PROGRESS REPORT ON A SURVEY OF THE FRESHWATER GASTROPOD MOLLUSCS OF THE INDIAN EMPIRE AND OF THEIR TREMATODE PARASITES.

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PART I.

BY

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ORIGIN OF THE SURVEY.

IT was not until towards the end of the war that I was able to persuade the Government of India to make any military use of the special knowledge of zoologists officially employed in the country as such. In May 1918, however, I arranged to undertake investigations on the purely biological aspect of the inland fisheries, with a view to placing information at the disposal of the authorities concerned with the food-supply of India; but on discussing the matter personally with Major-General W. R. Edwards, Director-General, Indian Medical Service, and asking him whether it would not be possible for us to give more direct assistance in

medical matters, he suggested that it would be of great help to his department if we could find out something about the etiology of the disease Schistosomiasis under Indian conditions. It was known that Indian troops were returning to India from Egypt and East Africa infected with this disease, which there was no reason to regard as previously endemic in the country. The researches of Leiper had recently drawn attention to the importance of the purely biological aspect of Schistosomiasis, which is due to certain trematode worms that necessarily pass one stage in their life-history as parasites in certain water-snails. It was most important, therefore, to discover whether these parasites were found in any indigenous mollusc and, if this was not the case, whether any indigenous mollusc was capable of being infected by them through the agency of human beings suffering from the disease. A scheme for the investigation of these points was drawn up by Dr. S. W. Kemp, Superintendent, Zoological Survey of India, and myself and was approved by the Sanitary authorities.

TOURS.

As there was reason to suspect that one of the districts most open to danger was that round Hyderabad, Deccan, owing to the heavy infection of the Imperial Service troops of H. E. H. the Nizam, Dr. Kemp proceeded direct to Secunderabad in August 1918, while I made a tour through the eastern districts of the Madras Presidency and inland to the base of the Nilgiri hills, in order to discover the precise distribution and mode of life of the different molluscs found in all bodies of water that could be visited. We met in Hyderabad at the beginning of September and returned together to Calcutta *vid* Vizagapatam in the north-east of the Presidency.

On the 4th November, having been delayed by the illness of one of us, we started for Seistan in the extreme east of Persia, as the authorities were apprehensive of the introduction of Schistosomiasis from that quarter. After spending some weeks in Seistan we visited several localities in Northern Baluchistan and the Nushki desert. Dr. Kemp then returned to Calcutta, while I proceeded through parts of the North-West Frontier Province to the northern part of the Punjab. I returned to Calcutta at the end of January 1919.

In the meanwhile Dr. Baini Prashad, who was then attached to the Bengal Fishery Department, kindly undertook, while on leave, to make a survey of the molluscs of the southern part of the Punjab.

In February and March Dr. F. H. Gravely paid, for the same purpose, a visit of about three weeks to the Central Provinces. Shorter visits were also made by myself to Ranchi in Chota Nagpur and to various localities in the vicinity of Calcutta, and by both Major Sewell and myself to the south end of the Chilka Lake in the Ganjam District of Madras.

The first half of April 1920 was occupied by Major Sewell, who had just rejoined the post of Surgeon-Naturalist from military duty, and myself in making a survey of the aquatic molluscs of certain parts of the Nilgiri plateau. Major Sewell also spent a fortnight in July in Bombay and certain places in the Western Ghats between that city and Poona, and travelled for about three weeks in October in the eastern part of the Nilgiri plateau and the adjacent Wynaad, tracing the distribution of the molluscs and their parasites downwards and westwards to the narrow plain between the Ghats and the sea.

These extensive tours could not be paid for from the ordinary budget of the Zoological Survey, and a special grant of Rs. 6,000 was made for the purpose from the Indian Research Fund Association in 1918. In 1920 an additional grant of Rs. 7,000 was made by the Education Department of the Imperial Government, partly to cover special expenses of the Seistan tour and partly for the salary of Major R. B. Seymour Sewell, I.M.S., while acting as Superintendent. In the course of our travels we were indebted for assistance to a large number of officials belonging to different departments. I may specially mention the names of Dr. A. Lankester, head of the Medical Department in Hyderabad, Capt. A. J. Powell, R.A.M.C., who was stationed in Secunderabad, Sir Frederick Nicholson, K.C.S.I., at the time Honorary Director of Fisheries in Madras, Mr. Sundara Raj of the same department, who was deputed to accompany me in my tour in Madras, Mr. B. J. Gould, I.C.S., and Major D. Heron, I.M.S., C.I.E., respectively British Consul and British Vice-Consul in Seistan, and Capt. C. H. Donald, Warden of Fisheries in the Punjab, who accompanied me in that province. I must also express my thanks to Capt. Froilano de Mello, of the Medical Service of Portuguese India, for sending many specimens from that country, and to Dr. H. H. Marshall, of Rangoon, for specimens from Burma.

We have been obliged to leave Sind out of consideration in our survey because the Government of Bombay wished to do the work themselves.

Malacological Results.

As a result of these tours and of laboratory work undertaken subsequently and in the intervals I have been able to examine practically all the freshwater Gastropod molluscs of the plains of India proper and of Baluchistan. The material already present in the Indian Museum made it possible to compare that freshly collected and observed in the field with specimens from other parts of the Indian Empire. The claim may seem a large one, but its foundations are greatly strengthened by the fact that, among the many thousands of specimens examined from Peninsular India and the Indo-Gangetic plain, the number of new species represented was extremely small; indeed, only one minute mollusc was found in the plains that had not been already described. In short, the work of the older Indian conchologists has been proved by recent investigations to be extraordinarily complete so far as it goes. On the other hand, numerous specimens have been collected that link together forms hitherto regarded as specifically distinct, and much confirmatory evidence has been obtained by the examination of the living animals and the dissection of preserved specimens. We are now able, further, to lay down the geographical boundaries of the range of different species and groups with a certainty that was hitherto impossible, while much information has been obtained as to the conditions in which all the common species can live and flourish.

The Zoogeography of the Indian Aquatic Molluscs.

I propose here to give a brief statement as to the zoogeography of the freshwater Gastropod molluscs of Peninsular India, the Himalayas and Baluchistan. It is not yet possible to do so in a satisfactory manner for Burma and Assam.

Even excluding these two provinces, the Indian Empire does not form a single unit in zoogeography, for its territories extend into two of the main zoogeographical regions of the world, namely, the Palæarctic and the Oriental. So far as the freshwater molluscs are concerned, the mountain valleys of the northern tributaries of the Indus and, probably, the whole country west of that river belong to the Palæarctic Region, while the Indo-Gangetic plain and Peninsular India, and even the lower valleys of the eastern Himalayas, belong to the Oriental. We have, therefore, two main types of molluscan fauna to consider; and these types, in view of the common facies of all freshwater molluscan faunas,

may be regarded as very distinct. Even in the Palæarctic sections, moreover, the type of Gastropod fauna found within the limits of the Indian Empire is by no means uniform. Indeed, two subsidiary types may be distinguished, one occupying the Upper Indus watershed, the other the hills of North Baluchistan and the Perso-Baluch desert. As in the Oriental sections of India the molluscan fauna is much more uniform, we may distinguish three distinct types of fauna in the country under consideration. I shall call these the Eurasian, the Afghan and the Indian types, the first two being Palæarctic, the third Oriental. Each type may be discussed briefly.

