11 days. The miracidium swims actively in straight line and rotates on its long axis while swimming. In the absence of a suitable snail host the miracidium dies and disintegrates. The span of life of the miracidium varies from 10 to 13 hours with an average of 11 hours. The miracidium is postively phototropic. While swimming the greatest width is noticed at the shoulder region and the anterior end appears to be conical while the posterior end is bluntly rounded. The larva measures 0.172×0.083 in contracted and 0.272×0.044 in extended conditions. In fixed condition it measures 0.178×0.063. The body of the miracidium is enclosed by 20 epithelial cells which are arranged in four tyres and the arrangement can be expressed by a formula as $6 : 8 : 4 : 2 = 20$. The epithelial cells of the different rows vary in length. The cells of the second row being the longest and the cells of the last row being the shortest. The cells of the first row measure 0.052 and the cells of the second, third and fourth rows measure 0.074, 0.068 and 0.043 respectively. The nuclei of the epithelial cells are large and elongated with irregular in shape. The nuclei in the first three rows are place near the posterior borders while in the last row near the anterior borders. The miracidium swims by the beating of the body cilia. The cilia present at the base of the apical papilla are very short in comparison to the other body cilia. The sub-epithelial layer also contains nuclei. The

flask-shaped gut lies ventral to the nervous system. The gut contains the coarsely granular material. Four nuclei are located on the posterior part of the gut. Two penetrating glands are present on the dorsal to the primitive gut. They are pyriform in shape with clear cytoplasm and nucleus. The nervous system consists of quadrangular fibrous mass which represents the brain and lies dorsal to the primitive gut. A knob-like protuberance is attached to the ventral aspect of the brain. The excretory system consists of flame cells, ducts and excretory pores. The portion of the body behind the primitive gut is filled with germ balls and germ cells. Only one germ ball measuring about 0.021 in diameter is found just behind the gut, while the rest of the region contains germ cells each possessing a large nucleus surrounded by a thin layer of cytoplasm. The presence of only one pair of penetration gland and the specialised nature of the nervous system provided with a characteristic pedunculated structure found in the miracidium of *Gastrodiscus secundus* can be regarded as specific features by which it could be differentiated from the other known aphistome miracidia.

Sporocyst : The sporocyst develops in the mantle tissue of the snail host. The sporocyst is a thin walled sac containing a pair of flame cells and their ducts and a few germ balls. By the 9th day, the germ balls began to get differentiated into redial structures. A mature sporocyst containing well formed rediae inside, it took a minimum period of 13 days, by which time few young rediae were also found in the snail tissue. Five days old sporocyst measures 0.126 x 0.112 and contains only germ balls. Seven days old sporocyst measures 0.296 x 0.134 and contains the germ balls. Nine days old sporocyst measures 0.407 x 0.148 and contains young rediae. The eleven days old sporocyst measures 0.461 x 0.194 and contains only immature rediae while the thirteen days old sporocyst measures 0.560 x 0.226 and contains well developed rediae. The mature sporocyst is an elongated body with bluntly rounded extremities and contains excretory system, developing rediae and germ balls. The outer wall of the sporocyst is sticky and sporocyst is visible to the naked eye as a minute opaque body.

Redia : Majority of the young rediae are found only in the posterior digestive gland of the infected snail whereas the older ones are lodged in the reproductive organs. The redia is elongated and sausage-shaped. The anterior end is rounded and the posterior end is bluntly pointed. The young redia measures 0.261 x 0.085. Second generation of redia is present. Mother redia containing daughter redia measures 0.741 x 0.167. The redia containing the immature cercariae measures 1.333 x 0.200. Locomotor appendages are absent in the redia. The mature redia presents

dark irregular pigment patches while the immature redia devoid of any body pigments. The birth pore in the mature redia present at the junction of first and second quarters of body length. In adult it is located at a level with or slightly posterior to the caecal termination at about 1/5 to 1/6 of the body length. The mouth is surrounded by a lip like cuticular thickening. The muscular pharynx measures 0.037 in young and 0.066 in adult specimens. The pharynx opens into the club-shaped gut. The salivary glands are of two types—a large number of small parenchymatous cells surrounding the greater part of gut and a set of 8 large drop-shaped cells arranged arround the pharynx. The excretory system consists of three pairs of flame cells with their ducts. A redia may contain daughter rediae and cercariae both.

18. Cercaria of **Gastrodiscus secundus** Peter and Mudaliar, 1948*. (= *Cercaria fraseri* Buckley, 1939)

(Fig. 20. A & B.)

1939. *Cercaria fraseri* : Buckley, *J. Helm.*, 17 : 25-30.

1948. Cercaria of *Gastrodiscus secundus* : Peter & Mudaliar, *Curr. Sci.*, 17 : 303-304.

Diagnosis : Body pigmented ; body measures 0.958 x 0.550 ; tail measures 0.917 x 0.133 ; eye spots conical with lenses, cone measures 0.046 in length, lens measures 0.023 in diameter ; oral sucker measures 0.057 in diameter, oral diverticula present, pouches measure 0.083 x 0.059 ; acetabulum measures 0.125-0.164 ; oesophagus narrow : caeca arched, end posterior to junction of last two quarters of body length ; caeca and oesophagus contain yellowish-brown rectangular granules ; main excretory ducts give of latteral diverticula in region of eye-spots, three pair of flame cells present ; rudiments of reproductive organs represented by genital pore, ovary, diagonally tandem testes, uterus, vasaefferentia, vasdeferens, vitelline glands, vitelline ducts.

Metacercaria measures 0.332 in diameter ; cyst wall measures 0.025 in thickness.

Snail host : *Indoplanorbis exustus*

Locality : Madras.

Remarks : The present author agree with the view expressed by Anantaraman and Balasubramaniam (1949) regarding the larva described by Peter and Mudaliar (1948). The cercaria described by Peter and Mudaliar (1948) was the same as was reported by Buckley (1939) as *Cercaria fraseri.* So this cercaria represents the larval form of *Gastrodiscus secundus* Looss, 1907. The subsidiary branch of the main excretory vessel in *C. fraseri* might have originated from the main excretory canal near the oral sucker which Buckley has not given due importance.

19. Cercaria of **Pseudodiscus collinsi** Peter and Srivastava, 1960*.

(Fig. 21. A & B.)

