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A CENTURY OF SCHISTOSOMIASIS IN INDIA: HUMAN AND ANIMAL

by

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SUMMARY

In this paper, the writer presents a critical analysis of the works * done in India on schistosomes of man and animals since 1878 to date.

REVISION

It is now a century that Batch (1878) reported, for the first time, a case of human urinary schistosomiasis in India. The patient was an Englishman who was admitted under Dr. Puttock into the then European General Hospital, Bombay, for treatment. The infection was, however, not contracted in India, but elsewhere as the patient had previously travelled through endemic areas in Arab countries and also through Egypt. Hatch (l.c.) also stated that Dr. Vandyke Carter had informed him of another case of urinary schistosomiasis, but in an African boy who was under his treatment in 1862 in the Jamsetjes Jejeebhoy Hospital. Bombay. Subsequently he (Hatch, 1887) published a note on the diagnostic features of urinary schistosomiasis based on his observations of as many as twelve cases in Bombay. In 1903, Hatch again published a note on the occu-

* Only important work on schistosomes and schistosomiasis have been considered here. Reports of the work done by the Army Department during and after the Second World War on the possibility of human schistosomiasis spreading in India were not available for consultation.

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rrence of human schistosomiasis in India wherein he stated that since his previous report (Hatch, 1878), he had seen some 30 cases of human schistosomiasis in J. J. Hospital, Bombay; but none of the patients in his opinion contracted the disease in India as they were all Mohammadans and most of them had been to Mecca on pilgrimage or elsewhere for trade purpose, and they had stayed in some endemic areas where they must have contracted the infection. Thus it follows that none of the cases that Hatch examined, or heard of, originated in India.

Powell (1903 a, b) published notes on the occurrence of human schistosomiasis in India. He, too, stated to have heard from I. M. S. Officers of the imported cases of human schistosomiasis in India, but in the same publication (Powell, 1903 a), he reported for the first time in India a genuine indigenous case of urinary schistosomiasis in a Hindu since, a resident of Bombay, who had never been out of India to any endemic area and had been living for the last 20 years either in Bombay, or Poona, or in Admadnagar. It is, then quite likely that the syce contracted the disease somewhere on the western side of India. Subsequently, Sewell, E. P. (1904) reported a case of schistosomiasis in a British soldier who came from England to India where he lived for four years. He had never been out to any other country. However, it is doubtful if at it was, truly speaking, an indigenous case as it is just possible that he picked up the infection while pasing through Egyp or South Africa en route to India.

Then followed other reports of the occurrence of indigenous cases of human schistosomiasis in India viz., by Christophers and Stephen (1905), Wardrop (1906), and Hooton (1914). All these reported cases of human schistosomiasis in India were urinary caused by *S. haematobium,* the characteristic eggs of which appeared in the urine of the patients.

The case reported by Christophers and Stephens (1.c.) was indeed peculiar inasmuch as in the urine of the patient, a native of Madras, typical eggs of *S. haematobium* as well as spindle-shaped eggs (i.e. *bovis*-type) were found. Even Looss, an eminent authority, who was consulted by Christophers and Stephens, could not account for this difference in the shape of the eggs. Later, some workers (Soparkar, 1919; Chandler, 1926) interpreted the case as being an infection with an animal-infecting

schistosome. In the light of our present-day knowledge, the presence of two types of eggs in the urine of Christophers and Stephens' patient is explicable as a case of polymorphism of eggs. Some species of *Schistosoma* are known to produce eggs other than their own types. Thus *S. haematobium* has been reported (van den Berghe, 1936) producing *bovis*-type and *matthei*-type of eggs, besides its own characteristic eggs. *S. bovis,* an animal-infecting schistosome, is also known to produce polymorphic eggs (MacHattie and Chadwick, 1932; van der Berghe, 1937; Porter, 1938). One important point having a bearing on the case is noteworthy. The patient had been to Africa. This fact was not stated by Christophers and Stephens (l.c.) in their publication, but Major Christophers personally disclosed it to Soparkar (1919). This fact lessens the importance of their case being considered as genuinely indigenous.

Wardrop (l.c.) reported five cases of human schistosomiasis and he believed all his patients contracted the disease in India. It is hard to admit Wardrop's all cases as being of Indian origin, but there is not the least doubt in admitting his last two cases (case nos. 4 and 5) as being indigenous the actual localities where the patients possibly contracted the disease being Mian Mir and Poone (now Pune).

Hooton (l.c.) recorded a case of schistosomiasis in a five-year old Parsi girl at or near Rajkot (Gujarat).

During the South African War (1899-1902), infected British Troops introduced human schistosomiasis into India (McLeod, 1903). After the First World War (1914-1918), when the Indian Troops returned home from Egypt, East Africa, Mesopotamia (now Iraq), or from other lands where the disease is endemic, danger was apprehended as some of the army personnel carried home schistosomiasis, or the African Troops stationed at several places in India during the war period must have left seeds of schistosomiasis to germinate: in either case, schistosomiasis would some day spread in this country and a serious outbreak of the disease was foreseen. The matter caused a great concern to the then India Government. Soon, some eminent workers (Kemp and Gravely, 1919; Sewell, 1919 a; Annandale and Sewell, 1920) of the Zoological Survey of India, a research organization of the Government of India located at Calcutta,

started making investigations on the possibility of human schistosomiasis getting a foothold on the Indian soil.

Kemp and Gravely (1919), in an attempt to find out if any indigenous snail would serve as a vector of human (urinary) schistosome in India, carried out infection experiments with 450 specimens of 13 species of common Indian snails collected chiefly in Secunderabad, Waltair and Calcutta. They exposed these snails individually to the miracidia of *S. haematobium,* viable eggs of which they obtained for their experimental work from the urine of infected army personnel staying in Secunderabad. But they failed to establish infection in the experimental snails as the latter proved to be refractory to the miracidia, and they concluded the common indigenous snails being incapable of serving as vectors of human-infecting schistosomes. They, however, desired future workers to repeat their infection experiments at different times of the year to confirm their finding. In compliance with their desire, Sewell (in Annandale and Sewell, 1920) repeated their infection experiments. He exposed 1532 specimens of 11 species of the common snails collected in Calcutta to the miracidia of *S. haematobium.* He also studied various cercariae found in Indian snails with a view to knowing if at all human-infecting schistosome cercariae naturally existed in India and infected snails. But he failed to infect the snails with the miracidia of *S. haematobium* and also to discover human schistosome cercariae in any common Indian snail. The monograph on Indian cercariae viz., "*Cercariae indicae*" which he subsequently published (Sewell, 1922) was the outcome of the efforts that he made to find out if at all human schistosome cercariae naturally occur in any indigenous snail. However, his view (Sewell, 1920) regarding the indigenous occurrence of human schistosomiasis in India accorded with that of Kemp and Gravely (l.c.). In the outskirts of the city of Calcutta, Sewell (1919 b) found *Indoplanorbis exustus* and *Limnae acuminata* (syn. *L, amygdalum*) being infected with a true schistosome cercaria viz., *Cercariae indicae* XXX, which he erroneously thought to be that of *S. japonicum.* This made him to believe in the possibility of the occurrence of *S. japonicum* infection in India. Sewell also found this cercaria in Wynaad in *Indoplanorbis exustus.* In fact, the cercaria in question happens to be the larval form of a cattle-infecting schistosome. A reference to this cercaria and to its adult would be made later in the present treatise in connection with the animal schistosomes.