The Eurasian Type of Aquatic Molluscan Fauna.

This type is at present fairly well known from the work of the older conchologists, so far as the shells are concerned, and in reference to the valley of Kashmir and the Upper Kangra valley. It is very similar to the type prevalent in Great Britain and many of the species are the same in the two countries; for example, *Bithynia tentaculata, Limnæa stagnalis* and *L. truncatula*. The only species known to be of any sanitary importance is *Limnæa truncatula*, the common host in Europe of the asexual generation of the Liver-fluke of sheep and cattle (*Fasciola hepatica*), an occasional parasite of man.

The Afghan Type of Aquatic Molluscan Fauna.

The geographical range of this type, which has been investigated by Dr. Kemp, Dr. Baini Prashad and myself, extends from the mountains of Afghanistan, through those of Baluchistan and across the Perso-Baluch desert, to Seistan. Some of its species are also found in Mesopotamia. The fact that Dr. Kemp and I found in Baluchistan and Seistan very few species that had not already been discovered eighty years ago by Hutton between Quetta and Kandahar proves that the fauna is now fairly well known. It consists of species distinctly different from those of the northern parts of the Palæarctic region and includes an undoubted Indian (*i.e.*, Oriental) element, but most of the species seem to be related rather to Palæarctic than to Oriental forms. No species is known to be a carrier of human disease, but strong circumstantial evidence was obtained by Dr. Kemp that one of the commonest (*Limnæa gedrosiana*) was the intermediate host of the southern liver-fluke of sheep and cattle (*Fasciola gigantea*), another trematode occasionally parasitic in man.

The Indian Type of Aquatic Molluscan Fauna.

One of the most important results of our investigations has been the proof that the aquatic molluscan fauna of all the plains of India, from Peshawar to Cape Comorin and from Bombay to Calcutta, is extremely uniform. Certain species (*e.g.*, *Vivipara bengalensis* and *Limnæa acuminnata*) are only found in places where there is a perennial supply of still water and, so far as the *Limnæa* is concerned, of succulent aquatic vegetation, while others, such as certain forms of the *Vivipara dissimilis* group, are specially modified to withstand periodic desiccation; but their distribution in either case depends on purely local conditions rather than on geographical factors in a wider sense.

Within the territory of the Indian type of acquatic molluscan fauna we find, as I have already inferred, certain little patches of territory that possess a fauna distinguished by the presence of isolated genera and species. Most of these patches of territory occupy mountain ranges. In the northern part of the Western Ghats, from the latitude of Bombay to that of Mahableshwar, two peculiar genera have their home, namely, *Cremnoconchus* and *Lithotis*. Both of these genera live on damp rocks in the spray of waterfalls and may be classed as quasi-aquatic rather than aquatic. *Cremnoconchus* belongs to the family Littorinidæ, which is otherwise exclusively maritime and estuarine. Some of its species are mainly terrestrial in habits, the majority amphibious. The presence of *Cremnoconchus* on the rocks of the Western Ghats is believed to be due to the fact that they were once surrounded by the sea. *Lithotis*, on the other hand, is a representative of the terrestrial and amphibious family Succineidæ, and has assumed a limpet-like form in correlation with its habit of clinging to rocks subject to the effects of a strong flow of water. The territory of *Cremnoconchus* and *Lithotis* is also occupied by a curious aquatic genus of Hydrobiidæ recently described by myself under the name *Sataria*. On the Mysore plateau, and on the east coast from Madras southwards, another genus of Hydrobiidæ (*Mysorella*) of restricted range, but also found in Ceylon, flourishes in rice-fields and ponds, while on the Nilgiri plateau a species of *Neritina*, a genus in India distinctly estuarine, has managed to survive. The hill-streams of southern India, although they have a very limited molluscan fauna, support a considerable number of species of the genus *Paludomus*, one species of which lives also in certain parts of the plains of western and southern India but does not make its way into the Indo-Gangetic plain. A closely allied genus (*Stomatodon*) is peculiar to the hills of Travancore. At the

other end of India proper a few Burmese forms have made their way into the Gangetic delta, notably *Melanoides lineatus* and *Acrostoma variabile*. The only other exception that I have been able to discover to the rule that the aquatic molluscan fauna of the Gangetic plain and Peninsular India properly so-called is homogeneous is that of the extraordinary genus *Camptoceras*, which is at present known only from Kashmir, the Ganges valley, that of the Brahmaputra, Manipur and Japan. The species of this genus are, however, sporadic in their appearance and only one of them (*C. lineatum*), which was originally described from the Dacca district and was recently rediscovered by myself in Manipur, has been found on more than one occasion.

With these exceptions, then, we may treat the Indian fauna in a restricted sense as a single unit, so far, at any rate, as the aquatic Gastropods are concerned. Its common species are *Amnicola orcula, Digoniostoma cerameopoma, Vivipara bengalensis, V. dissimilis* (*sensu lato*), *Pachylabra globosa* (*s. l.*), *Melanoides tuberculatus, M. scabra, Limnæa luteola, L. acuminata, Indoplanorbis exustus, Gyraulus euphraticus, G. convexiusculus* and, perhaps, *Ancylus* (*Ferrissia*) *verruca*.

No direct proof is yet forthcoming that any of these molluscs have a sanitary importance, but Major Sewell's investigations render it probable that at any rate *Indoplanorbis exustus* and *Limnæa acuminata*, two of the commonest and most widely distributed water snails, may, in certain circumstances, details of which are as yet unknown, harbour the asexual generation of trematodes affecting human health. In Bombay, Lt.-Col. W. Glen Liston, I.M.S., and Dr. M. B. Soparkar have proved that *I. exustus* is the carrier of a serious cattle-pest, *Schistosomum spindalis*.

Synopsis of the true Freshwater Gastropods of the Plains of Peninsular India and the Indo-Gangetic Trough.

The species found in the plains of India are so few that it is already possible to give a synopsis of the families, subfamilies and genera, and in most cases genera of the species.

Key to the Families of the Freshwater Gastropods found in the Plains of India.

A. Operculate forms.

1. Shell thick, porcellaneous, hemispherical, with the spire small and flattened, lateral and directed obliquely backwards,

sometimes practically absent; aperture large, broadly truncate posteriorly. Operculum calcareous, semi-circular or quadrate, occasionally hidden in the muscles of the foot, provided with internal processes .. *Neritidæ.*

2. Shell more or less ovate, globose or elongate, with the spire pointing directly backwards and the aperture pointed or rounded posteriorly. Operculum without internal processes.

(*a*) Shell of small size (less than 1 cm. in length), with the operculum either calcareous or horny; if horny, always ornamented with a spiral figure. Male intromittent organ situated above the head, as a rule towards the right side .. *Hydrobiidæ.*

(*b*) Shell resembling that of the Hydrobiidæ but much larger, as a rule thinner and often less elongate. Operculum horny, with a strong scar on theinternal surface, never bearing a spiral figure. Right tentacle modified to form an intromittent organ in the male .. .. *Viviparidæ.*

(*c*) Shell elongate or ovate, sometimes nearly spherical, as a rule of a large or moderate size. Operculum horny, as a rule ornamented with a spiral figure. Male organ behind upper surface of head.

Melaniidæ (*Tiaridæ*).