1954. Cercaria of *Pseudodiscus collinsi* : Peter and Srivastava, *Proc. Indian Sci. Cong.*, 41 : 221.

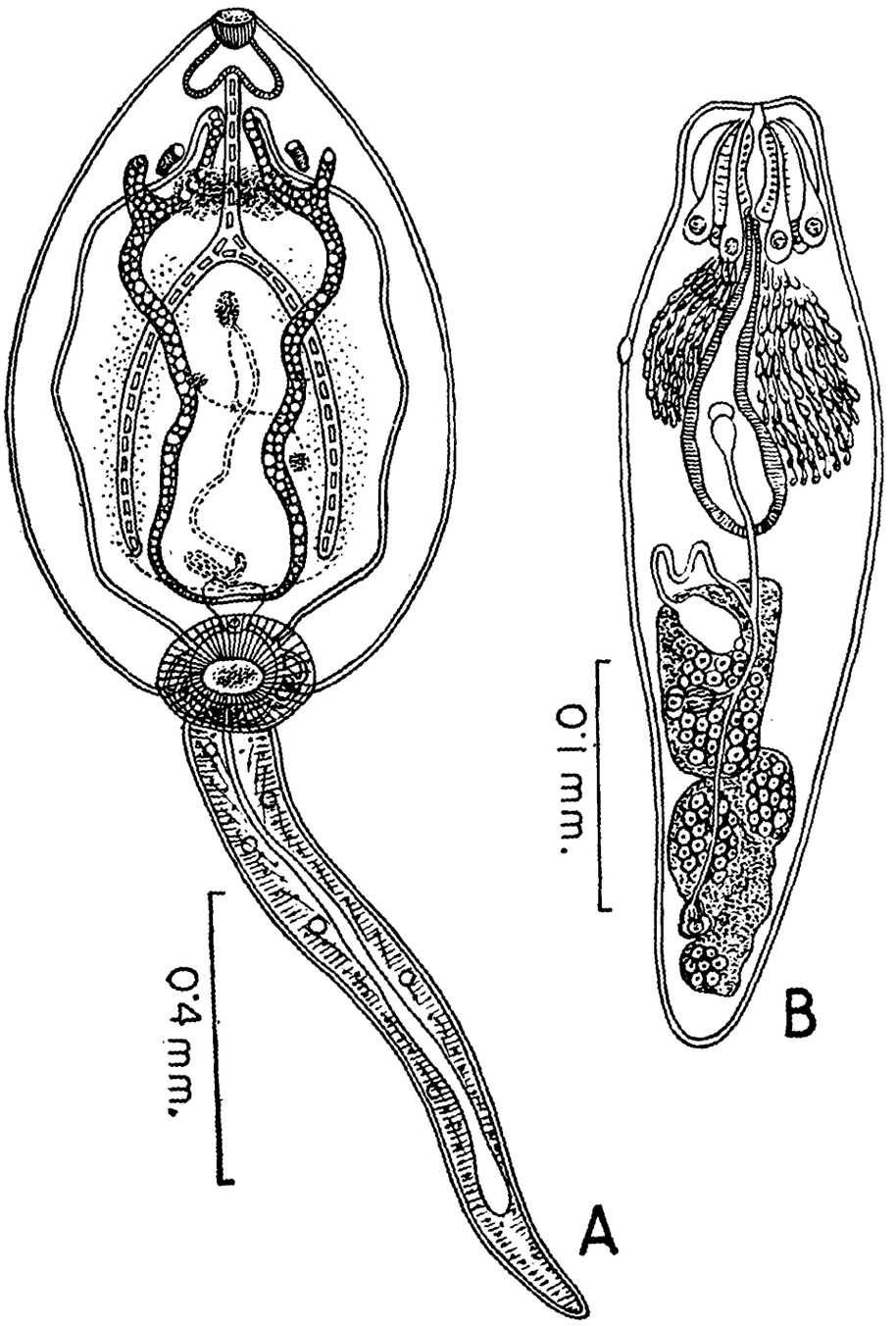


Fig. 20A. Carcaria of *Gastrodicus secundus* Peter and Mudaliar, 1948 (After Peter and Mudaliar, 1948).

B. Redia of *Gastrodiscus secundus* Peter and Mudaliar, 1948 (After Peter and Mudaliar, 1948).

Diagnosis : Body with dark isolated patches of pigment in anterior third of body ; body measures 0.992 x 0.474 ; tail measures 1.113 x 0.120,

longer than body ; eye spots conical with lenses ; oral sucker measures 0.074 x 0.083, oral diverticula present, measures 0.085 x 0.057 ; acetabulum measures 0.158 x 0.169 ; oesophagus long ; caeca slightly converge

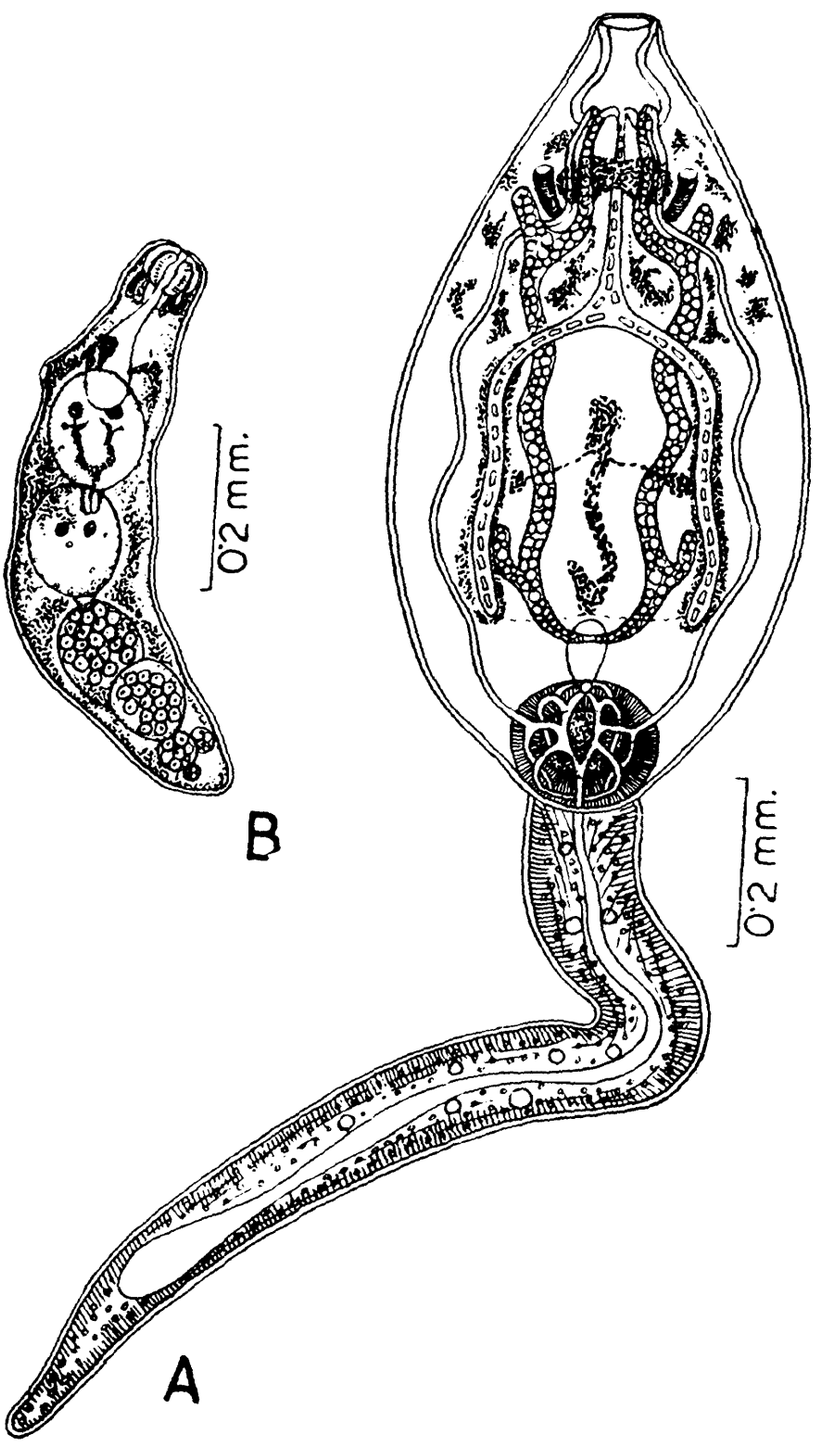


Fig. 21A. Cercaria of *Pseudodiscus collinsi* Peter and Srivastava, 1960 (After Peter and Srivastava, 1960).

B. Redia of *Pseudodiscus collinsi* Peter and Srivastava, 1968 (After Peter and Srivastava, 1960).

in middle, terminate at about junction of last two quarters of body ; yellowish brown rectangular crystal like granules present in oesophagus and caece ; main excretory ducts with two lateral diverticula present— one near caecal termination and other near eye spots ; rudiments of reproductive organs represented by genital pore, ovary, horizontally arranged testes, vasaefferentia, vasdeferens, uterus, vitelline glands, vitelline ducts.

Redia measures 0.475-1.043 x 0.170-0.229 ; sausage shape ; body pigment present ; birth pore about 1/4th from anterior end ; oral sucker measures 0.046 x 0.055 ; gut sacular, empty sac ; salivary glands present ; flame cells three pairs.

Metacercaria measures 0.356 in diameter ; cyst wall measures 0.022 in thickness.

Snail host : *Indoplanorbis exustus*

Locality : Bareilly.

V. DIPLOCOTYLEA GROUP

Diagnosis (emended) : Oral diverticula in cercaria present ; transverse excretory duct between two main canals in cercaria absent ; locomotor appendages in immature and mature redia present.

KEY TO INDIAN SPECIES

1.	Body pigment in cercaria present	2.
	Body pigment in cercaria absent	*C. helicorbisi.*
2.	Oesophageal bulb present	3.
	Oesophageal bulb absent	*C. indicae XXI.*
3.	Excretory granules present in retrograde excretory tube and intestinal glands present in cercaria	*C. kylasami.*
	Excretory granules in retrograde ezcretory tube and intestinal glands absent in cercaria	4.
4.	Excretory granules present throughout the length of main excretory canals	*C. bareillyi.*
	Excretory granules in posterior and anterior portions of main excretory canals absent	*C. mathurapurensis.*

20. **Cercaria bareillyi** Peter and Srivastava, 1955.