Annandale (in Annandale and Sewell, 1920) with a view to studying the etiology of human schistosomiasis occasionally eppearing in India, made an extensive survey of the fresh-water gastropods mainly of the plains of India namely Hyderabad, Secunderabad, Madras, Bombay, Punjab, Ranchi, Calcutta, etc. and also of Beluchistan. As troops were stationed at some of these places, a danger was foressen of human schistosome being introduced in India through infected army personnel. Hyderabad was possibly the worst area owing to the heavy infection of Imperial Service Troops of the then H.E.H. the Nizam. Fortunately, however, he found *Bulinus,* species of which elsewhere mainly serves as vectors of *S. haematobium,* to be non-existent in India. Further, he discovered that *Bulinus* was once extant in India, but become extinct later. Surprising enough that he doubted the existence of true *Planobir* in India. According to Annandale's finding, then, human schistosomiasis cannot ordinarily gain a footing in India.

Milton (1914, 1919a, 1919b) firmly believed in the endemic existence of human schistosomiasis in India, but it escaped detection by medical men. He put forth the argument that India is situated within the parallels of longitude roughly 35° North and 35° South of the equator, and human schistosomiasis is prevalent in almost all countries except India lying in the belt. Further, in his opinion, conditions in India —enviromental as well as mode of living of the population— are well-suited for the propagation of human schistosomiasis. He further believed that a fourth human-infecting species of *Schistosoma* exists in this country and that species has such a strong old on this land that no other species is able to thrive in India although the country was exposed several times in the past to schistosome infection when muslim pilgrims from Arabian countries and army personnel from African countries came to India. He further held the view that in a country or a district, only one species of *Schistosoma* reigns supreme and any other species, if at all exists, would be only subordinate to it.

Sewell (1919 a) trenchantly criticized Milton for his views. He was, however, unable to give any definite answer either to the possibility of endemic occurrence of human urinary schistoso-

miasis in India, or to the chances of *S. haematobium* getting an endemic foothold in this country whenever introduced from outside particularly in view of the absence of *Bulinus,* the reputed vector of the human urinary schistosomiasis, in this country. He advised to follow the Asquithian dictum "Wait and See".

Soparkar (1919), too, diverted his attention to study the possibility of human schistosomiasis spreading in India if introduced from abroad, but could not come to any definite conclusion. He also carried out infection experiments by exposing *Planorbis* * to the miracidia of *S. haematobium,* but failed to establish infection in the snail. In an attempt to find human schistosome cercariae in indigenous snails, he studied the cercarial fauna of the snails living in the vicinity of Bombay city, and he found as many as 17 species of cercariae, including cercariae of a cattle-infecting schistosome, parasitizing them, but not any of human schistosome. His plan to infect *Planorbis* with the miracidia of *S. mansoni* nipped in the bud as patients with *S. mansoni* infection were not available.

From the foregoing accounts, some of the reported cases of urinary schistosomiasis in India evidently appear to be indigenous, but it is hard to explain as to how the patients contracted the disease in view of the fact that proper snail vectors (*Bulinus* with its subgenus *Physopsis*) are non-existent in India; further, the common Indian snails, as evident from the results of the infection experiments carried out by Kemp and Gravely (l.c.), Soparkar (l.c.) and Sewell (l.c.), proved to be refractory to the miracidia of *S. haematobium.* The only possible explanation will be to presume that the parasite has in this country adapted itself to complete its life cycle in a snail which is either quite uncommon, or elsewhere, or dosely related to those that serve as its vectors in Africa or elsewhere. Inspite of the best efforts of a band of eminent workers cited before,

* Species has not been mentioned by Soparkar. Possibly it was *P. exustus* Deshayes which was later made the type species of *Indoplanorbis* Annandale and Prasad, 1919. Kemp and Gravely (l.c.), too, utilized this snail as one in their infection experiment.
The writer has been lately informed by Dr. N. V. Subha Rao, Malacologist, Zoological Survey of India, Calcutta, that true *Planorbis* is found in Kashmir in India.

the problem remained a mystery. Yet reports of stray cases of human urinary schistosomiasis in India continued appearing in medical journals.

After the First World War, Harkness (1922) reported a case of urinary schistosomiasis in an Englishman who, in his opinion, contracted the disease during his three years stay in India, and he, too, believed human schistosomiasis to be endemic in India. It has not been mentioned by Harkness where exactly his patient was stationed when on active service in India.

Milton (1922) cited Capt. Smith who recorded (in the April issue of the Journal of R.A.M.C., 1922) a case of urinary schistosomiasis in a British soldier at Bolarum, then in the Hyderabad State, who apparently came direct from England to Secunderabad in 1920 and had previously never been out of home. Possibly he got the infection from some tanks existing in the vicinity of Bolarum village at the border of which were situated the army establishments. Milton believed Bolarum to be an infected area, and the infected army personnel of the Imperial Service Troops, who contracted the disease while on active service in Egypt, under treatment in the Hyslop War Hospital at Bolarum were the source of the infection.

Leiper (1923) believed the reported cases of human schistosomiasis in India to be of animal origin as schistosomiasis in animals was known by then to be quite common in this country.

Literature is almost barren of reports of the occurrence of human schistosomiasis in India for about two decades that followed (1923-1944). Only one case by de Mello was reported during this period.

De Mello (1936) recorded in Goa (then in Portugese India) an autochthonous case of human urinary schistosomiasis in a nine-year old child born of an African soldier and a Goanese woman living in the village "Valpoi" where infected African Troops lived for over two decades (1912-1934). Strangely, eggs were also found by him in the faeces of the child this is quite an unusual feature of urinary schistosomiasis. He performed infection experiments and exposed three species of snails collected from the said village to the miracidia obtained from the eggs passed out by the same child, but he was unsuccessful in his attempt to establish infection in any snail. Yet, he believed some local molluscs, to which the schistosome eventually

became adapted and which he termed "eventual" hosts, were responsible for such sporadic cases of schistosomiasis in Goa. Amongst molluscs, he stated two species viz., *Melanoides tuberculata* and *Limnaea luteola* var., *pinguis* are found in "valpoi" village, of which one might be serving as an eventual host. And he claimed to have actually found in the said village one *Melanoides tuberculata* naturally infected with a furcocercaria not unlike that of *S. haematobium.* Gopsill, he pointed out, had already incriminated this snail as the vector in the transmission of both *S. haematobium* and *S. mansoni* in the Lower Shire District of Nyasaland, East Africa. Earlier, Franca and de Mello (1921) had, however, reporter the infection of *S. mansoni* in troops in Goa who had returned from Mosambique, East Africa. They failed to infect local snails with the miracidia of *S. mansoni* (vide Chandler, 1926 and de Mello, 1936).

After the Second World War (1939-1945), reports of autochthonous cases of human urinary schistosomiasis again appeared in medical journals and alarmed the public health authorities to be vigilant otherwise the disease would spread in India through infected army personnel coming from endemic areas.

Andreasen and Suri (1945) reported at Rawalpindi (now in Pakistan) an autochtonous case of urinary schistosomiasis in a sikh sepoy, a resident of Ambala District in the Punjab, who was stationed for a short period in Poona (now Pune, Maharashtra State) where, of course, once African Troops were stationed, but he had never been out of India.