1. Shell elongate .. *Subfam, Melaniinæ.*
2. Shell relatively broad, as a rule globose. *Subfam. Paludominæ.*

(*d*) Shell as a rule very large, globose. Operculum (in Indian forms) calcareous, with a large internal scar and without spiral figure .. *Ampullariidæ.*

B. NON-OPERCULATE FORMS.

1. Shell with the opening on the left side. Ovoid (rarely elongate) as a rule of moderate size, with the spire well developed .. .. .. *Limnæidæ.*

2. Shell as a rule discoidal, with the spire flat and the opening (morphologically) on the right side; if not discoidal, more or less elongate, with the suture between the whorls markedly deep, broad or oblique, and with the aperture distinctly on the right side .. *Planorbidæ.*

3. Shell limpet-like, without a coiled spire, small and fragile .. .. .. *Ancylidæ.*

The classification summarized in this key is in the main that set forth by Pelseneer in the volume on the molluscs in Sir Ray Lankester's *Treatise on Zoology*. Either this work or the Rev. A. H. Cooke's volume in the *Cambridge Natural History* may be consulted as to technical terms. The best figures of the shells of the common Indian species are to be found in Hanley and Theobald's *Conchologia Indica*.

It will be noted that there is no reference in the key to the family Physidæ, which is included in the official 'Fauna of British India.' Statements as to its occurrence within the limits of the Indian Empire appear to be based entirely on evidence that breaks down on investigation. Two species attributed to the genus *Physa* have been recorded from India, namely, *P. aliciæ*, Sowerby, and *P. coromandelica*, Dunker, but, as has been shown by von Martens and E. A. Smith, neither of these species actually came from India and both belong to the genus *Bullinus* or *Isidora*, which on anatomical grounds is now placed in the family Planorbidæ. I shall refer to this genus again in discussing that family.

FAMILY—Neritidæ.

The Indian species of this family are mostly estuarine or marine, and only one (*Neritina* (*Neritæa*) *perotetiana*, Récluz) has established itself inland in the Peninsula. It is found only in hill-streams in a very limited area on the Nilgiri plateau. Two other species of the same genus (*N. reticularis*, Sowerby, and *N. obtusa*, Benson) have been found in freshwater pools in the Gangetic delta.

FAMILY—Hydrobiidæ.

There has been much confusion about the Indian genera of this family, but I have been able recently to assign most of the more important Indian species to their correct genera. The following keys include all the true freshwater genera found in the area under consideration. *Stenothyra*, Benson, is exclusively estuarine and is therefore excluded. The shell is very small and has a peculiar contracted aperture and a more or less marked flattening of the body-whorl on the ventral surface. Omitting this genus, the remainder found in Peninsular India may be divided into three subfamilies as follows :—

Hydrobiinæ.—Shell minute and fragile, smooth to the naked eye, more or less elongate, with the peristome nearly or quite

continuous. Operculum horny, with a small spiral figure ; its nucleus eccentric. Central tooth of radula with not more than one basal denticulation. The external male organ without a lateral process.

Bithyniinæ.—Shell never very thick, smooth to the naked eye or with spiral ridges, ovate or globose, with the peristome continuous and the columellar fold ridge-like. Operculum calcareous, concentric or spiral. The central tooth of the radula bearing a series of latero-basal denticulations on each side.

The external male organ with a well-developed lateral process.

Mysorellinæ.—Shell rather thick, with strong spiral ridges, turbinate, with the peristome continuous and prominent. Operculum thick, calcareous, concentric. The central tooth of the radula without latero-basal denticulations but bearing a single downwardly-directed blunt process on either side. The external male organ as in the Bithyniinæ.

Although I propose to treat these subfamilies separately, it may be convenient to give a single key to all the Indian genera of the family.

Key to the Indian genera of freshwater Hydrobiidæ.

A. Operculum calcareous.

1. Operculum spiral on *both surfaces*, with the nucleus eccentric. Whorls of shell more or less tumid and body-whorl very large ; umbilicus closed or rimate ; columellar fold ridge-like but by no means prominent ; central tooth of radula with latero-basal denticulations in a series on either side .. .. *Amnicola* (*Alocinma*).
2. Operculum concentric, or mainly so, externally, with the nucleus central or sub-central, almost smooth internally.
   (*a*) Shell conspicuously perforate, turbinate, ornamented with strong spiral ridges ; peristome continuous, prominent, uniform ; central tooth of radula with a strong, blunt, downwardly-directed lateral process at each side .. *Mysorella.*
   (*b*) Shell broadly but shallowly umbilicate, with a broad oblique groove proceeding downwards from the umbilicus to the lower margin of the mouth ; sculpture consisting of fine spiral grooves ; central tooth of radula as in *Amnicola* .. *Sataria.*

(*c*) Shell narrowly umbilicate or subumbilicate, with a narrow groove descending obliquely from umbilicus but not reaching margin of mouth; columellar fold forming a sharp, prominent ridge continuous with outer lip; outer lip slightly thickened, angulate and produced at its inner extremity; central tooth of radula as in *Amnicola*. *Digoniostoma*.

B. Operculum thin and horny.

Shell minute, very fragile, elongate, with the umbilicus closed or nearly so; peristome continuous but not thickened. Animal with the characters of the Hydrobiinæ .. *Tricula*.

Subfamily—Hydrobiinæ.

This subfamily is represented in the freshwater fauna of the Gangetic valley and Peninsular India only by the genus *Tricula*, Benson, which consists of minute species with more or less elongate shells as a rule only 2 or 3 mm. long. Hitherto this genus has been known in India only from one species from Kumaon, *T. montana*, Benson. A second species, not yet described, has been discovered by Dr. F. H. Gravely in the rivers of the Central Provinces.

Subfamily—Bithyninæ.

Amnicola, Gould and Haldeman. The Indian species of this genus belong to a subgenus (*Alocinma*, Annandale and Prashad) only recently described. It is also found in Eastern Persia, Mesopotamia, Burma and Ceylon, and is distinguished from the North American subgenus *Amnicola* (*s.s.*) by having a calcareous operculum, and from the European and Central Asiatic subgenus *Pseudamnicola* in that this structure is both calcareous and spiral and of large size. It agrees in the structure of its radular teeth with the former subgenus rather than the latter. I am doubtful whether more than two species occur in Peninsular India, but a third, the southern form *stenothyroides* (Dohrn), has been regarded by most authors as distinct. I have found many shells intermediate between this form and the common *A. orcula* (Frauenfeld) of the Gangetic plain. From the latter species *A. travancorica* (Benson), which was described from the plains of Travancore and is abundant in the Wynaad, may be readily distinguished by the fine spiral lines on

its shell. As Major Sewell has discovered, *A. travancorica* is infected by a larger number of species of cercariæ than any other Indian mollusc as yet investigated, except *Melanoides tuberculatus* and *Indoplanorbis exustus*.

DIGONIOSTOMA, gen. nov. A race of the type-species of *Bithynia*, Leach, *B. tentaculata* (Linné), originally described from Europe, is apparently common in Kashmir, but its range does not extend to the plains of India, in which the species of my new genus, distinguished by the structure of the mouth of the shell, are common. The type-species is *D. ceramcopoma* (Benson).