(Fig. 22. A & B.)

1955. *Cercaria bareillyi* : Peter and Srivastava, *Indian J. Helm.*, 12 ; 68-70.

Diagnosis : Body pigment in flecks distributed all over body with dark concentrated patches in second quarter of body ; body measures 0.308-0.756 x 0.175-0.350 ; tail measures 0.609-0.924 x 0.077-0.098 ; eye

spots conical with lenses ; oral sucker measures 0.146 x 0.088, oral diverticula rudimentary ; acetabulum measures 0.135 x 0.145 ; oesophagus 1/5th

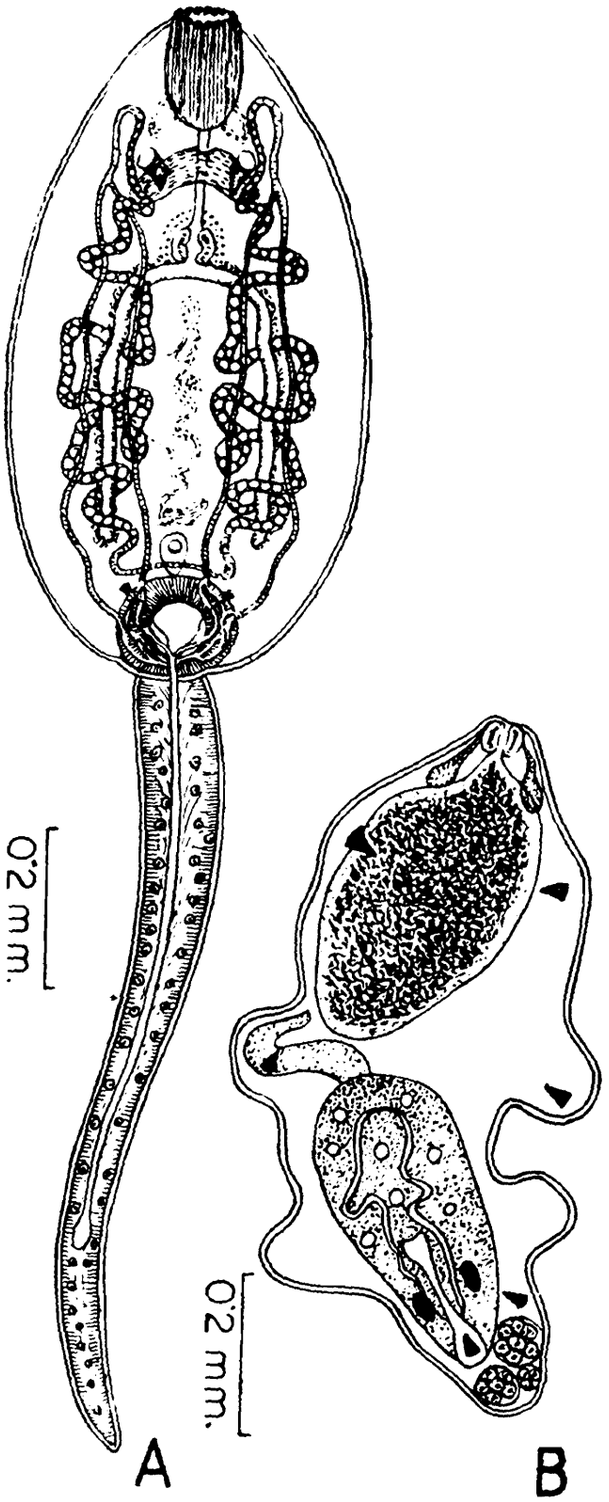


Fig. 22A. *Cercaria bareillyi* Peter and Srivastava, 1955 (After Peter and Srivastava, 1955).

B. Redia of *Cercaria bareillyi* (After Peter and Srivastava, 1955).

body length, oesophageal bulb present ; caeca slightly convoluted, extending posterior to 3/4th body length : main excretory ducts highly coiled around caeca ; rudiments of reproductive organs represented by genital pore, ovary, tandem testes, uterus, vasaefferentia, vasdeferense.

Redia measures 0.70-1.12 x 0.26-0.40 ; locomotor appendages present ; oral sucker 1/26th of body length ; gut filled with dark granules, extends to level of anterior or posterior locomotor appendages ; birth pore at junction of first two quarters of body length.

Metacercaria measures 0.378 in diameter.

Snail host : *Indoplanorbis exustus*

Locality : Bareilly.

21. **Cercaria helicorbisi** Kumar, Dutt and Jain, 1968

(Fig. 23.)

1968. *Cercaria helicorbisi* Kumar, Dutt and Jain, *Indian J. Helm.*, 20 (1) : 40-45.

Diagnosis : Body dirty white in colour, unpigmented, pyriform ; body measures 0.357-0.687 x 0.293—0.508 in live and 0.56-0.66 x 0.36-0.45

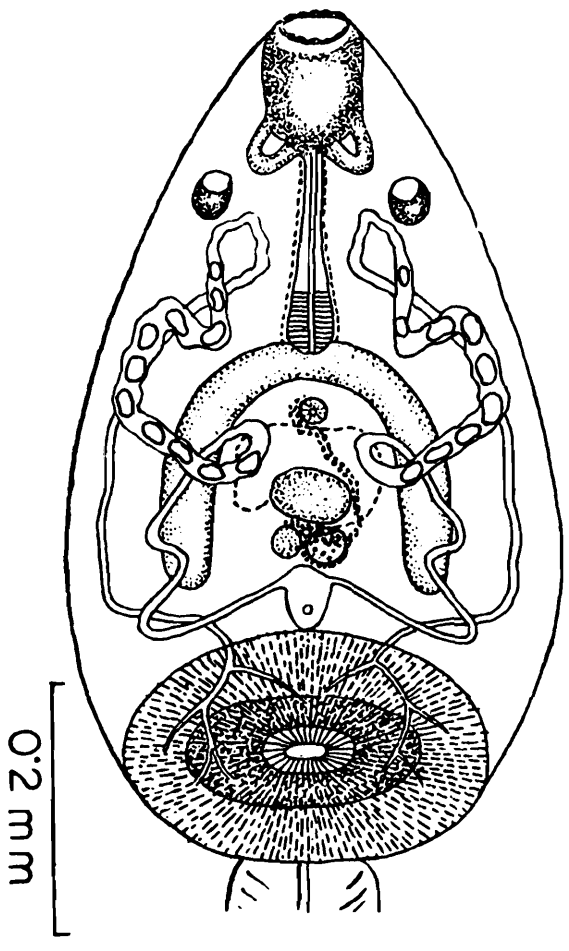


Fig. 23. *Cercaria helicorbisi* Kumar, Dutt and Jain 1968

in fixed specimens ; tail twice the length of body ; eye-spots with clear lenses, measures 0.040-0.068 x 0.025-0.045 ; mouth with indistinct papillae ; oral sucker measures 0.104-0.127 x 0.089-0.109 ; acetabulum muscular, large, measuring 0.145-0.182 x 0.265-0.279 ; thick wall oesophagus, measures 0.114-0.158 in length, oesophageal bulb measures 0.05 x 0.04 ; caeca wide, measures 0.183-0.375 in length ; main excretory ducts without excretory granules at proximal and distal ends, filled with granules at middle region only ; rudiments of genital organs represented by testes, ovary, genital pore, uterus, vasa efferentia, vasdeferens.

Snail host : *Helicorbis coenosus.*

Locality : Bareilly

22. **Cercaria indicae** *XXI* Sewell, 1922

(Fig. 24. A—C.)

1922. *Cercariae indicae XXI* : Sewell, *Indian J. Med. Res. (Supl.)* 10 : 82-88.

Diagnosis : Body with scattered pigment, located between and behind eye spots, pigment on dorsal side forms two very distinct irregular longitudinal bands on either side of middle line and pigment aggregate into masses at intervals, two similar less marked pigment lines present on ventral side ; body measures 0.438-0.965 x 0.300-0.088 ; tail measures 0.614-0.877 in length, 0.088 in diameter at base ; oral sucker measures 0.178 x 0.118 ; acetabulum measures 0.158 in diameter ; eye-spots conical, lenses present, measures 0.035 x 0.026 ; mouth papillonated ; oral diverticula present : oesophagus short, wide, oesophageal bulb absent ; caeca wide, long, terminate into, spirally coiled blind ends ; main excretory ducts follow irregular wavy course, fiilled with excretory granules, tip of caudal excretory duct provided with a pair of short straight canals to open outside ; rudiments of genital organs represented by ovary, genital pore, tandem testes, uterus, vasaefferentia, vitelline glands.