Mukerji et al. (1946) repeated the infection experiments initiation by Kemp and Gravely (l.c.). They exposed 99 specimens of five different species of snails collected from the environs of Ranchi and Chas (Bihar) to the miracidia of *S. haematobium,* viable eggs of which they obtained from the infected soldiers of the West African Troops stationed at that time in Ranchi. But they failed to establish infection in the experimental snails. Subsequently, they again exposed 888 specimens of eight different species of snails collected from the outskirts of the city of Calcutta to the miracidia of *S. haematobium,* and 289 to that of *S. mansoni*; the source of the viable eggs being the same. But again the snails proved to be refractory to the miracidia of either. However, the results of these experiments performed by Mukerji et al. (l.c.) further substantiated the

conclusions reached by previous workers (Kemp and Gravely, Soparkar, and Sewell) that human schistosomiasis would not be able to get an endemic footing on the Indian soil if introduced from outside as the common indigenous snails are all non-susceptible.

Attempts were made by Khaw (1947) to investigate the possibility of human schistosomiasis being introduced in this country by the West African Troops posted here. He studied the cercariae infesting the snails and found two schistosome cercariae —one infesting *I. exustus* in Bihar and the other *L. luteola* var. *ovalis* in Chittor District, Madras State— and heraised their adults in experimental mammals. The adult of the cercaria infesting *I. exustus* turned out to be *S. indicum* and that of the other one *S. incognitum* (syn. *S. suis*). Neither he found cercariae of human schistosomes in snails in nature, nor schistosome infection in humans living in clase association with the West African Troops. Thus he found no possibility of human schistosomiasis spreading in India.

But one should not ignore the fact that the parasite responsible for the occurrence of sporadic cases of human urinary schistosomiasis in India may, in the absence of its optimal snail vectors, adapt itself to live and to complete its life cycle in some uncommon, if not in common, indigenous snail, or in all probability it might have already done so in some niche.

Towards the end of the first half of the present century, de Sa and Monterio (1949) reported a case of human schistosomiasis in India. Factually speaking, this report paved the way for the subsequent discovery of the existence of an endemic focus of human urinary schistosomiasis in India. These investigators reported an autochthonous case of urinary schistosomiasis in a 19-year old girl patient who hailed from "Gimvi" village in Guhagar Taluka of Ratnagiri District, Maharashtra State, and was hospitalized for treatment in King Edward Memorial Hospital, Bombay. On being questioned by these investigators about the incidence of haematuria in her village, she informed them that her own brother, too, had suffered from the same complaint and that none of them had ever left the of India. She also provided valuable informations regarding the prevalence of this malady in "Gimvi" village.

However, at the beginning of the second half of the present

century, the long-standing enigma —the possibility of endemic occurrence of human urinary schistosomiasis in India— was solved by Gadgil and Shah (1952, 1955) when they discovered the existence of an endemic focus of human urinary schistosomiasis in India viz., the "Gimvi" village on the western border in Guhagar Taluka of Ratnagiri District, Maharashtra State. Thus dreams of Montgomery (1906), Milton (l.c.) and Harkness (l.c.) came to be true. These workers (Shah and Gadgil, 1955b) studied the incidence of infection in the population of the village and found that 278 out of 603 inhabitants (i.e. 46 per cent of the native population) belonging to all age-groups —from 4 to 80 and above— had had the infection. They found haematuria to be the main symptom of the disease. Since the eggs voided with the urine had a terminal spine, they concluded the species involved to be *S. haematobium*. From the history of the disease, as given by old inhabitants and patients of the village, Gadgil and Shah (1955b) concluded that urinary schistosomiasis must have been in existence in "Gimvi" village for about 75 years. Evidently in this endemic focus, the parasite has already established itself to complete its life cycle in some local mollusc.

By successful infection experiments, these workers (Gadgil and Shah, 1955, 1956) found *Ferrissia tenuis*, a snail of the family *Ancylidae* which abounds in the rivulet flowing through the "Gimvi" village, to act as an intermediate host, and therefrom they (Gadgil and Shah, 1956) concluded "This experiment proves that *F. tenuis* can and does act as intermediate host of *S. haematobium* in the endemic focus at Gimvi, India". This conclusion that they made is a mere presumption as subsequently they again stated-"This experiment points to the existence of a molluscan host capable of harboring the larval stages of *Schistosoma haematobium*". Their statements regarding the identity of the snail that they found naturally infected in the endemic area are rather contradicting. Initially they (Gadgil and Shah, 1952) stated —"Out of 300 snails dissected, we found 8 infected. The cercariae discovered were indistinguishable from those of *S. haematobium*". In a subsequent paragraph, they further stated —"The snail belongs to the family *Ampullaridae*. The gross morphology resembles that of the genus *Turbinicola*". But in a later publication (Shah and Gadgil, 1955 a), they

referrer to this snail as being *Paludomus obesa* belonging to the family *Melanidae*. They clearly stated —"In a previous communication (Gadgil and Shah, loc. cit.), this snail was described as belonging to the genus *Turbinicola*. It was, however, later identified as *Paludomus obesa*". They found three species of snails existing in the endemic area viz., *Paludomus obesa, Ferrissia tenuis* and only shells of *Indoplanorbis exustus*. Strangely enough, in the fourth part of the series, they (Gadgil and Shah, 1956) contradicted their previous statements by stating —"*P. obesa* collected from nature has been negative so far for schistosome cercariae". Thus they have left it to workers to infer that the snail that they found naturally infected with schistosome cercariae in "Gimvi" village was possibly *P. tenuis*. Jhala (1956), in support of Gadgil and Shah's work, stated —"The snail involved in transmission cycle of human schistosomiasis in "Gimvi" in Ratnagiri district is *Ferrissia tenuis* and this is not an incrimination but has been experimentally proved". But sthis statement is not admissible unless and until *F. tenuis* naturally infected with schistosome cercariae identical with those emitted by experimentally infected *F. tenuis* are obtained from the endemic focus. That Gadgil and Shah (1955, 1956) were able to establish the intramolluscan phase of life cycle of the "Gimvi" schistosome experimentally in *F. tenuis* merely shows this ancylid snail to be a potential vector of human urinary schistosomiasis in "Gimvi" village. This point is further accentuated by their (Gadgil and Shah, 1955) statement —"In will be evident from the results that the *F. tenuis* is most likely the intermediate host in the endemic focus". Gadgil and Shah (1956) obtained only a pair of adult worms from one out of four white mice that they exposed to the cercariae emerging from the experimentally infected *F. tenuis*. These workers, however, paid no attention to study the morphology of the cercariae or the adult either —even illustrations of these are lacking in their accounts. Their identification of the "Gimvi" Schistosome was exclusively based on the character of the eggs— an undesirable procedure indeed. Consequently, Varma (1955) and Anon (1956) double the identity of the "gimvi" schistosme as being *S. haematobium*, and they believed human schistosomiasis in "Gimvi" village to be caused by some species of animal schistosomes which are quite common in this sub-

continent, and some of them viz., *S. indicum* indeed produces, like *S. haematobium* of humans, terminal-spined eggs, the difference being the route of exit of the eggs. In support of their view, Varma (l.c.) cited the report of Kisner et al. (1953) of the finding of schistosome eggs, assigned to *S. bovis* by experimentally raising the adult, in the urine of a European School boy, and Anon (l.c.) of Fairley (1951) who, while studying the susceptibility of humans to bovine schistosme, pointed out the difficulty of distinguishing the eggs of some bovine species of schistosomes from those of *S. haematobium*. Thus views of Varma and Anon regarding the occurrence of human schistosomiasis in India accord with Leiper's (l.c.). Animal schistosomes are known to infect humans. In this connection, Pitchford's (1959) finding is noteworthy. e reported animal schistosomiasis in man in the Eastern Transvaal, South Africa, with incidences of occurrence being up to 23 per cent.