SATARIA, Annandale. This genus has been erected to contain a single species (*Bithynia evezardi*, Blanford) only known from Satara and Khandalla in the Bombay Presidency. It is doubtful whether it occurs in the plains even in the Satara district, in which its range may very well be limited to the Mahableshwar plateau.

SUBFAMILY—MYSORELLINÆ.

The subfamily Mysorellinæ consists of a single genus and species, *Mysorella costigera* (Küster), with a local race (*curta*, Nevill). The typical form is found on the east coast of India from Madras southwards and in the plains of Ceylon, while the subspecies occurs on the Mysore plateau. The shell bears a superficial resemblance to that of the Littorinid, *Cremnoconchus syhadrensis* (Blanford), which lives in the spray of waterfalls in the Western Ghats at Khandalla near Bombay, but may be easily distinguished by the perforate condition of its base. It is remarkable for its strong spiral ridges.

FAMILY—VIVIPARIDÆ.

A considerable number of species belonging to the genus *Vivipara* have been described from Peninsular India. They fall naturally into two groups, which may be called the Viviparæ bengalenses and the Viviparæ dissimiles. The former are easily distinguished by the presence of dark spiral bands on the shell and by the thin margin and comparatively poorly developed muscular scar of the operculum. In the Viviparæ dissimiles (one Burmese species of which has been placed in a separate subgenus, *Idiopoma*, by Pilsbry) the shell is uniform in colour or bears a broad pale transverse band near the base. The operculum is much thicker and has a coarser scar, while, in certain circumstances, connected with the desiccation of the bodies of water in

which these species live, the edge of the operculum is liable to become greatly thickened.

The Viviparæ bengalenses exhibit great plasticity and individual variability, but I am convinced, after careful study of both of the shell and the soft parts of numerous specimens from different types of environment and from different localities, that only a single species (*V. bengalensis*, Lamarck) occurs within the limits of the Indian Peninsula. *V. annandalei*, Kobelt, for instance, which is referred to by its author as a 'critical' form, is merely a phase produced by life in foul water, while the form *elongata*, Swainson, is a common aberration.

The Viviparæ dissimiles have not yet been completely worked out, but I have no doubt that several distinct species occur; for example, the true *V. dissimilis* (Müller) and *V. heliciformis* (Frauenfeld).

FAMILY—MELANIIDÆ.

The shells of the two subfamilies of this family are in most species so unlike that while there is rarely any difficulty in recognizing one of the Melaniinæ by its elongate tapering form, those of the Paludominæ are often liable to be confused with shells of *Vivipara* or even *Neritina*. From all the Indian species of the former genus they can be readily distinguished by their porcellaneous texture and by the presence of a spiral figure on their operculum. From those of *Neritina* they can be readily distinguished by the direct backward orientation of their spire. In other parts of the Oriental region forms intermediate between the Melaniinæ and the Paludominæ occur, and on anatomical grounds there is very little justification for recognizing the two subfamilies.

The Paludominæ are, as already stated, mainly mountain forms and live in clear, rapid-running water. *P. tanschaurica* (Gmelin), however, is common in sluggish streams and even in rice-fields in the neighbourhood of Madras and in many parts of Western India as far north as the latitude of Bombay. The shell is smaller, narrower and more sharply pointed than that of most species of the genus. It is of a pale yellowish colour, often marked with dark spiral bands. Its thickness, combined with its colouration, renders it easily distinguishable. The species has many synonyms, but so far as I am aware all the forms found in the open plains of India south of the Indus and the Ganges can be referred to it.

The Indian Melaniinæ of fresh water have usually been referred to a single genus, *Melania*, Lamarck (=*Tiara*, Bolten), with a number of

subgenera, but they differ very considerably from typical species of the genus both in shell-structure and in the form and structure of the operculum. The true *Melania* (*s.s.*), indeed, seem to be mainly insular in distribution and is found, so far as the Indian Empire is concerned, only in the Nicobar Islands and doubtfully in one of the Andaman group. Among the Indian species, moreover, two distinct genera can be recognized, namely, *Melanoides*, Olivier, and *Acrostoma*, Brot. Olivier's genus has long priority over the Adams' genus of the same name, and is of undoubted authenticity. It has a local race of the common *M. tuberculatus* (Müller) as its type-species. This is the more unfortunate as *Acrostoma* is, to a large extent, synonymous with *Melanoides*, H. & A. Adams, though abundantly distinct from *Melanoides*, Olivier.

The two genera may be distinguished as follows :—

1. Shell never very large or heavy, occasionally almost smooth, but usually ornamented with longitudinal and transverse grooves which produce by their intersection a tuberculate pattern, occasionally with spines round the upper part of the whorls. Operculum ovate, with a small spiral figure near the base. Edge of the mantle provided with finger-shaped processes. Denticulations of radular teeth slender and relatively numerous .. .. *Melanoides*.
2. Shell as a rule much larger and heavier, elongate and tapering gradually, as a rule with at least traces of strong longitudinal ribs. Operculum almost circular, relatively small, bearing a spiral figure which occupies practically the whole of its area. Edge of mantle smooth. Denticulations of radular teeth few and stout .. *Acrostoma*.

MELANOIDES, Olivier. At least five species of this genus are found in Peninsular India. They may be distinguished as follows :—

1. Shell always very narrow, as a rule without longitudinal ribs ; if these are present, they are not produced into spines or prominent tubercles on the upper part of the whorls ; outer lip of aperture not sinuate.
   (*a*) Aperture of shell very small, considerably less than one-third the length of the whole shell. *M. tuberculatus*.
   (*b*) Aperture of shell at least one-third as long as the whole shell .. .. .. *M. pyramis*.

2. Shell as a rule broader and with well-defined longitudinal ribs, the upper extremity of which is as a rule produced into strong tubercles or even spines; outer lip strongly sinuate .. .. .. *M. scabra.*
3. Shell narrowly ovate, without any trace of longitudinal ribs, but with well-defined but narrow spiral ridges.
   (*a*) Outer lip of shell distinctly emarginate above. *M. riqueti.*
   (*b*) Outer lip of shell not emarginate .. *M. lineatus.*

The typical forms of *M. scabra* on the one hand and of *M. tuberculatus* and *M. pyramis* on the other are so distinct that they have been placed in separate subgenera, namely, *Plotia*, H. & A. Adams, and *Striatella*, Brot. (*Striatella* is an absolute synonym of *Melanoides*, Olivier.) Some forms of *M. scabra*, however, the species being extraordinarily plastic and variable, can be distinguished from *M. pyramis* only by the sinuate outer lip of the shell and by traces of the tubercles at the upper end of the ribs. This is so with the race *puteicola* recently assigned by Dr. Baini Prashad and myself to *pyramis*. Nevill was quite right in regarding it as a form of *scabra*.

M. lineatus and *M. riqueti* have also been placed in separate subgenera, the former in *Terebia*, H. & A. Adams, the latter in *Melanella*, Swainson, but the differences between them are trivial, and *riqueti* has little real resemblance to the European species to which the name *Melanella* was originally given. Both species seem to me to fall well within the limits of *Melanoides*.