Redia measures 1.316 x 0.351 ; two pairs of locomotor appendages present ; gut well developed, filled with dark brown granules ; oral sucker measures 0.053 ; eight large pyriform glands present around oral sucker ; three pairs of flame cells present.

Metacercaria measures 0.386.

Snail host : *Indoplanorbis exustus.*

Locality : Calcutta.

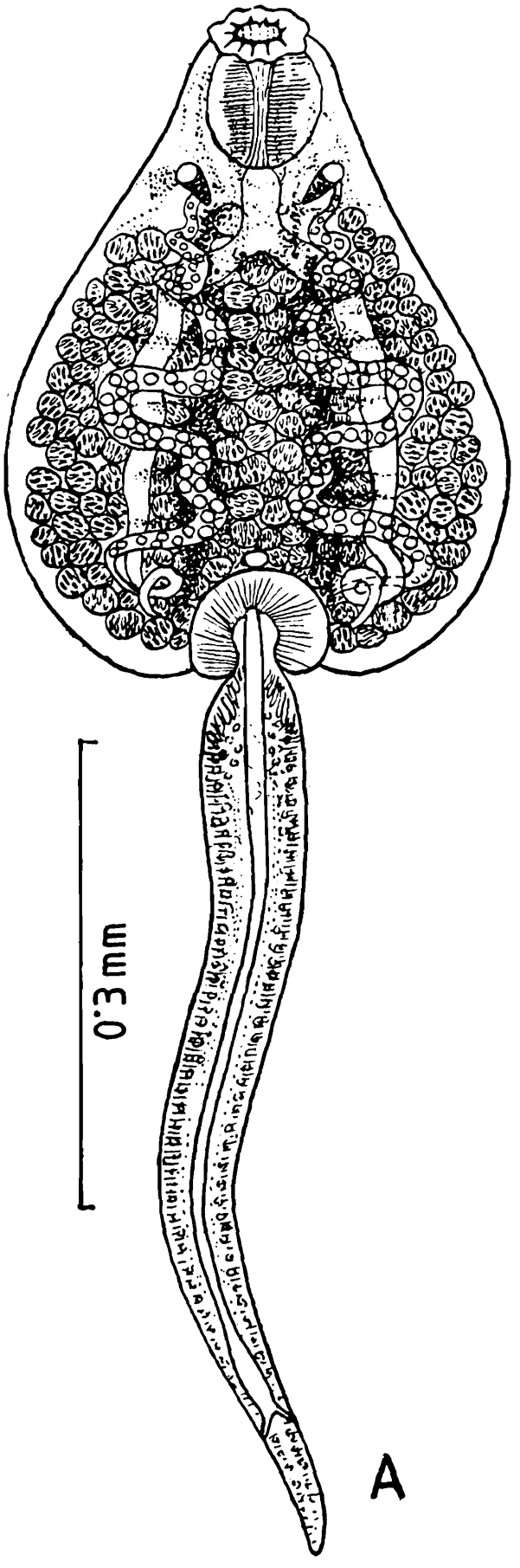


Fig. 24A. *Cercaria indicae* XXI Sewell, 1922 (After XXI Sewell. 1922).

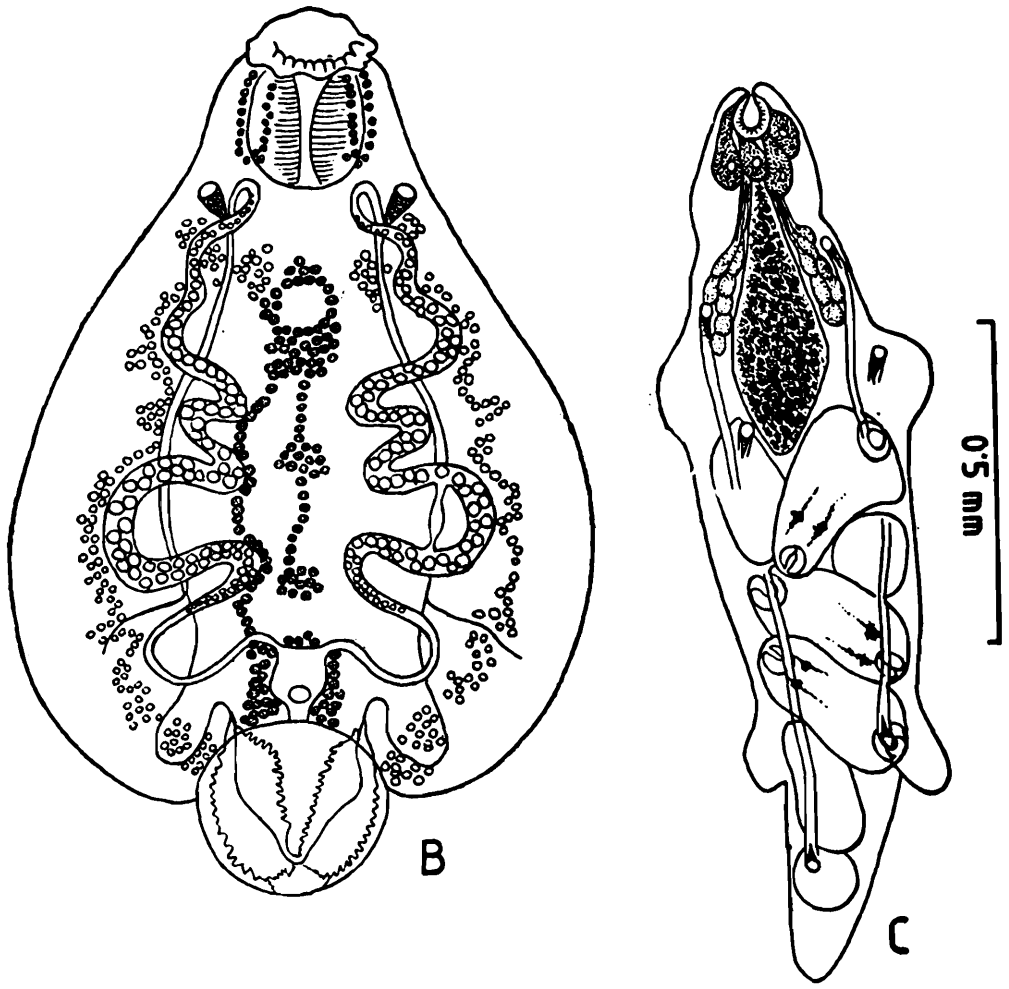


Fig. 24(B-C). Redia of *Cercaria indica* XXI Sewell, 1922 (After XXI Sewell, 1922).

23. **Cercaria kylasami** Rao, 1932.

(Fig. 25. A-C.)

1932. *Cercaria kylasami :* Rao, *Indian J. Vet. Sci. Anim. Husb.*, 2 : 259-261.

Diagnosis : Body large, pigmented ; eye spots conical with lenses ; oral sucker well developed, rim of cuticle with sinuous, oral diverticula present ; oesophagus provided with muscles at its bifurcation ; two intestinal glands one in each caecum present, glands open into muscular portion of oesophagus ; caeca long, fairly wavy ; main excretory ducts follow tortuous course, replete with excretory granules, excretory granules present in retrograde tubule also, granules disappear in tubules in posterior third of body, caudal excretory duct opens to exterior by two small canals ; genital rudiments represented by testes, ovary.

Redia with short gut full of dark materials ; three flame cells present ; birth pore some distance behind oral opening ; each redia with three to four mature cercariae.

Snail host : *Planorbis exustus*

Locality ; Egmore.