Dave and Dhage (1958) resurveyed the "Gimvi" village to study the incidence of schistosome infection in its population. According to these workers, there are ten localities of human habitation in the neighbourhood of the river in the village. There was not any case of infection among the inhabitants of some localities, and this absence is attributed to the source of water supply from wells. They found the infection to be maximum in the population of the Lower Marathawada —the overall incidence of infection being 39.9 per cent amongst the males and 6.1 per cent amongst the females. The cause of this high incidence of infection in this locality being the source of water supply mainly from the snail-infested river. Next comes the Upper Marathawada where the overall incidence of infection being 11.1 por cent amongst the males and 8.7 per cent amongst the females.

With a view to restudying the "Gimvi" schistosome from taxonomic viewpoint, Gadgil (1963) carried out infection experiments afresh. He exposed as many as 2500 laboratory-bred *F. tenuis* (originally brought from the endemic area) to the miracidia of the "Gimvi" schistosme, viable eggs of which he obtained from the urine of a patient brought from the "Gimvi" village to Grant Medical Collage Hospital, Bombay, and he again succeeded in establishing schistosome infection in this ancylid snail in the laboratory.

This time he raised the adult worms in both mice and hamster from the cercariae emerging from the experimentally infected *F. tenuis,* and was able to establish infection in 18 mice and 4 hamsters, and he obtained as many as 150 worms from these experimentally infected mammals. He restudied the morphology of the adult "Gimvi" schistosomes (male as well as female) from these worms and provided some additional morphological data good for identification. He paid special attention to study the eggs, and compared them with those of *S. haematobium* obtained from Egypt and also with those of *S. indicum*, an animal schistosome, obtained from goats slaughtered in Bandra abattoir, Bombay. From these studies, he confirmed their previous identification of the "Gimvi" schistosome as being *S. haematobium*. This was further substantiated by the opinion expressed by LeRoux of the London School of Hygiene and Tropical Medicine, and by Pitchford of the South African Council for Scientific and Industrial Research, Eastern Transvaal, South Africa, who also examined the eggs sent by Gadgil, that the eggs resemble those of Egyptian *S. haematobium*.

However, Gadgil and Shah's work is not yet a complete success. A gap still exists in our knowledge in the infection cycle of the "Gimvi" schistosome in nature —that *F. tenuis* actually serves as an intermediate host in nature in the transmission of the disease in the population of "Gimvi" village still awaits confirmation. A drastic search for the naturally infected *F. tenuis* —infected with schistosome cercariae identical with those obtained from experimentally infected *F. tenuis*— in the endemic area be launched and, if and when found, adults, from these cercariae be raised in experimental mammals and compared with those raised from the cercariae emitted by the experimentally infected *F. tenuis*: this is essential, from the strict scientific standpoint, in order to establesh the fact that the two are identical. The writer further suggests that sheep, goats and cattle of "Gimvi" village be examined for schistosome infection and, if found infected, these animal schistosomes be carefully compared with the human form found in "Gimvi" village to obtain a clear picture of their relationship viz., are they mutually exclusive or otherwise.

Gadgil and Shah (1955) also reported to have come across an autochthonous case of infection of *S. haematobium* in Mal-

sana village, Nasik district (Maharashtra State) on the western border of India. Details of the case are not recorded. Further investigations, if carried out, may reveal the existence of another endemic focus on the western side.

Dhanda (1956) reported the finding of schistosome eggs in four out of 500 samples of human faeces during the course of a routine examination of the same in Delhi. None of the persons whose faeces contained the eggs had developed any clinical symptom of the disease. They had never been out of India to any endemic area. They belonged to Punjab, and they remained and moved about in Northern India. This gives a clear indication of the probable existence of an endemic focus in the Northern zone of India. She apparently assigned the eggs to the infection of the humans with *S. haematobium* on account of the terminal spined eggs. One notable and interesting point being the faeces that contained the eggs in all the four cases and not the urine. This evidently shows that there was no vesical involvement. This fact goes in favour of *S. intercalatum* Fisher, 1934 as being the schistosome involved. This species produces *haematobium*-type of eggs and causes intestinal schistosomiasis without vesical involvement. Thus this schistosome uses the intestinal tract for evacuating the eggs. *S. haematobium* rarely, if at all, causes intestinal schistosomiasis, but accompanied by vesical involvement as in the case reported by de Mello (l.c.) Fisher (1934) established this species as a result of his investigation of the intestinal schistosomiasis prevalent in the Stanleyville District of the Republic of the Congo. He further cited several cases of intestinal schistosomiasis reported by workers mostly from West Africa with *haematobium*-type of eggs exclusively passing out with the faeces of the infected humans. This endemic focus in the Norther India should be located. The matter should be taken up for investigation by the Indian Council of Medical Research and the like organizations.

Just a decade back, the existence of one more endemic focus of human urinary schistosomiasis came to light due to the efforts of Santhanakrishnan and Sundararajulu (1967). This endemic focus is located in "Tirupparankundaram" village in Madurai District, Madras State. The village has a population of about 3000 individuals. They found 300 per cent of the inhabitants of the village —of both sexes and of all ages— suffering from urinary schistosomiasis. They found every sample of urine of the infected villagers tinged with blood and contained a large number of terminal-spined eggs on account of which they treated the disease as being schistosomiasis haematobium. It has not been stated by these workers how old is the disease in the village. A tank exists in the village and the villagers use it for bathing, washing and, nauseating as it is, for defaecating and urinatig purposes. The tank provides ideal conditions for the propagation of the schistosome. These workers made a study of the snails abounding in the tank. They found 90 out of 200 snails examined by them to be infected and the cercariae emerging from these snails resembled those of *S. haematobium*. They did not raise the adult from the cercaria. The snail is stated to be *Vivipara heliciformis*. However, their account lacks a reference to other snails living in the tank.

Srivastava and Arora (1969) reported yet another case of human schistosomiasis in India in Raipur Distric of Madhya Pradesh. A woman patient, aged 26 years and complaining of painless haematuria, came for treatment from the village "Lahager" in the district of Raipur. Cystoscopic examination revealed a pallillomatous growth in the bladder, and biopsy of the same showed schistosome eggs and thereby suggested a possible infection of *S. haemotobium*. Later, they visited the village for further investigation. The village is populated by 400 individuals. They examined 263 samples of urine in the village out of which 53 showed haematuria, and one of the latter had had schistosome (terminal-spined) eggs highly suggestive, in their opinion, of *S. haematobium*. Further, these investigators found the incidence of haematuria to be maximum in the age-group 6 to 12 years, and it decreased in advanced age-groups. They also found the incidence of haematuria to be more prevalent amongst the male children than female: this is perhaps attributable to the out-door activities of the boys.