M. tuberculatus is one of the commonest of freshwater molluscs practically all over Africa and Southern Asia. *M. scabra* has also an extremely wide distribution, almost throughout the Oriental and the western parts of the Australian Regions, but is less abundant than *M. tuberculatus*. *M. pyramis* is only known from India, Baluchistan, Southern Persia and Mesopotamia and appears to be of somewhat sporadic occurrence. A number of local races, however, occur, and some of these have been confused with *M. tuberculatus*. It is not yet certain whether the former species occurs in the Malay Archipelago. *M. lineatus* is mainly an Assamese species, but is common in the lower Gangetic delta, while *M. riqueti* is a scarce form, apparently of sporadic occurrence in Peninsular India, and also recorded from Java and the Philippines.

Acrostoma, Brot. The forms that I group together in this genus have usually been separated into two subgenera, *Acrostoma*, Brot., and

Brotia, von Martens (= *Melanoides*, H. & A. Adams). Certain phases and varieties of *A. variabile* found in Assam provide, however, a complete link between the two groups of species. The type-species of *Acrostoma*, *A. hugeli* (Philippi), is found both in the rivers of Southern India and in Assam, while *A. variabile* (Benson), which is mainly an Assamese and Burmese species, comes at least as far west as Calcutta, where it is one of our commonest freshwater molluscs in a somewhat dwarfed form. The shell of *A. hugeli* is readily distinguished from that of all other Melaniidæ found in Peninsular India by its massive structure and almost smooth surface. This applies to the phases and varieties of *A. variabile* found in the Gangetic delta, the shell of which as a rule bears strong longitudinal ribs; but in Sylhet and Manipur a variety of *A. variabile* occurs in which the shell resembles that of *A. hugeli* very closely.

FAMILY—AMPULLARIIDÆ.

The Oriental species of this family are distinguished from the true *Ampullaria* of America by their calcareous operculum and by the structure of the siphon by means of which they inhale air. In the American forms this is a slender tubular organ when fully extended and a mere papilla when contracted, while in those of the Oriental Region it is a conspicuous but incomplete tubular fold when contracted and a broad funnel-shaped organ when expanded. The members of the family, though not Pulmonates, possess a gill-like breathing organ. They can be distinguished from those of all other families commonly found in fresh water by the fact that they possess both stalked eyes and two pairs of tentacles. Hitherto all the Oriental species have been placed in a single genus, for which I believe that *Pachylabra*, Swainson, is technically the correct name. It is probable, however, that a small species (*A. nux*, Reeve) will have to be separated off on anatomical grounds as the type of a distinct genus. This species inhabits mountain torrents in the Bombay Ghats.

The common large species of the plains of India, in which it is widely distributed, is *Pachylabra globosa* (Swainson). The typical form of this species is, however, found chiefly in the Gangetic valley, to the east of which it is replaced by a closely allied species or race, *P. maura* (Reeve). In Peninsular India, properly so-called, the common form is *carinata* (Swainson), but this form must be regarded merely as a local race of *globosa*, for many intermediate individuals occur, and the differences between the shells and the soft parts are small. Other species are undoubtedly found both in the Gangetic valley and in Peninsular India,

but their precise synonymy has not yet been worked out. It is probable that the genus does not occur within the limits of the Indus watershed.

FAMILY—LIMNÆIDÆ.

Until comparatively recently all the true aquatic Pulmonate molluscs were grouped together in the family Limnæidæ. but it is now recognized by malacologists that at least four families can be distinguished among the Asiatic forms, namely, the Limnæidæ, the Physidæ, the Planorbidæ and the Ancylidæ.

So far as the true Limnæidæ are concerned, it is doubtful whether more than one genus can be recognized, namely, *Limnæa*, Lamarck; but the North American forms have been divided into a number of genera, largely on anatomical grounds, by Baker. The Indian forms are certainly congeneric, and practically identical in anatomy with those called *Galba* by Baker. Some peculiar species have been described from Burma and Assam on the one hand and from Baluchistan on the other, while those of the valley of Kashmir are for the most part specifically identical with European and North Asiatic species. A large number of names have been given to the forms found in the Indo-Gangetic plain and Peninsular India, but I am convinced by careful study of a very large amount of material that the late Mr. G. Nevill was right in recognizing only three distinct species. These species may be distinguished by the following key :–

1. Spire of shell narrow, tapering gradually, with the suture between the whorls very oblique, as long as or longer than the basal breadth; aperture of shell more than twice as long as broad .. .. .. *L. acuminata.*
2. Spire of shell short and broad, with the whorls increasing rapidly and the suture between them by no means oblique; penultimate whorl considerably broader than length of spire, but much narrower than upper end of body-whorl; terminal two or three whorls extremely narrow and small; body-whorl subquadrate; aperture about twice as long as broad .. *L. ovalis.*
3. Spire resembling that of *L. ovalis*, but with the whorls increasing more gradually and evenly in size, and with the penultimate whorl hardly narrower than the upper end of the body-whorl; body-whorl ovate; aperture about twice as long as broad .. .. .. *L. luteola,*

As these species may prove to be of sanitary importance, I will discuss each separately.

L. ACUMINATA, Lamarck. This species is much the most variable of the three, and the shape, size, texture and colour of the shell are so different in different specimens that it is difficult to believe them to be specifically identical unless large series are examined. We may take as extreme forms the variety called *gracilior* by von Martens and that called *patula* by Troschel. In the one, the whole shell is extremely long and narrow with the spire produced and the body-whorl more than twice as long as broad ; in the other, the spire is very nearly as broad at the base as it is high, and the body-whorl is nearly four-fifth as broad as long. Both these forms may occur together, with all intermediates, but one or other usually predominates at a given spot. On the other hand, one finds definite phases, such as Clessin's *hians*, a race common at Ootacamund, or Sowerby's *ventricularius*, which has recently been rediscovered in the Kumaon lakes. These are small mountain forms, but while *hians* has a fairly thick, pigmented shell, that of *ventricularius* is extremely fragile and almost colourless. *L. acuminata* is a species dependant on dense aquatic vegetation and is usually found in association with plants such as water-lilies that have floating leaves. It occurs all over the Indian Empire (from Peshawar to Cape Comorin and Bhamo), except in the area of the Afghan type of fauna and probably in that of the Eurasian type. It is, however, comparatively scarce in Peninsular India, doubtless owing to the rarity of a suitable habitat. A variety, probably introduced with ornamental water-plants, is also found in Mauritius.

L. OVALIS, Gray. This form is much less variable than *L. acuminata*, but several distinct varieties are recognized. It is not so common as either *L. acuminata* or *L. luteola*. Its shell is usually much thicker and coarser than that of either species and frequently attains a large size. *L. ovalis* is found in ponds with abundant vegetation, but I have also taken specimens in a large well (in the Fort at Golconda) and it appears to be a lover of mud, from which it obtains its food. The distribution is probably similar to that of *L. acuminata*, but the occurrence of the species is for some reason much more sporadic.

L. *luteola*, Lamarck. Some authors call this species *L. succinea*, Deshayes, but the identity of Lamarck's species is fixed by a comparison of Delessert's figure of the type-specimen with certain shells from Bengal, while there can be no doubt as to that of Deshayes. The typical form has a rather large but narrow shell with distinct whitish

longitudinal stripes. This form is, however, scarce. The phase *succinea*, which is also scarce, lacks these stripes, but is also large. It has the body-whorl very cylindrical. I have only seen it in ponds with abundant vegetation on the east coast of Peninsular India. The common form of the species is the phase *impura* of Troschel, a much smaller form with a broader and darker shell. This is the common *Limnæa* of Peninsular India: it is not so abundant in the Gangetic valley. The normal habitat includes small pools of muddy water, channels in rice-fields and other evanescent bodies of water, apparently in preference to large permanent ponds. The species is often almost amphibious in habits but buries itself deep in the mud in dry weather.