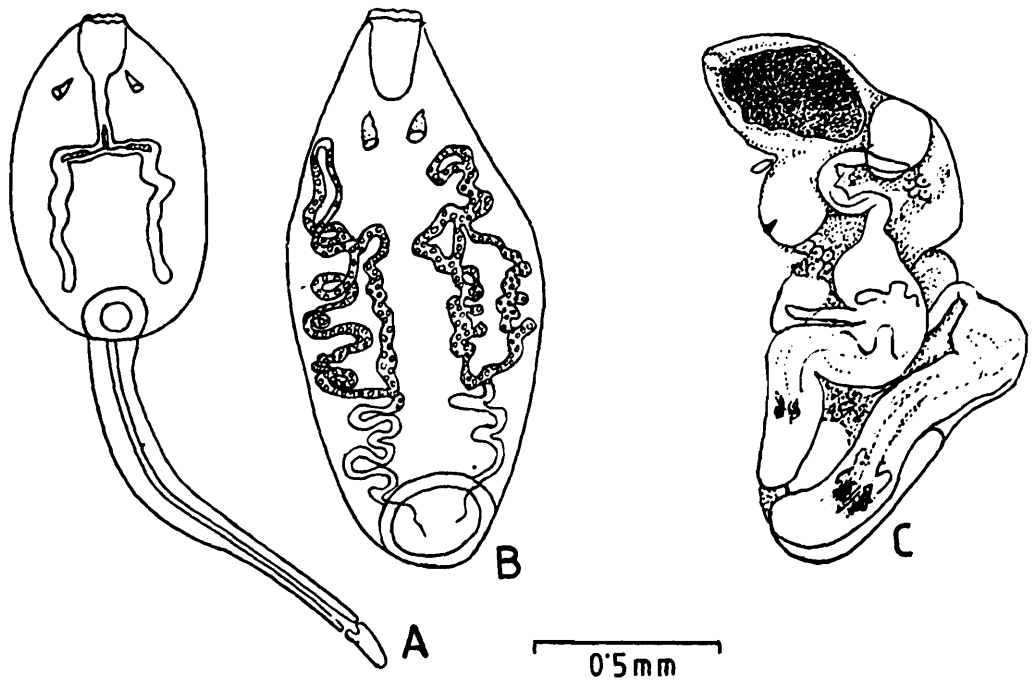


Fig. 25(A-B). *Cercaria kylasami* Rao, 1932 (After Rao, 1932).
C. Redia of *Cercaria kylasami* Rao, 1932 (After Rao, 1932).

24. **Cercaria mathurapurensis** Mukherjee, 1960 (=Syn. *Cercaria onkari* Jain, 1972 *Cercaria chandrapali* Bansal and Jain, 1976). (Fig. 26. A & B.)

1960. *Cercaria mathurapurensis* : Mukherjee, *Proc. Indian Sci. Congr.*, 47 : 439.

1968. On two new amphisome cercariae : Mukherjee, *Indian Jour. Helm.*, 20 (2) : 155-168.

1972. *Cercaria onkari* : Jain, *Zool. Anz* 188 (3-4) : 261-267.

1976. *Cercaria chandrapali* : Bansal and Jain, *Agra Univ. J. Res. (Sci.)*. XXV (3) 5-10.

Diagnosis ; Black Body pigment restricted mostly between two caeca at anterior half of body, at places pigment presents in patches ; body measures 0.643-1.095 x 0.313-0.434 ; tail measures 0.608-0.817 x 0.069-0.104 ; eye spots conical with lenses ; oral sucker measures 0.076-0.115 x 0.057-0.096, oral diverticula present ; acetabulum measures 0.103-0.146 x 0.103-0.146 ; oesophagus measures 0.107-0.269 in length, oesophageal bulb present ; caeca long ; main excretory ducts much coiled, form loops at places, two big loops present, large posterior and small anterior parts of main ducts devoid of cxcretory granules ; rudiments of reproductive organs represented by ovary, genital pore, diagonally tandem testes, uterus, vasaefferentia, vasdeferens, vitelline glands, vitelline ducts.

Redia measures 0.747-1.478 x 0.208-0.486 ; oral sucker measures 0.269-0.384 x 0.269-0.384 ; gut large, provided with dark brown black pigment.

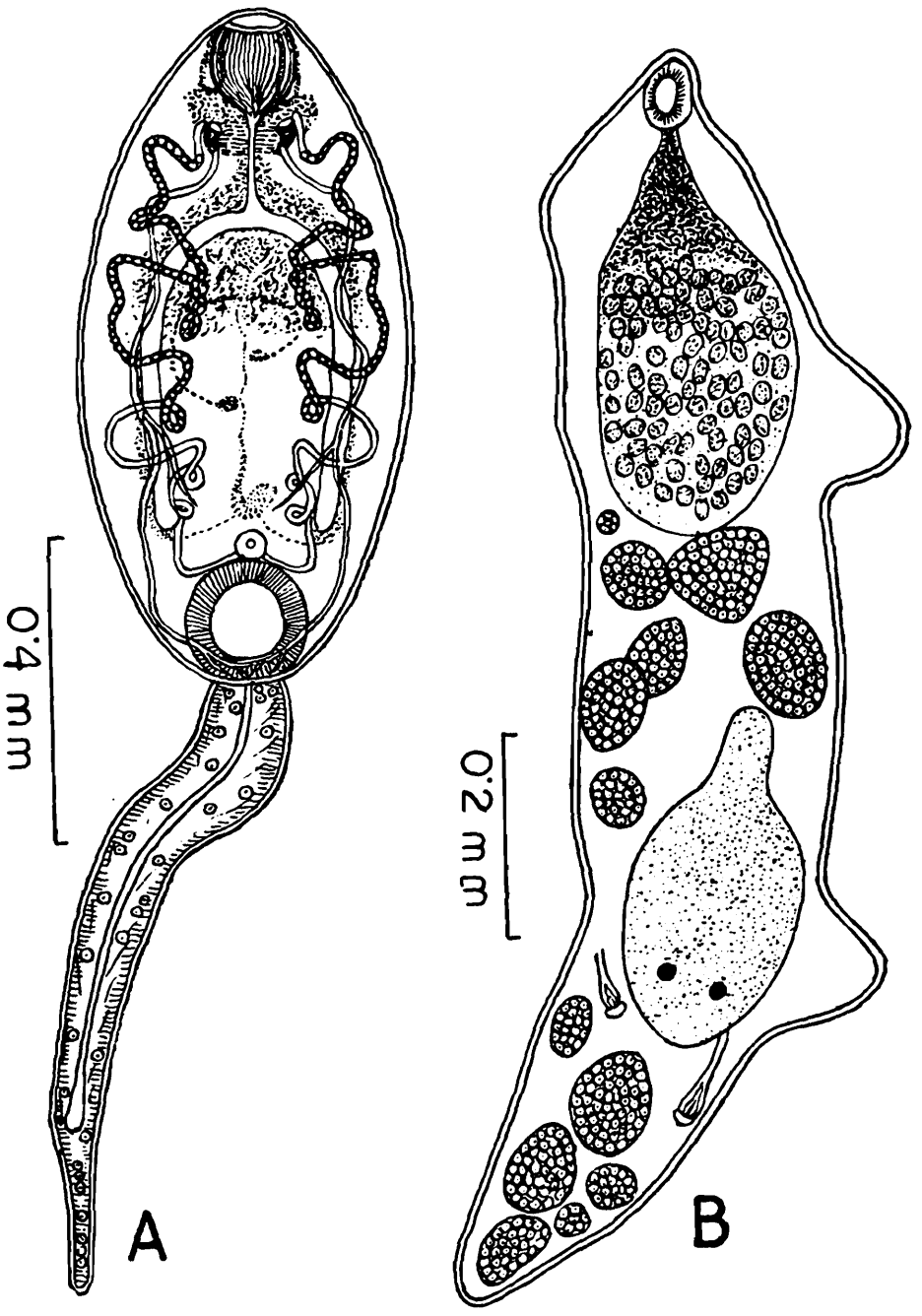


Fig. 26A. *Cercaria mathurapurensis* Mukherjee, 1960 (After Mukherjee, 1960).
B. Redia of *Cercaria mathurapurensis* Mukherjee, 1960 (After Mukherjee, 1960).

Metacercaria measures 0.347-0.399 in diameter ; cyst wall measures 0.034-0.052 in thickness.

Snail host : *Indoplanorbis exustus*

Locality : Bareilly

VECTOR SNAILS OF AMPHISTOMES.

(Plate I. A-G.)

Most of the snails which act as vectors of amphistomes are widely distributed in this country. However, their population varies from season to season and are found in abundance generally during the rainy and winter seasons. Many cases of amphistomasis in Indian cattle were recorded during the rainy season or just after the rains when the snail population started to built up. Heavy mortality in the snails was recorded by many workers during the summer months when the temperature increased and the tanks and diches began to dry. The brief descriptions of the snails that act as vector of amphistomes are given below.