The village "Lahager" has a pond where Srivastara and Arora (l.c.) found four species of snails viz., *Limnea luteola, L. acuminata, Indoplanorbis exustus* and *Vivipara bengalensis* living. They found 3 specimens of *L. luteola* infested with a furcocercous cercaria highly suggestive of being the larva of *S. haematobium*. They also found *I. exustus* being parasitized

by a schistosome cercaria which they assigned, on morphological ground, to an animal-infesting schistosome. In view of this fact, the cattle of the village should be examined, from zoonotic standpoint, for schistosome infection.

Anantaraman (1973) thrice visited the village "Tirupparankundaram" to study human schistosomiasis, but it is disappointig and astonishing too that he found neither any case of haematuria amongst the villagers, nor even infection of schistosome cercaria in *Vivipara heliciformis* there.

It is evident from the foregoing discussions that the human urinary schistosomiasis (schistosomiasis haematobium) has an endemic existence in this country and that the schistosome got o foothold in India long ago. In fact, the schistosome circumvented the human efforts of detection by quitting the usual molluscs that serve as its vectors in Africa or elsewhere and surreptiously establishing itself in indigenous snails to complete its life cycle. Three endemic foci have already been discovered and some more are awaiting discovery.

However, a knowledge of indigenous occurrence of animal schistosomes in India dates from 1882 when Cobbold at a meeting of the Medical Chirurgical Society in London first reported schistosome infections in cattle and sheep in India. Subsequently, Bomford (1886, 1887) recorded the findings of schistosome eggs, erroneously assigned to *S. haematobium*, in faeces of two bullocks belonging to the Transport Department in Calcutta. About two decades later, Montgomery (1906a, 1906b) made important contributions to our knowledge of animal schistosomes in India by describing three new, species viz. *S. indicum, S. spindalis* * and *S. bomfordi*. Credit is accorded to him for paving the way for the study of animal schistosomiasis in India, and to-day schistosome infections in domestic animals in India are known to be fairly common and widely distributed. Animal schistosomiasis is known to occur in several States in India viz., Assam, West Bengal, Bihar, Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Rajasthan, Madras and Maharashtra,

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The publication by Sen-Gupta and Kapoor, cited by Anantaraman (1973), could not be consulted.

* Following Porter (1938), the trivial name will be spelt hereinafter as *spindale*.

and seven valid species, shortly to be referred to, are known to parasitize varieties of domestic animals in India.

Liston and Soparkar (1918) found a true schistosome *(Schistosoma)* cercaria parasitizing *Indoplanorbis exustus* in the environs of Bombay. They experimentally raised its adult in goat and guinea-pig, and it turned out to be *S. spindale* described by Montgomery (l.c.) about a decade ago. They found eggs of *S. spindale* to pass out with the faeces of infected animals.

Sewell (1919b) also described a true schistosome cercaria viz., *Cercariae indicae* XXX which he erroneously believed, as stated before, to be the larval form of *S. japonicum*. As it will be evident later, this cercaria is the larval form of another cattle-infesting schistosome.

Soparkar (1921) further carried out infection experiments with the same cercariae that he and his co-worker (Liston and Soparkar, l.c.) had found in *I. exustus*, and confirmed their previous finding that the cercariae were the larval form of *S. spindale*. He gave a detailed description of the cercaria.

Sewell (1922) in his monographic work on Indian cercariae described one more new species viz., *Cercariae indicae* XLVII of a true schistosome cercaria (apharyngeal, brevifurcate and non-ocellate), besides the one, namely *Cercariae indicae* XXX, which he had described earlier (Sewell, 1919b).

Chandler (1926) found schistosome eggs, quite unlike those of any human species known till then, in two samples of stools collected from villages in Bengal. He believed the stools to be human. He designated this unknown schistosome, characterized by its eggs ("spine subterminal, eggs flattened on spine side"), as *S. incognitum*.

Fairley and Mackie (1925, 1930) and Fairley and Jasudasan (1927, 1930a, 1930b) further studied *S. spindale* and added much to our knowledge of the life cycle of this animal-infesting schistosome. They found buffaloes to be the definitive host of *S. spindale*.

Price (1929) found *Schistosoma bomfordi* Montgomery, 1906 closely resembling in its morphology *O. intermedia* Odhner, 1912, the type species of *Ornithobilharzia* Odhner, 1912, and consequently he treated them to be congeneric and transferred *S. bomfordi* to *Ornithobilharzia*. He further considered this

schistosome to be normally a parasite of birds and the report of its finding in a mammal a case of accidental infection. Since there is no subsequent report of the occurrence of this schistosome, workers doubt its identity. Bhalerao (1932) and LeRoux (1958) appear to treat this species as a synonym of *O. turkestanicum*.

Rao (1929) described a hitherto unknown species of furcocercous cercaria viz., *Cercaria anomala* from *Indoplanorbis exustus* in Madras which incorporates several peculiar and interesting characters —of which the cystic enlargement of the tail is of particular interest. In the following year, Sewell (1930) restutied the material (obtained from Rao) on which Rao's account was based and he added a few more details to the original description. Sewell concluded *Cercaria anomala* to belong to the apharyngeal, brevifurcate distome group of furcocercariae, and pointed out its relationship with schistosome cercariae which is evident from the following excerpt from his publication —"With the exception of the cystic enlargement of the tail, the structure of this species agrees closely with that of certain of the furcocercous cercariae and particularly with those of the Schistosome series".

From 1931 onwards, advances in our knowledge of animal schistosomes and schistosomiasis in India made rapid strides due to the efforts of a number of Indian workers, amongst whom contributions of Rao (M.A.N.) and of Srivastava and Dutt will remain a monument in the field of veterinary helminthology.

The year 1932 marks an important chapter in the annals of veterinary helminthology. Datta (1932) in Muktesar (Uttar Pradesh) and Malkani (1932) in Patna (Bihar) worked on the etiology of "nasal granuloma", a widely prevalent cattle disease known since long to cattle owners and veterinarians in this country and regarded by some as fungal, and by others bacterial. But they threw a new light on the subject. Both independently discovered the disease to be a clinical manifestation of schistosomiasis, and caused by a species of *Schistosoma* greatly resembing *S. spindale* Montgomery, 1906, and yet showing some differences. Fortunately their conclusions were the same, and it was based on the finding of the characteristic eggs not in the urine or faeces but in the nasal discharges of the affected animals and of adult worms in the pathological tissues excised

from the diseased animals. Their works received due recognition and did them credit. In the same year, Bhalerao (1932) studied the schistosome causing the bovine "nasal granuloma" from morphological and taxonomical standpoints. He found no difference between the nasal schistosome and *S. spindale,* and consequently he concluded the schistosome causing the bovine "nasal granuloma" to be conspecific with *S. spindale.* In the same publication, Bhalerao also included brief descriptions of *S. spindale* and *S. indicum* from materials collected by him from different mammals. These are important additions to the original descriptions of the species by Montgomery (l.c.). In the following year, Malkani (1933) published a detailed account of his finding of the etiology of the "nasal granuloma" in cattle. He confirmed the schistosome as being closely related to *S. spindale* but treated it as a variety viz., *nasale* of *S. spindale* for it definitely revealed some differences.