FAMILY—PLANORBIDÆ.

This family, so far as we know at present, is the most important, from a sanitary point of view, of all those of the freshwater Gastropods, for its members include all the known intermediate hosts of *Schistosoma hæmatobium* and *S. mansoni*, though, curiously enough, the host of *S. japonicum* in Japan is an operculate mollusc (*Hypsobia nosophora*) belonging to the family Hydrobiidæ. Both in Africa and in South America the host of *S. mansoni* belongs to the genus *Planorbis* (*sensu lato*), but I am not aware that the anatomy of these hosts has been investigated, and in the Planorbidæ the soft parts are of particular importance from a classificatory point of view. Indeed, the shell seems to be of comparatively little value in taxonomy in this family.

It is only recently that the genus *Bullinus*, in which are included the common hosts of *S. hæmatobium*, has been recognized on anatomical grounds as belonging to the Planorbidæ, and it is only within the last few weeks that I have been able, with the assistance of Dr. Baini Prashad, now Assistant Superintendent in the Zoological Survey of India, to work out the true systematic position of the Indian species of the family, most of which we have now examined.

We find in the first place that it is very doubtful whether the true *Planorbis* occurs in India, the common species representing a new genus quite distinct anatomically from the European forms with the same type of shell. The only Indian form in which the shell resembles that of *P. corneus* (the type-species) we have not examined is Clessin's *P. hindu*, but all that is known of this species is the original figure and description of the shell, published many years ago. It has not been found in India recently and its occurrence within

the limits of the Indian Empire must be regarded for the present as doubtful. All the known Indian forms with a shell of this type belong, as Mons. L. Germain has shown in a paper shortly to be published in the *Records of the Indian Museum*, to the species described by Deshayes as *Planorbis exustus*.

In the second place, we have found definite evidence that the genus *Camptoceras*, which has a shell totally unlike that of normal Planorbidæ, belongs to this family and yet is distinct anatomically from *Bullinus*. Further, we have been able to find reasons for separating the smaller forms with a discoidal shell into three genera. The results of our investigations are embodied in the following key :—

1. Shell flat and discoidal.

   (*a*) Shell large (usually over 1 cm. in diameter), comparatively thick, with swollen whorls, clearly sinistral, when young *Physa*-like. Animal with an incomplete siphon and an elongate or folded branchial process on the left side. Radula relatively large and broad ; its teeth *Limnæa*-like. Penis without stylet, long, slender, thin, uniform in diameter ; præputium hardly differentiated .. .. *Indoplanorbis*.

   (*b*) Shell small (always less than 1 cm. in diameter), thin, apparently dextral, convex above and below but flattened as a whole, usually with a more or less well-developed peripheral keel. Animal with an incomplete siphon on the left side and a simple branchial process. Radula like that of *Planorbis* but with fewer denticulations on the laterals and marginals. Penis relatively long, provided with a horny stylet .. .. *Gyraulus*.

   (*c*) Shell small or of moderate size (rarely over 1 cm. in diameter), thin, convex above, flattened below, without internal teeth or folds. Animal with an incomplete U-shaped siphon on the left side and a simple branchial process. Radula extremely small, with the teeth minute ; laterals twinned. Penis somewhat resembling that of *Segmentina* but with the vas deferens much coiled outside .. ..(?) *Hippeutis*.

(*d*) Shell small and thin, resembling that of the last genus but usually with hard enamel-like internal vertical ridges. Animal as in (*c*). Radula as in *Gyraulus*, but with the denticulations of the laterals and marginals more numerous. Penis sheath with a pair of ear-like processes above; penis oblique, stout, without a stylet .. *Segmentina*.

2. Shell elongate, ovate or very narrow, with the suture remarkably broad, deep and oblique.

Shell small and thin, sinistral, frequently ornamented with spiral lines of minute chætæ. Animal with a simple branchial process, and a well-developed left epipodial leaf-shaped lobe, which can be spirally coiled to form a complete anal funnel. Radula like that of *Gyraulus* but with broader denticulations on the teeth. Penis broad and stout, without a stylet .. *Camptoceras*.

We are a little doubtful as to the generic position of those species assigned provisionally to *Hippeutis*. The shell agrees with that of the type-species of this genus (*P. fontanus*, Lightfoot), a European form, but we can discover no account of the anatomy of that species.

INDOPLANORBIS, Annandale and Prashad. So far as we know at present *I. exustus*, which is one of the commonest freshwater molluscs all over the plains of India, Burma, Siam and Sumatra, is the only species that can be assigned to this genus. Its most peculiar feature is the possession of a folded gill-like structure on the left side of the body. In this feature it agrees with *Bullinus* and allied genera, and differs from *Planorbis*. It is interesting therefore to note that its young shell closely resembles that of *Bullinus* or *Physa*, though in the adult the shell is like that of *Planorbis*.

GYRAULUS, Agassiz. Several small species common in the Ganges valley must be assigned to this genus. We have examined the following forms anatomically:—*G. convexiusculus* (Hutton), *G. euphraticus*, Mousson, *G. labiatus*, Benson, *G. rotula*, Benson, and *G. cantori*, Benson. All these agree closely in anatomy and the shells can only be distinguished by very careful study.

SEGMENTINA, Fleming. Among the forms found in the area under consideration we can assign only two to *Segmentina*, namely, *S. calathus*,

Benson, and *S. trochoides*, Benson. Here again there is a close anatomical similarity and the shells must be distinguished with great care.

? HIPPEUTIS, Agassiz. The only species with a shell resembling that of *Hippeutis* we have examined is *H. umbilicalis* (Benson), but we believe that the same author's *P. cœnosus* is congeneric. The anatomy is very peculiar and it is not impossible that the Indian species will have ultimately to be separated from the European.

CAMPTOCERAS, Benson. Perhaps the best idea of the peculiar shells of this genus is to be derived from the scientific name (= twisted horn). If we imagine the spiral of a Markhor's horn tightened until its whorls were in contact a very good impression of the appearance of the shell would be gained. All the living species are, however, minute. Larger shells assigned to the genus by Col. Godwin-Austen have been found fossil in Eocene beds in England. In both the Indian and Japanese species the anatomy is in some respects nearer to that of *Gyraulus* than to that of *Bullinus*, though the shells resemble those of the latter genus in some characters.

I have already alluded to the apparently discontinuous distribution and rare occurrence of *Camptoceras*. The type-species (*C. terebra*, Benson) was found at Moradabad eighty years ago, and has not since been rediscovered. Two other species (*C. austeni*, Blanford and *C. lineatum*, Blanford) were found in 1870 by Col. Godwin-Austen in what is now the Dacca district. *C. austeni* has not been rediscovered, but I found two specimens of *C. lineatum* a few months ago in Manipur. A fourth species was described last year from Japan, and a fifth from Kashmir has just been described by Dr. Baini Prashad and myself in the *Journ. As. Soc.*, Bengal, XVI, pp. 28-30 (1920).