Lymnaea acuminata (A) : It generally lives in fresh water ponds with abundant vegetation and distributed throughout India. It is a most variable species and exhibits considerable plasticity and response to environment. The main characters are aperture relatively high and narrow, whorls not tumid and upper extremity never flattered or truncated, suture linear, body whorl not inflated, with high spire and pointed apex.

Lymnaea luteola f. snccinea (B) : It is distributed from Kashmir to Assam, Western and Southern India. The shells are rather pale, thin, with characteristic sculpture which includes very fine spiral striae interrupted by longitudinal striae, large and narrow tith large tapering spire and comparatively small mouth and arched outer lip.

Indoplanorbis exustus (C) : It is commonly found in stagnant water, ponds, pools and tanks throughout the plains of India from east of Jammu to West Bengal, Assam and South India. Outside India it is reported from Siam, Malaysia, Indo China, Sumatra and Pakistan.

The main characters are large and thick discoidal shell, whorls convex with deeply impressed sutures, aperture ear shaped. sinistral, foot short and leaf shaped, tentacles elongated and filiform with sessile eyes, situated on their bases.

Digoniostoma pulchella (D) : It is reported from the plains of India, east of Jammu, West Bengal, Assam and South India and is found in small ponds and pools. The main characters are shell ovately conical with pointed spire, sutures depressed, umbilicus practically closed, the channel running forward from it is not so deep or well defined, the angle at the inner extremity of the lip is also blunted or rounded off, operculum distinctly concentric and surface divided into several distinct areas by prominent concentric ridges.

Gyraulus convexiusculus (E) : The geographical range of this species extends from lower Mesoptamia through eastern Persia, Afghanistan and northern India to upper Burma, Indo China, China, Japan and the Malay Archpelago. It is common on weeds in channels, pools and ponds. As in many other species in this family it rises to the surface in the evening and crawls shell downwards on the surface of the water film.

Shell of this specics rarely exceeds 5 mm in diameter, depressed, pale horn colour, shining, closely and obliquely striate, whorls 4 or 5 deeper with well defined sutures, whorls raising gradually and spirally from the horizontal and rounded below, umbilicus wide, aperture ovato lunate but not influenced by the periphery, hence no angle on the middle of the outer lip is found.

Gyraulus euphraticus (F) : Though essentially a Palaearctic species, it is reported from many places in India and its distribution extends from Mesopatamia to Kiangsu Province of China. Like other species of the family it floats shell downwards but the forward movement is in the form of repeated strokes or jerks. The shell of this species is more compressed and more carinate than in *G. convexiusculus*. The shell is larger, more opaque and coarsely and irregularly sculptured. The last whorl deviates from the shpiral of the upper whorls.

Helicorbis caenosus (G) : This species is recorded from (Bhimtal, Moradabad, Bareilly, etc.) U. P. ; (Jamalpur, Manbhum) Bihar and Bengal. It is also reported from Yawnghwe Province of Burma.

Shell discoidal and planispiral, apex sunten, transparent and glossy with fine striatious, whorls narrowly coiled, each whorl embracing a greater part of the previous one, internal septa absent.

Alocinma travancorica : This species has been reported from Quilon. Shell is coloidly globose, irregularly striated, translucent, sutures impressed, whorls $4\frac{1}{2}$, convex, aperture obliqnely ovate, operculum radiately striated externally with subcentral nucleus.

REFERENCES

ANANTARAMAN, M. AND BALASUBRAMANIAM, G. 1949. A study of *Cercaria fraseri* Buckley, 1939 in Madras. *Curr. Sc.*, **18** : 124-126.

BAWA, H.S. 1939. Intestinal paramphistomiasis of sheep in Sind. *Indian Jour. Vet. Sci. Anim. Husb.*, **9** (4) : 425-429.

BHALERAO, G.D. 1931. Two new trematodes from reptiles, *Paryphostomum indicum* n. sp. and *Stunkardia dilymphosa* n. g.n. sp. *Parasit.*, **23** : 99-108.

——— 1935. Helminth parasites of the domesticated animals of India. *Imp. Coun. Agri. Res. India.* No. **6** : 50-68.

——— 1937. Studies on the helminths of India Trematoda, *IV. Jour. Helm.*, **15** : 97-124.

——— 1943. The cercarial fauna of the irrigated tract of the Nizam's Dominions, with suggestions regarding the relationship to the trematode parasites in man and in domestic and other animals. *Indian Jour. Vet. Sci. Anim. Husb.*, 13 : 294-296.

——— 1944. Some remarks on the identity of immature amphistomes causing diarrhoea in domestic animals in India. *Proc. Indian Sci. Congr.*, **31** (3) : 141.

——— 1945. The commonest amphistome of domestic animals in the Central Province and its intermediate host. *Proc. Indian Sci. Cong.*, **32** : 97.

CHATTERJEE, R.C. 1931. Preliminary observations on the life history of an amphistome cercaria *Cercariae indicae XXVI* Sewell, 1922. *Zool. Anz.*, **95** : 177-179.

COBBOLD, T.S. 1875. On the destruction of elephants by parasites : with remarks on two new species of entozoa and on the so called earth eating habits of elephants and horses in India. *Veterinairan*, **21** : 733-743.

D'SOUZA, B.A. 1949. Observations on the out break of the socalled obscure sheep disease at the Live Stock Research Station, Hosur in 1946-47. *Indian Vet. Jour.*, **25** (5) : 321-350.

DUTTA, S.C. AND SRIVASTAVA, H.D. 1972. The life history of *Gastrodiscoides hominis* (Lewis aud McConnel, 1876) Leiper, 1913—the amphistome parasite of man and pig. *Jour. Helm.*, XLVI (1) : 35-46.

DWIVEDI, M.P. 1967. *Kachugotrema amboinensis* n. g.n. sp. (Paramphistomidae : Trematoda) *Indian Jour. Helm.*, **19** : 45-55.

FISCHOEDER, F. 1901. Die Paramphistomiden der Saugetiere, *Zool. Anz.*, **24** : 367-375.

——— 1903. Die Paramphistomiden der Saugetiere. *Zool. Jahrab. Syst.* **17** (4-6) : 485-660.

FUKUI, T 1926. Three new species of amphistomata from mammals. *Jour. Fac. Sci. Japan Univ. Tokyo.* 97-113.

GUPTA, N.K. 1951. On the morphology of *Paramphistomum bathycotyle* Fischoeder (1901) a common amphistome in the bile ducts of Indian bovines. *Res. Bull. Punjab Univ. Zool.*, **15** : 33-38.

——— 1963. On *Paramphistomum epiclitum* Fischoeder, 1904, a parasite of farm animals in the Punjab. *Res. Bull. Punjab. Univ.*, **14** : 307-311.

——— AND GUPTA, P. 1969. Amphistomid parasites of some ruminants at Ernakulam (South India). *Proc. Indian Sci. Congr.*, **56** (3) : 517.

HARSHEY, K.P. 1934. On aphistome parasites of sheep and goats from Allahabad. *Proc. Acad. Sci. U.P. Agra and Oudh.* **4** : 95-106.

IYAR, P.R.K. 1949. Immature amphistomiasis in sheep in the government cattle farm, Hosur. *Proc. Indian Sci. Cong.*, **35** (3) : 87.

JAIN, S.P. 1972. On the validity of characters used in the classification of amphistome cercariae. *Zool. Anz.*, **188** (3-4) : 267-271.

JOHNSON, J.C. 1939. *Paramphistomum magnum* (New species). *Proc. Penusylv. Acad, Sci.*, **13** : 68-69.

KATIYAR, R.D. ANA VARSHNEY, T.R. 1963. Amphistomiasis in sheep and goats. *Indian Jour. Vet. Sci.*, **33** : 94-98.

KUPPUSWAMY, P.B. 1948. 'Pitto' and 'Gillar' in sheep and goats. *Indian Farm.*, **9** ; 73-74.

LEIPER, R.T. 1913. Observations on certain helminths of man *Trans. Roy. Soc. Trop. Med. Hyg.*, **6** : 265-297.

LEWIS, T.R. AND MCCONNAL, J.F.P. 1876. *Amphistoma hominis* n. sp. a new parasite affecting man. *Proc. Asiat. Soc.*, **8** : 182-186.