Rao (1933a) in Madras studied the histopatology of the lesions of "nasal granuloma", which is now definitely established to be a form of schistosomiasis. He described the morphology of the schistosome from materials collected from nasal growths of the affected animals in and around Madras. He concluded the parasite to be a distinct species which he designated as *S. nasalis* *. Further, he proposed the name "Nasal schistosomiasis" for the so-called "Nasal granuloma" of cattle caused by a schistosome in order to distinguish it from another granulomatous disease of the nose of cattle known by the same name, but caused by a rhinosporidium. He also reported this disease —Nasal schistosomiasis— in a buffalo which was hitherto known only in cattle. Malkani (1933) remarked that nasal granuloma occurs but rarely in buffaloes. Subsequently, Rao (1933b), in an attempt to find out the vector of *Schistosoma nasale* in Madras, collected snails from endemic areas, and found *Indoplanorbis exustus* (syn., *Planorbis exustus*) emitting two apharyngeal furcocercariae —one was similar to the cercaria of *S. spindale* as described by Soparkar (l.c.) and the other one was *Cercariae indicae* XXX Sewell, 1919, and *Limnae luteola* emitting only the latter type. By experimental infections of

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* Following Dutt (1967), the trivial name will be hereinafter spelt as *nasale* for reasons mentioned therein.

calves with *Cercariae indicae* XXX, he found these calves beginning to develop symptoms of nasal schistosomiasis in about three months time. He found eggs in the nasal discharge of the experimental calves which were identical with those present in naturally infected cattle. Thus Rao is accorded credit for establishing two facts concerning nasal schistosomiasis of cattle-first, *I. exustus* and *L. luteola* serve as vectors of *S. nasale* in Madras and second, *Cercariae indicae* XXX Sewell is the larval form of this schistosome.

Rao and Ayyar (1933) added one more species viz., *S. suis* to the genus *Schistosoma* from India. They described this species from pigs slúaughtered in Madras abattoir, but the animals came all from North Arcot Distric. They further found the eggs of their porcine schistosome closely resembling those described by Chandler (l.c.). Because of the close similarity of the eggs, Rao and Ayyar believed that in all probability the samples of stools collected in villages in Bengal from which Chandler obtained schistosome eggs were of pigs and not human. The close resemblance of the eggs constrained them to conclude the schistosomes as being conspecific, but strangely enough they merged *S. incognitum* Chandler, 1926 as a synonym *of. S. suis* described by them, although the former has priority over the latter — indeed an unwarranted procedure. The valid name *S. incognitum* is followed here for reasons given later.

Datta (1933) studied from pathological viewpoint schistosomiasis in army horses caused by *S. indicum* Montgomery, and concluded the infection of this schistosome to be one of the causes of the so-called nodular cirrhosis of liver in horses and the same is an important factor in the causation of persistent debility of equines in this country.

Mahajan (1933) reported the occurrence of nasal schistosomiasis in cattle and also in goats in the then Hyderabad State (now merged in Andhra Pradesh). He also reported to have found there cercariae of the type *Cercariae indicae* XXX Sewell in *Limnaea luteola.*

Since the identity of the nasal schistosome became a controversial issue in view of the conclusions arrived at by Bhalerao (1932), Datta (1932), Malkani (1933), and Rao (1933), consequently Rao (1934) made a fresh attempt to solve the tangle true relationship between *S. spindale* and the causative orga-

nism of nasal schistosomiasis of cattle. A parallel case may be cited here. Leiper (1916) studied, while in Egypt, the etiological relation between the vesical or urinary schistosomiasis and Manson's intestinal schistosomiasis which was for long a controversial issue. *S. haematobium* was previously incriminated as being the causative organism of the two distinct clinical manifestations of schistosome infection in humans. But it reflects credit on Professor Leiper for he proved, for the first time by experimental work, that the causative organisms of vesical and intestinal schistosomiasis in humans are two distinct entities: one producing terminal-spined eggs and the other lateral-spined eggs. He clearly distinguished *S. haematobium,* the schistosome causing vesical schistosomiasis from that causing intestinal schistosomiasis for which he suggested Sambon's nomenclature viz., *S. mansoni* to be adopted. Thus Rao (1934) made a comparative study of the morphology of the adults of *S. spindale* and of the nasal schistosome, and of the different stages of their life cycles from his own work. He found distinct diferences in all stages —from egg to adult— o these schistosomes and he concluded these two schistosomes to be distinct entities. Not only in morphology but even in habitats, *S. spindale* an the nasal schistosome, *S. nasale.* differ: *S. spindale* inhabits the portal and mesenteric viens, while *S. nasale* the nasal veins; further, the eggs of the former find their exit with the faeces, but those of the latter with the nasal discharge of the affected animals. In the choice of the intermediate host, *S. spindale* prefers *Indoplanorbis exustus,* rarely, if at all, likes *Limnaea acuminata,* while *S. nasale* prefers *Limnaea* species *(L. luteola, L. acuminata),* but may develop *in Indoplanorbis exustus* if compelled by the enviromental exigencies. He cited Sewell (1922) who found the cercariae of the nasal schistosome in *L. acuminata.* He adduced experimental evidence that the cercaria of *S. spindale* obtained from naturally infected snails failed to produce nasal schistosomiasis. He also studied the histopathology of infected tissues severed from cattle suffering from nasal schistosomiasis.

Bhalerao (1934) reported the occurrence of *S. japonicum* in India. This report was based on some schistosomes (males only) that he received from Dr. P. A. Maplestone who had collected them from a pig in Calcutta, and which he identified, indeed

erroneously, as *S. japonicum* because Sewell (l.c.) had already reported the occurrence of the cercariae of *S. japonicum* in snails in Calcutta.

Swaminathan (1934) reported, for the first time in India, a case of canine schistosomiasis. He found eggs in the faeces of a dog at Jabalpur (Madhya Pradesh), the animal was suffering from dysentery. The eggs were identical with those of *S. incognitum* (syn. *S. suis*) lately described by Rao and Ayyar (l.c.).

Rao and Ayyar (1935) reported a second case of canine schistosomiasis. They found eggs in the faeces of a dog brought for the treatment of dysentery to the Veterinary Hospital at Ootacamund (Nilgiri: Madras State). The animal periodically developed dysentery while in Jabalpur (M.P.) from where it came with his master to Ootacamund. The eggs passed out by the dog remarkably resembled those of *S. incognitum* (syn. *S. suis*) described earlier by Rao and Ayyar (l.c.) from pigs in Madras, and consequently these workers concluded the dog to have had an infection of this porcine schistosome. This conclusion gained support from the statement of the master who informed Rao and Ayyar, when inquired, that pigs were plenty around the lakes in Jabalpur where he used to go with pets for a shooting. It is quite likely, then, that the dog contracted the infection from the lakes while in Jabalpur. This is the second case of canine schistosomiasis reported from Jabalpur. It is worth mentioning that three more dogs, as Rao and Ayyar were informed by the master, had had the same complaints as the one in question, but they had all died.

Rao and Ayyar (1935) doubted Bhalarao's identification of the schistosome of pig from Calcutta (Maplestone's material) as being *S. japonicum*. Bhalerao (1934) was apparently unaware of the publication by Rao and Ayyar (1933) on schistosome of pigs when he studied Maplestone's material and identified it as being *S. japonicum*. They reasonably believed the pig schistosome from Calcutta to be *S. incognitum* (syn. *S. suis*).