We have been able to find no evidence of any kind that any species of the genus *Bullinus*, the chief carrier of Schistosomiasis, occurs living within the limits of the Indian Empire, but one widely distributed form (*B. contortus*), the common carrier of *S. hæmatobium*, has been found in Lower Mesopotamia. In late Cretaceous times the genus flourished in Baluchistan, the Central Provinces and Madras, and a gigantic species (*B. prinsepii*, Hislop) was the predominant freshwater mollusc in the swamps of which the remains are now known as the Intertrappean beds of the Central Provinces. This mollusc appears to have perished owing to its attainment of a relatively enormous size, which probably caused its extinction in a period of diminished food-supply.

FAMILY—ANCYLIDÆ.

The little limpet-like species of this family, with their inconspicuous appearance and fragile shells, are difficult to find and to preserve in a satisfactory condition. We know as yet comparatively little about their distribution and specific limits, but at least two species occur in Peninsular India, namely, *Ancylus verruca*, Benson, and *A. tenuis*, Bourguignat. Both of these can apparently be assigned to the subgenus *Ferrissia*, Walker, which is distinguished mainly by differences in the radular teeth. These teeth are so minute that they can be examined only with the aid of an oil-immersion lens.

A. verruca is widely distributed in the plains of India, while *A. tenuis* was described from streams in the Nilgiris and is not uncommon in the Bhavani valley at the base of that range.

The great majority of the genera referred to in this brief synopsis are of very wide geographical range. The only genera confined to Peninsular India are *Stomatodon* (Melaniidæ Paludominæ) and *Sataria* (Hydrobiidæ); *Mysorella* is only known from S. India and Ceylon; *Digoniostoma* from India and Assam. *Melanoides, Acrostoma, Paludomus, Pachylabra* and *Indoplanorbis* are essentially tropical genera; *Acrostoma, Paludomus* and *Indoplanorbis* Oriental in a zoogeographical sense.

SOME OF THE MORE IMPORTANT AND MORE RECENT WORKS ON THE FRESHWATER GASTROPOD MOLLUSCS OF THE INDIAN EMPIRE AND NEIGHBOURING COUNTRIES.

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PART II.

R. B. SEYMOUR SEWELL.

It is now just over a year since my services were placed at the disposal of the Director, Zoological Survey of India. On my return from military duty to Calcutta in April 1919, I was appointed to take charge of and to continue the observations and experiments which had been begun by Dr. S. W. Kemp in 1918 on the question of the possibility of Schistosomiasis being introduced into India by troops returning from overseas, and of this disease becoming endemic in this country. The results of Dr. Kemp's work have already been published (Kemp and Gravely, 'On the possible spread of Schistosomiasis in India,' *Ind. Journ. of Med. Research*, Vol. VII, No. 1, 1919) and my researches since April 1919 have only served to confirm the results obtained by these authors, apart from the detailed descriptions of many forms of cercariæ that I have prepared.

Work has been carried out mainly along two lines:

(1) a continuation and repetition of infection experiments with living miracidia of *Schistosoma hæmatobium* of the more common freshwater molluscs of the Calcutta district, and

(2) a study of the various forms of cercariæ that are indigenous to this country.

I propose in the following report to deal with these two branches of work separately.

I. Infection experiments with miracidia of Schistosoma hæmatobium.

The experiments that had been carried out by Dr. S. W. Kemp and Dr. F. H. Gravely were conducted during the pe iod September-October, 1918, and as these authors pointed out at the conclusion of their report, 'our experiments need repetition especially at different times of the year, before it can be assumed that any of the molluscs we employed are harmless as transmitters of disease.' Leiper in his report of the Bilharzia

Commission in Egypt 1915 has stated that at certain periods of the year the cercariæ of human Schistosomiasis were not present in the snails, and it was largely due to this assertion that Kemp and Gravely called attention to the necessity of repeating the experiments at other seasons of the year. Leiper's statement has, however, subsequently been shown to be incorrect for Manson—Bahr and Fairley (*Parasitology*, Vol. 12, No. 1, 1920, 'Observations on Bilharziasis amongst the Egyptian Expeditionary Force') have found these cercarfæ present at all periods though more frequent at certain seasons than at others. Consequently, if the Schistosomes of human disease can undergo development in any of the common Indian molluscs, evidence of this should be obtainable at any period of the year, though possibly more easily so at certain seasons.

Attempts to infect the more common molluscs of the Calcutta district were carried out by me during the months May-July, 1919, and those examples that remained alive were carefully examined for evidence of infection at periods ranging from 6 to 8 weeks later. As Dr. Kemp found in his experiments, there was a high mortality among the snails in the experimental tanks in the first two months, May-June, but during July in the third series of experiments this was not so marked. The species of mollusc that showed the highest mortality in the experimental tanks in May and June were as follows :—in May, *Limnæa ovalis*, *Gyraulus euphraticus* and *Melanoides lineatus*, and in June *Limnæa ovalis*, *Melanoides lineatus*, *M. tuberculatus* and *Vivipara bengalensis*. Infection with Trematode parasites has been shown to be fatal, in a large percentage of cases, to the mollusc host, and in consequence, many post-mortem examinations were made on the dead snails from the experimental tanks in order to detect, if possible, whether the cause of death was the growth of these parasites; but in every case the result was negative. It seems quite clear then that the mortality among the molluscs was not due to infection with Trematode larvæ. It was noticed that during these months, May-June 1919, there was a very heavy death roll among the molluscs that were living in their natural 'habitat' in the tank in the compound of the Indian Museum, and this was especially the case among the *Limnæa*, the *Melanoides* and *Vivipara bengalensis* : that is to say, the species in which the high mortality was present in the experimental tanks were the same as those which showed simultaneously a high mortality in their natural surroundings, and it seems clear that there is a natural high mortality among snails at this period of the year, from which the examples under experiment were naturally not exempt.

Examination of those individuals that survived in the experimental tanks showed that in no case had infection taken place ; no trace of any Schistosome larvæ was found in any specimen. Furcocercous cercariæ of various kinds were found in a small percentage, but no Schistosome cercaria was discovered. All attempts therefore to infect the snails with the miracidium of *Schistosoma hæmatobium* had been a complete failure.

In the accompanying table below I have given the various kinds of snails that were subjected to experiment and in the succeeding columns the numbers that were exposed to infection, and that were examined at the termination of the prescribed period.

	May 1919	July 1919	June 1919	August 1919	July 1919	September 1919	Total.	
	Number exposed to infection.	Number still living and subjected to examination.	Number exposed to infection.	Number still living and subjected to examination.	Number exposed to infection.	Number still living and subjected to examination.	Number exposed to infection.	Number subjected to examination.
Amnicola orcula ..	44	13	50	19	50	20	144	52
Pachylabra globosa ..	11	8	10	7	..	..	21	15
Limnæa ovalis ..	46	1	50	1	50	31	146	33
Limnæa acuminata var. gracilior	38	16	26	15	..	..	64	31
Gyraulus euphraticus ..	73	18	160	44	100	30	333	92
Melanoides lineatus ..	51	15	55	2	50	24	156	41
Melanoides tuberculatus ..	31	14	50	3	50	39	131	56
Acrostoma variabile ..	33	24	50	28	50	41	133	93
Indoplanorbis exustus ..	61	29	69	62	100	69	230	160
Vivipara bengalensis ..	61	27	50	5	50	12	161	44
Pisidium clarkianum ..	13	..	..	..	..	..	13	..
Grand Total ..	462	165	570	186	500	266	1,532	617

It was hoped that experiments might also be carried out with miracidia of *Schistosoma mansoni.* Cases of infection with this parasite have returned to India from overseas, and it was thought to be quite possible for this form to undergo development in this country in *Indoplanorbis exustus,* one of the commonest and most widely distributed of the freshwater Gastropod molluscs. It has been shown that *Sch. mansoni* usually, if not invariably, developes in a species of *Planorbis,* and that in different countries different species can act as the

intermediate host; thus, in Egypt development occurs in *Planorbis boissyi*, in Venezuela in *P. quadeloupensis* and in Brazil in *P. olivaceus*. Unfortunately no experiments could be undertaken, as no case of infection with this parasite could be obtained.