LOOSS, A. 1907. On some parasites in the Museum of the School of Tropical Medicine, Liverpool with a contribution on a case of distomiasis of the liver and the rectum, by Edward Cuffey. *Ann. Trop. Med. Parasit.*, **1** : 121-154.

MAPLESTONE, P.A. 1923. Revision of the amphistomata of mammals. *Ann. Trop. Med. Parasit.*, **17** : 113-212.

MAQSOOD, M. 1944. Acute amphistomiasis in a cow in Northern India. *Indian Vet. Jour.*, **20** : 266-269.

MINETT, F.C. 1950. Mortality in sheep and goats in India. *India Jour. Vet. Sci. Anim. Husb.*, **20** : 69-103.

MOGHE, M.A. 1945. Results of a survey on the nature and incidence of helminth infection in cattle, goats and sheep in the Central Provinces and Berar and Central India. *Indian Jour. Vet. Sci. Anim. Husb.*, **15** : 222-230.

MUDALIER, S.V. 1944. *Cercariae indicae XXVI* Sewell possibly larva of *Cotylophoron cotylophorum. Proc. Indian Sci. Cong.*, 31 : 112.

MUDALIER, S.V. 1945. Fatal enteritis in goats due to immature amphistomes, probably *Cotylophoron cotylophorum*. *Indian Jour. Vet. Sci. Anim. Husb.*, **15** : 54-56.

MUKHERJEE, R.P. 1960. Studies on the life history of *Ceylonocotyle scoliocoelium* (Fischoeder, 1904) Nasmark, 1937 an amphistome parasite of sheep and goats. *Proc. Indian Sci. Cong.*, **47** (3) : 438-439.

——— 1962. A study on the development and morphology of the miracidum of *Stunkardia dilymphosa* Bhalerao, 1931 an amphistome parasite of fresh water turtles. *Sec. All India Cong. Zool.* 36.

———— 1962. Studies on some amphistomatous trematodes of domesticated animals. *Agra Univ. Jour. Res.*, (*Sci*). XI (2) : 131-136.

——— 1963. On two new species of amphistomes from Indian sheep and goat. *Indian Jour. Helm.*, **15** : 70-76.

——— 1966. Studies on the life history of *Fischoederius elongatus* (Poirier, 1883) Stiles and Goldberger, 1910, an amphistome parasite of cow and buffalo in India. *Indian Jour. Helm.*, **18** (1) : 5-14.

MUKHERJEE, R.P. 1966. Seasonal variations of cercaial infections in snails. *J. zool. Soc. India*, **18** (1 & 2) : 39-45.

——— 1968. On two new amphistome cercariae. *Indian Jour. Helm.*, **20** (2) : 155-166.

———— 1980. Collection and study of larval trematodes (Platyhelminthes). *Proc. Workshop Tech. Parasitol. Zool. Surv. India.* 23-26.

——— AND SRIVASTVA, H.D. 1960. Studies on the life history of *Gigantocotyle explanatum* (Creplin, 1847) Nasmark, 1937, a common amphistome parasite in the bile duct and gall bladder of buffaloes. *Proc. Indian Sci. Cong.*, 47 : 440.

——— 1981. Studies on the life history of *Gigantocotyle explanatum* (Creplin, 1847) Nasmark, 1937 an amphistomatous parasite of bovine in India., *Jour. Zool. Soc. India.* **33** (1&2) : 111-130.

——— AND SHARMA DEORANI, V.P. 1962. Massive infection of sheep with amphistomes and the histopathology of the parasitised rumen. *Indian Vet. Jour.*, **39** : 668-670.

——— AND CHAUHAN, B.S. 1967. Studies on the trematode Fauna of India—Part V. Sub class Digenea : Paramphistomidae Fischoeder (1901). *J. Zool. Soc. India*, (1965) 17 (1 & 2) : 150-225.

——— AND CHAUHAN B.S. 1972. On Indian amphistomes. *Rec. Zool. Surv. India.*, **67** : 65-80.

NASMARK, K.E. 1937. A revision of the trematodc family Paramphistomidae. *Zool. Bid. Fron. Uppsala.* **16** : 1-565.

PANDE, B.P. 1937. On some digenetic trematodes from *Rana cyanophlyctis* of Kumaon Hills. *Proc. Indian Acad. Sci.*, **6** : 109-120.

PANDE, P.G. 1935. Acute amphistomasis of cattle in Assam. A preliminary report. *Indian Jour. Vet. Sci. Anim. Husb.* **5** : 364-375.

PETER, C.T. 1956. Studies on the cercarinal fauna of Madras-IV. The amphistome and gymanocephalous groups of cercariae. *Indian Jour. Vet. Sci. Anim, Husb.* **26** : 27-30.

——— 1958. On two new specics of amphistome cercariae *Proc. Indian Sci. Congr.*, **45** : 342-343.

——— 1960. Studies on the life history of *Gastrodiscus secundus* Looss, 1907, an amphistomatous parasite of equines in India. *Indian Jour. Helm.*, **12**(1) : 18-50.

——— AND SRIVASTAVA, H.D. 1954. Studis on the life history of *Pseudodiscus collinsi* (Cobbold, 1875) Sonsino. 1895, an amphistomatous parasite of equines in India. *Proc. Indian Sci. Congr.*, **41** : 221.

——— AND ——— 1960. Studies on the life history of *Pseudodiscus collinsi*, (Cobbold. 1875) Sonsino, 1895, an amphistomatous parasite of equines and elephants in India. *Indian Jour. Helm.*, **12**(1) : 1-17.

——— 1960. On amphistome cercariae in India with a description of some new species. *Indian Jour. Helm.*, **12** (1) : 51-73.

——— 1961. On *cercaria chungathi* Peter et Srivastava, 1955 and its relationship to *Gastrothylax crumenifer* (Crepl) *Parasit.*, **51** : 111-115.

RAMAKRISHNAN, M. 1950. An outbreak of acute amphistomiasis among cattle in Nellore districts. *Indian Vet. Jour.*, **27** : 267-272.

RAO, M.A.N. 1932. A comparative study of cercarial fauna in Madras. *Indian Vet. Jour.*, **9** : 107-111.

SAKSENA, J.N. 1966. On the egg and miracidium of *Diplodiscus amphichrus magnus* Srivastava, 1934 (Paramphistomidae, Trematoda) *Proc. 2 All India Congr. Zool.*, (1962) : 375-381.

SEWELL, R.B.S. 1922. Cercariae indicae. *Indian Jour. Med. Res.*, 10 (Suppl.) 1-370.

SHARMA DEORANI, V.P. 1964. Preliminary histopathological observations on Gigantocotyliasis in buffaloes. *Proc. Indian Sci. Cong.*, **52** : 470.

SHARMA, R.M. AND MALIK, P.D. 1960. Amphistomiasis in cattle in the Punjab. *Anim. Heal.*, 1 : 1-5.

SIDDIQI, A. H. 1965. Three new species of *Orientodiscus* (Trematoda : Paramphistomata) from freshwater turtles. *Jour. Helm.*, **39** : 377-382.

SINGH, K.S. 1955. A new method for the study of cercariae. *Curr. Sci.*, **24**(1) 21.

——— 1957. On a new amphistome cercaria *C. lewerti* from India. *Trans. American Micros. Soc.*, **76** : 366-370.

SINGH, K. S. 1958. On the development of the excretory system in the larval stages of *Gigantocotyle explanatum* (Creple. 1847). *Trans. American Micro. Soc.*, 77(2) : 89-96.

SRIVASTAVA, H.D. 1934. On a new trematodes of frogs and fishes of the United Provinces, India, Part IV. The occurence and seasonal incidence of infection of certain trematodes in the above hosts. *Bull. Acad. Sci. U. P. Agra and Oudh.* **4** : 113-119.

——— 1938. Studies on the amphistomatous parasites of Indian food fishes, Part I. Two new genera of amphistomes from Indian fresh water fish, *Silundia gangetica* cuv.et. val. *Indian Jour. Vet. Sci. Anim. Husb.*, **8** : 367-374.

——— 1938. A study of the life history and pathogenicity of *Cotylophoron cotylophorum* (Fischoeder, 1901) Stiles and Goldberger, 1910 of Indian ruminants and biological control to check thc infection. *Indian Jour. Vet. Sci. Ani. Husb.*, **8** : 381-385.