Rao (1935) made a further study of the relationship of *S. spindale* and the nasal schistosome viz., *S. nasale*. Following the line of work of Fisher (1934), he, too, plotted curves of the length frequencies of the eggs of these two schistosomes, and arrived at the conclusion that the length-frequency curves show graphically that these two schistosomes are different species.

Inspite of this, Bhalerao in a subsequent, publication (Bhalerao, 1938) still stuck to his previous view regarding the systematic position of the nasal schistosome.

Rao (1935) repeated his previous infection experiments (Rao, 1933b, 1934), and infected a calf, first with the cercariae of *S. spindale*, and about three months later with the cercariae of *S. nasale*. This experiment confirmed his earlier conclusions that *S. spindale* does not produce symptoms of nasal schistosomiasis and that *Cercariae indicae* XXX of Sewell are the larvae of *S. nasale*, the causative organism of nasal schistosomiasis of cattle. It was amazing that the experimental calf did not develop gross lesions in the nose but only manifested small nodular abscesses therein, and a causal observer would hardly suspect the animal as being a victim of nasal schistosomiasis. Rao further concludes from this infection experiment that the calf having a prior infection of *S. spindale* developed a certain measure of immunity against the later infestation with *S. nasale*, and that is why the experimental calf developed only mild symptoms of nasal schistosomiasis. In the light of the results of this infection experiment, he attempts to explain the natural cases of buffaloes and some cattle who do harbour nasal schistosome, but they do not develop symptoms of gross lesions in the nose —the infestation being more or less "sympton-free" as he himself states. He explains such natural cases of non-clinical nasal schistosomiasis, from immunological viewpoint, as follows— "The buffalo and some bovines appear to have a partial immunity conferred by *S. spindalis* against a later infestation with *S. nasalis*".

Rao (1937) again reported a case of canine schistosomiasis. The dog in question came to Madras from Gudiattam, North Arcot District, where the animal, being fond of swimming, used to do so in ponds. The dog was suffering from dysentery and eggs, identical with those of *S. incognitum* (syn. *S. suis*), were found in the faeces. It may be recalled here that the pigs from which Rao and Ayyar (l.c.) collected the material, described by them as *S. suis*, came from North Arcot Distric —a pig-rearing area— where porcine schistosomiasis appears to be endemic. Evidently, the dog got the infection of *S. incognitum* (syn. *S. suis*) from infected ponds in North Arcot Distric while enjoying swimming. Rao also studied the morphology of the miracidium

of *S. incognitum* by hatching mature eggs obtained from the faeces of the dog in water, and compared it with the miracidia of other schistosomes — both human and animal.

Rao (1939) briefly reviewed the schistosomes known to affect the domestic animals in this country. He referred to the occurrence of *S. indicum, S. spindale* and *S. nasale* in India. Regarding the record of the occurrence of *S. bovis* (Sonsino, 1876), by Montgomery (1906) in sheep at Bareilly (U.P.), he believed it to be a case of mistaken identity — Montgomery's fluke was in all probability *S. indicum*. Since molluscan vectors of *S. bovis* viz., *Physopsis africana, Physopsis globosa* and *Bulinus contortus* do not exist in India, the possibility of indigenous occurrence of this animal-infesting schistosome, in his opinion, is totally ruled out. He referred to a record of the occurrence of *S. bovis* existing in the Annual Report of the then Hyderabad State. He managed to obtain the worms in question and, on re-studying, found them to be typical *S. indicum*. He also annulled the possibility of the existence of *S. japonicum* in India in view of the absence of the its snail vectors (*Katayama nosophora, K. formasana* and *Oncomelania hupensis* cited by him) in this country. Bhalerao's (1934) material, as earlier pointed out by him and his co-worker (Rao and Ayyar, 1933), was *S. incognitum* (syn., *S. suis*). Further, Rao listed nine schistosome cercariae described till then in India of which only four are cercariae of true schistosomes (genus *Schistosoma*) viz, *Cercariae indicae* XXX Sewell, 1919; *Cercariae indicae* XLVII Sewell, 1922; *Cercaria anomala* Rao, 1929, and cercaria of *S. spindale*. The adults of two of these cercariae viz., the second and third are yet unknown.

Srivastava (1942) reported three cases of canine schistosomiasis at Bhimtal (U.P.) in the Northern India. Rao (1943) again reported a case of canine schistosomiasis in Madras. The identification of schistosomes in all other cases reported earlier by Swaminathan (l.c.), Rao and Ayyar (l.c.), Rao (l.c.) and Srivastava (l.c.) was based solely on the eggs found in the faeces of the infected animals; but in the present case, besides the eggs obtained from the faeces, adult worms (six pairs) were recovered from the mesenteric veins during autopsy of the dog that later died apparently not of schistosomiasis but of nephritis. A study of the adult worms fully corroborated the diagnosis

made earlier from the eggs that the schistosome harboured by the dog was *S. incognitum*.

Moghe (1945) carried out a survey (from September 1940 to March 1943) of the incidence of occurrence of helminths in cattle sheep and goats in Nagpur and Amraoti (Maharashtra) and in Jabalpur, Indore and Mhow (Madhya Pradesh). He reported to have found four species of schistosomes viz., *S. indicum, S. spindale, S. bovis* and *S. haematobium* in these animals. While he found the infection of the first three species in the said animals in almost all the districs he surveyed, but that of the fourth species viz., *S. haematobium* only in Nagpur — the incidence of infection being 12 por cent in cattle, 3 per cent in sheep and 2 per cent in goat. The report of such regular occurrence of *S. haematobium,* a human-infesting schistosome, in cattle, sheep and goat is indeed amazing, particularly when its endemic occurrence as a human parasite was being hotly discussed in view of the absence of its reputed vectors in this country and the refractory behavious of its miracidium to the common indigenous snails as repeatedly found by several workers mentioned before. Obviously, the report of its occurrence, by Moghe, in cattle, sheep and goats is a case of mistaken identity. In the opinion of the writer, the infestation in these animals must have been with *S. indicum* — a species widely prevalent in animals in India. Likewise, Moghe's report of the finding *S. bovis* in cattle, sheep and goats is again a case of mistaken identity as Rao (l.c.) had actually found one case of mistaken identity in the then Hyderabad State. It is more than probable that the schistosome taken to be *S. bovis* by Moghe was actually *S. indicum*. The occurrence of *S. bovis* in animals in India is still doubtful.

Mudaliar and Ramanujachari (1945) obtained a schistosome from the liver of a she-elephant at Coimbatore (Madras State) that had died possibly of old age. Apparently being unaware of the genus *Bivitellobilharzia* already established by Vogel and Minning (1940) for a proboscidean schistosome known from Africa, Mudaliar and Ramanujachari assigned their blood fluke to *Schistosoma* and described it as a new species viz., *S. nairi*. The description of the species, whatever may be the cause, is meagre and the allocation of the fluke to the genus *Schistosoma* is unwarranted in view of the number of testes in male and the

distribution of the vitellaria in female. Bhalerao (1947) assigned this species to *Ornithobilharzia*, but subsequently Dutt and Srivastava (1955, 1961a) transferred it to *Bivitellobilharbia*. In the present state of our knowledge of the morphology of this schistosome from an Indian elephant, the writer tentatively accepts its assignment to *Bivitellobilharzia* by Dutt and Srivastava (l.c.) as it conforms to the characters of this proboscidean genus of blood fluke at least in two fundamental characters cited above.