II. A STUDY OF THE CERCARIÆ THAT ARE INDIGENOUS TO INDIA.

Throughout the whole period April 1919—April 1920, investigations have been carried out in order to discover what cercariæ are indigenous in this country. While the majority of my observations have been conducted on snails obtained in the Calcutta area, opportunity has also occurred of visiting other parts of India, and advantage has been taken of this to study the molluscan fauna and its parasitic trematode larvæ. Investigations have been conducted in the following areas :—

(*a*) The Nilgiri Plateau, Wynaad, and adjoining plains of Malabar at the foot of the Nilambur and Vayitri Ghats.

During this tour in October 1919 I received every assistance from the resident planters, who not only very kindly provided me with accommodation, but also supplied coolies to assist me in the collection of the molluscs. This tour resulted in the discovery of many new forms of cercariæ, as well as increasing my knowledge of the distribution of forms that had been previously discovered elsewhere.

(*b*) Bombay and its suburbs.

Two visits were made to Bombay in July 1919, and again in April 1920. I have to express my thanks to Lt.-Col. Glen Liston, I.M.S., Major Kunhardt, I.M.S., and Dr. Soparkar for the assistance that they gave me.

(*c*) Rambha and the neighbourhood at the south end of the Chilka Lake, Ganjam.

This area was visited in August 1919, and again in April 1920.

In addition to the above tours, collections of living molluscs have been made for me by various officers and Research Assistants of the Zoological Survey of India, and I have been able to examine specimens from the Loktak Lake in Manipur, Dimapur in Assam and from Lahore.

My investigations have shown that India is extremely prolific as regards trematode infection and especially so in various forms of Furcocerous cercariæ. In all 61 different cercariæ have been examined and I hope shortly to submit a full report on these. Their study has

thrown much new light on the classification and interrelationships of the cercariæ. From the medical point of view the most important result of my investigations was the discovery in September 1919 of a true Schistosome cercaria infecting both *Indoplanorbis exustus* and *Limnæa acuminata* in the outskirts of Calcutta. A full description of this cercaria has already been published (Sewell, *Rec. Ind. Mus.*, Vol. XVI, Part VI, No. 29, October 1919). The importance of this discovery lies in the fact that morphologically this cercaria appears to be indistinguishable from that of *Schistosoma japonicum*, Katsurada, which is known to infect human beings and to give rise to dysentery in Japan and parts of China. Observations made during my tour of the Wynaad in October 1919, revealed the fact that this parasite is certainly indigenous and is by no means uncommon in certain areas. Moreover, a study of the localities in which it was found, renders the importance of this form still more marked. In Calcutta it was first found in a swamp close to some native huts and evidence of fœcal pollution of the water was only too obvious around the margin: in the Wynaad this form was again found, and in this district *Indoplanorbis exustus* was the mollusc host. Out of a total of six rice-fields examined, one contained no examples of *I. exustus*: of the remaining five this parasite was found in three, the percentage of infection in *I. exustus* ranging from 6·5 per cent to 17 per cent. It was never found beyond the limits of cultivation, even in places where there was no definite boundary between rice-field and adjoining swamp, and where *I. exustus* flourished in both. In every case, therefore, where this parasite has so far been found, it has been associated with evidence of human activity.

It is much to be regretted that on neither of the occasions when I visited Bombay was I able to examine living examples of the cercaria of *Schistosoma spindalis*, the life-history of which was worked out in 1918 by Lt.-Col. Glen Liston, I.M.S., and Dr. Soparkar, and which also passes its sporocyst stage in *Indoplanorbis exustus*. Dr. Soparkar, however, has kindly shown me his notes on the structure of this form, and these show quite clearly that not only is the cercaria of *Sch. spindalis* different from the form discovered by me, but it actually belongs to a different though closely-related group. This raises the very important question whether the cercariæ of those forms which cause disease in the human being and of those which only infect cattle may not belong to entirely separate groups. In spite of the work of Manson—Bahr and Fairley, recently published in

Parasitology, Vol. 12, No. 1, January 1920, we are still completely ignorant of some of the most important structural details of the cercariæ of *Sch. hæmatobium* and *Sch. mansoni*, and it is of the very greatest importance that our knowledge of these forms should be rendered complete, as well as researches carried out on the structure of other animal-infecting forms such as *Sch. bovis*. If it should prove that the cercariæ of *Sch. hæmatobium* and *Sch. mansoni* agree as regards their structural characters with that of *Sch. japonicum*, while the cercaria of *Sch. bovis* agrees with that of *Sch. spindalis*, we should have very great grounds for believing that the true Schistosomes form two different groups not only structurally, but pathologically, namely, the more primitive and more tolerant human-infecting group, and the higher developed and less tolerant animal-infecting group. Should this prove to be the case, the structure of the form found by me would show that, even it be not identical with *Sch. japonicum*, it is equally a human-infecting form.

SUMMARY OF RESULTS.

(*a*) Malacological.

1. The freshwater Gastropod fauna of India (excluding Assam and Burma) has been found to be, from a zoogeographical point of view, of three types, which may be called the Afghan type, the Eurasian type and the Indian type.

2. The Afghan type occupies the whole of Baluchistan and the mountains west of the Indus and extends its range from those of Afghanistan to Eastern Persia.

3. The Eurasian type, essentially identical with that of Europe and N. Asia, is found, in the Indian Empire, only in the mountain valleys of the Indus watershed.

4. The true Indian type occurs all over the Indo-Gangetic plain and the plains of Peninsular India from the Indus to the Bay of Bengal and from Peshawar to Cape Comorin.

5. An account of the Afghan type has already been published in Vol. XVIII of the *Records of the Indian Museum*; the Eurasian type calls for further study in Kashmir, etc.; a brief synopsis of the Indian type is given in this paper.

6. Further investigations in Sind, Western Himalayas, Assam and Burma are necessary to complete an account of the freshwater Gastropod molluscs of the Indian Empire.

(*b*) PARASITOLOGICAL.

1. Attempts to infect examples of the more common molluscs of the Calcutta area with miracidia of *Schistosoma hæmatobium* have given negative results.

2. The peninsula of India has a very large indigenous Trematode population and is particularly rich in those forms whose cercariæ belong to the forked-tailed group. A full description of the cercariæ will be published separately.

3. A cercaria, apparently morphologically identical with that of *Schistosoma japonicum*, has been discovered and appears to be widely distributed : it is certainly indigenous, and all our evidence tends to show that it is connected with human activity.

4. Full descriptions of most other Schistosome cercariæ are still unavailable and are urgently required.