——— 1944. A study of the life history of *Paramphistomum explanatum* of bovines in India. *Proc. Indian Sci. Congr.*, **31** : 113.

——— 1944. A study of the life history of *Gastrothylax crumenifer* of Indian ruminants. *Proc. Indian Sci. Congr.*, **31** : 113.

——— 1948. On the pathogenicity of *Gastrothylax crumenifer* the common pouched amphistome of ruminants in India. *Proc. Indian. Sci. Congr.*, **34** : 174.

STILES, C.W. AND GOLDBERGER, J. 1910. A study of the anatomy of *Watsonius* (n.g.) *wotsoni* of man and 19 allied species of mammalian tremetode worms of the superfamily Paramphistomoidea. *Bull. 60 Hyg. Lab. U.S. Publ. Heal. Mar. Hosp, Serv. Washington* 1-259.

TANDON, R.S. 1951. On a new amphistome, *Olveria bosi* n. sp. from the rumen of buffalo, *Bos bubalis* from Lucknow. *Indian Jour. Helm.*, **3** : 93-100.

——— 1955. On a new amphistome *Paramphistomum spinicephalus* n. sp. from the rumen of buffalo, *Bos bubalis*, from Lucknow. *Indian Jour. Helm.*, 7 : 35-40.

——— 1958. Development and morphology of the cercaria of an amphistome, *Fischoederius elongatus* (Stiles and Goldberger, 1910) recovered from a naturally infected. *Limnaea luteola at* Lucknow. *Zool. Anz.*, **161** (7 & 8) : 200-206.

THAPAR, G.S. 1956. Systematic survey of helminth parasites of domesticated animals in India. *Indian Jour. Vet. Sci. Anim. Husb.*, **26** : 211-271.

——— 1960. A new genus of amphistomatous parasite from the intestine of a fish, *Cirrhina fulungel*, from India. *Libro Homenaje al Dr. Eduardo Caballero Y Caballero.* 315-320.

THAPER, G.S. AND SINHA, B.B. 1945. On the morphology of a new genus of amphistomes from the rumen of cattle in the United Provinces. *Indian Jour. Vet. Sci. Ani. Husb.*, **15** : 219-221.

VAIDYANATHAN, S.N. 1941. Experimental infection with *Fischoederius elongatus* in a calf at Madras. *Indian Jour. Vet. Sci. Anim. Husb.*, **11** (3) : 243.

VARMA, A.K. 1954. Human and swine *Gastrodiscoides. Indian Jour. Med. Res.*, **42** : 475-479.

——— 1961. Observation on the biology and pathogenicity of *Cotylophoron cotplophorum* (Fischoder, 1901). *Jour. Helm.*, **35** (1 & 2) : 161-168.

YAMAGUTI, S. 1958. *Systema helminthum*, Interscience. N.Y. Vol. I,

——— 1975, *A synoptical review of life histories of digenetic trematodes of vertebrates*. Keigaku Publishing Co., Tokyo, Japan.

INDEX

ERRATA

Page	Line	Printed	Read
5	15	Gold-berger	Goldberger
12	14	as poroeyst	a sporocyst
17	1	longevity	longivity
17	6	longevity	longivity
18	26	dissolved	dissolv
21	15	fluctuation	fluctuations
25	22	distance testes	distance between testes
31	33	(cercariae Indicae XXXII Jain and Sharm, 1971)	(=Cercariae Indicae XXXII Jain, Gupta and Sharma, 1971)
33	After 8 lines (No. 4) add (=*Cercaria chelawaensis* Srivastava, 1978)		
33	After 10 lines add 1978 *Cercaria chelawaensis* : Srivastava, Indian Acad. Sci., 87B (12) : 329-337,		
35	6	established	establish
38	35	Goldbergen	Goldberger
47	28	unclei	nuclei
59	37	miracldium	miracidium

PLATE I

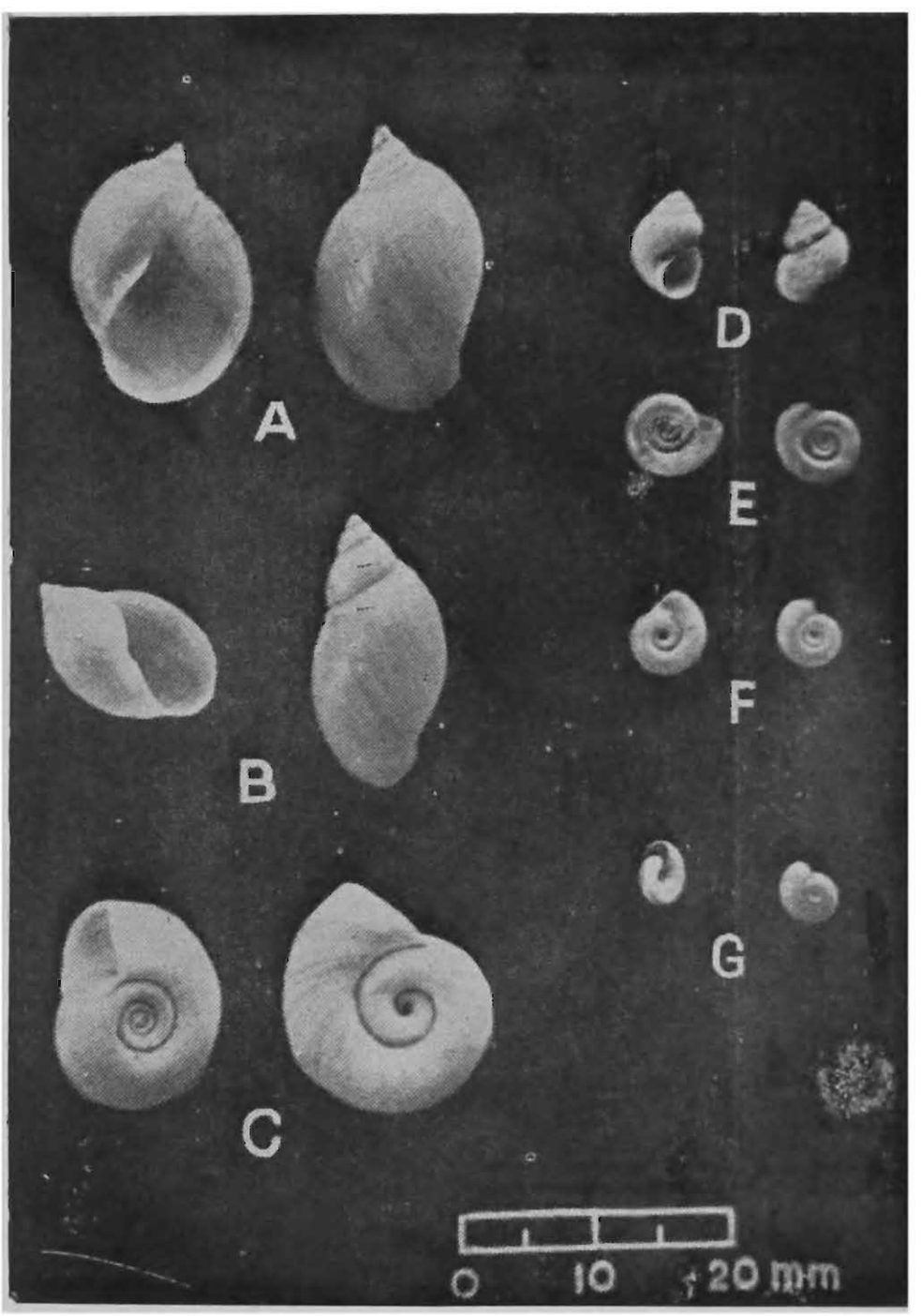


Plate I (A-G)
Vector snails of amphistomes.

Dr. R. P. Mukherjee, born at Gorakhpur in Uttar Pradesh, took his Ph.D. degree from Agra University on the Amphistomes of domesticated animals. After a brief stay at Indian Veterinary Research Institute, Izatnagar, Dr. Mukherjee joined the Zoological Survey of India in 1961. He has been working on helminth parasites for the last three decades and has contributed on their systematics, life history and ecology. For the last one decade Dr. Mukherjee has been studying the behaviour and ecology of non-human primates of India and in this field also he has made notable contributions. His forthcoming volumes deal with other larval trematodes of India.