According to Alwar (1950), authentic reports of the occurrence of only five species of animal schistosomes in India exist in the literature. He reported to have found eggs of *S. spindale* and *S. incognitum* (syn. *S. suis*) in dogs in Madras; the infection of the latter he also reported in dogs from Salem District, Madras State.

Singh (1950) studied the hatching of the miracidium of *S. indicum* and also its morphology. He concluded that both absorption of water from outside and also the activity of the miracidium within the shell are involved in the process.

The year 1951 marks the beginning of another important chapter in the annals of the veterinary helminthology with the rich contributions of Srivastava and is co-workers (1951-1967).

Srivastava and Dutt (1951) briefly elucidated the life cycle of *S. indicum* and later, in 1962, they published a monograph on the morphology, life cycle and biology of this blood fluke. They found *Indoplanorbis exustus* to serve as a natural as well as an experimental intermediate host. This schistosome is known to parasitize a number of host species. From the results of their experimental infections, they concluded sheep and goats to be the principal natural definitive hosts, while buffaloes play only a minor role as such.

Dutt and Srivastava (1952) found *Limnaea luteola*, collected at Izatnagar (U.P.), emitting a schistosome cercaria — the adult of which they raised in experimental mammals including a buffalo-colf and found it to belong to the genus *Ornithobilharzia*. In post-mortem examinations of buffaloes, they found 3 out of 13 animals harboring schistosomes identical with those that they experimentally raised from cercariae emitted by the naturally-infected *L. luteola*. They gave a detailed account of the

morphology of the cercaria and of its adult, and treated this schistosome as a new species viz., *O. dattai*.

Rao and Hiregaudar (1953) found schistosome eggs in the faeces of six elephants in North Kanara (Karnatak). The eggs, as they observed, resembled those of *B. nairi* which they treated as *O. nairi* but they were much larger — about double in size. They had, however, doubt about the identity of the schistosome as being specifically the same as that described by Mudaliar and Ramanujachari in view of the significantly larger size of the eggs.

Singh (1955) studied the miracidium of *S. spindale* and made additions to our knowledge of its morphology.

Meantime, several veterinarians viz., Sen (1949), Rao and Mohiyudeen (1955), Biswal (1956), Biswal and Das (1956), Rao and Naik (1957) and others reported cases of nasal schistosomiasis — both clinical and non-clinical — in buffaloes from different parts of India. Rao's (l.c.) explanation of the rarity of the infection of *S. nasale* in buffaloes, cited before, did not appeal to some, if not to all workers. They believe some factor other than prior infection of *S. spindale* being involved in the incidence. In the opinion o some, nasal schistosomiasis is not rare in buffaloes, but the absence of clinical symptoms gives the false impression of the infestation being rare in buffaloes. Rao and Naik (l.c.) suggested the possibility of the nasal schistosomes of cattle and buffaloes being distinct species.

Dutt and Srivastava (1955, 1961a), revised the genus *Ornithobilharzia* and they isolated from it their previously described species viz., *O. dattai* and two more mammalian species viz., *O. bomfordi* (Montgomery, 1906) and *O. turkestanicum* (Skrjabin, 1913) — the latter two, as satted before, were removed by Price (l.c.) from *Schistosoma* to *Ornithobilharzia* — as these three mammalian species differ in morphology from the avian species included in the genus *Ornithobilharzia*. They established the genus *Orientobilharzia* with *O. dattai* as the type species, and also included therein the other two mammalian species cited above. They chiefly characterized the new genus by the larger number of testes in male, ovoid shape of the ovary and one set of vitellaria in female, and manmmalian hosts. Later, they (Dutt and Srivastava, 1961b) elaborately discussed the issue and defined their newly-established genus *Orientobilhar-*

zia. Opinion is divided amongst workers regarding the validity of *Orientobilharzia*. The writer has discussed the taxonomy of this genus of oriental blood fluke in a separate paper under preparation. Suffice to say here that the genus has been recognized by him with some amendments. Subsequently, Dutt and Srivastava (1961c, 1962a), worked out the complete life cycle of *O. dattai* and gave detailed accounts of all the stages — egg to adult — including the parthenitae. Only *L. luteola* was found to serve as the natural intermediate host. Naturally and experimentally infected *L. luteola* furnished materials for their study. Dutt and Srivastava (1962b) also studied the host-specificity of this blood fluke. Buffaloes, cattle, sheep and goats are the natural definitive hosts of *O. dattai*: of these, the buffaloes are the principal natural host — a host of choice. About 68 per cent buffaloes harbour this blood fluke in nature, but as compared with this, sheep and goats play only a minor role as definitive hosts. This is just the opposite to that found by them in case of natural infections in buffaloes, sheep and goats with *S. indicum*. Further, Dutt and Srivastava (1962c) made biological studies on the free-living stages of *O. dattai*.

In 1961, Dutt and Srivastava (1961c) also made an important contribution to our knowledge of the epidermal structures of miracidia of as many as six species of animal schistosomes and also discussed their importance in the identification of schistosomes.

Sinha and Srivastava (1956) made a detailed study of the morphology of the pig schistosome and discussed its valid nomenclature. They rightly pointed out that according to the Articles 25 and 27 of the International Code of Zoological Nomenclature, the valid name of the pig schistosome is *S. incognitum* given by Chandler (1926), and consequently the name proposed by Rao and Ayyar (1933) viz., *S. suis* lapses as its synonym. Later, Sinha and Srivastava (1960) published a detailed account of their work on the life cycle of the pig schistosome under the valid name *S. incognitum* (syn. *S. suis*).

Orientobilharzia turkestanicum (Skrjabin, 1913) Dutt and Srivastava, 1955 was an alien species to India till 1957 when Srivastava and Trisal first reported its occurrence in this country. Bhalerao (1932) had previously described it from material obtained throug the courtesy of Chadwick from Bagdad.

Dutt and Srivastava (1964) made a preliminary study of the life cycle of this fluke. Originally, they obtained the material for their study from a village in the vicinity of Srinagar (Kashmir) where its infection in cattle, sheep and goats is endemic. They found *Limnaea auricularia* to serve as a natural intermediate host in the endemic area. Naturally and experimentally infected snails were brought to Izatnagar (U.P.) where the infection of *O. turkestanicum* was established in experimental mammals — these provided materials for their further studies.

Dutt (1965) experimentally studied, from zoonotic standpoint, the susceptibility of the common Indian monkey, *Macaca gulatta,* to the infection of *S. incognitum*. The results of his experimental work clearly point out that the pig schistosome, *S. incognitum,* which is already known to parasitize dogs in this country, is of zoonotic importance. He exposed 13 monkeys to the cercariae of *S. incognitum* obtained from naturally and experimentally infected *Limnaea luteola*. When the experimental monkeys were examined at varying intervals, 6 of them were found harbouring *S. incognitum* and two of them even died of the infection. A post-mortem examination of these two monkeys showed that they were heavily infected. The infections in the other positive monkeys were mild.

In pursuance of the suggestion made by Rao and Naik (l.c.) of the possibility of the nasal schistosomes of cattle and buffaloes being two distinct species, Dutt (1967) initiated his experimental work on *S. nasale* with a view to finding out if any difference — morphological or physiological — exists in any stage between the schistosomes affecting the two host species (*Bos indicus* and *Bos bubalus*). He also performed cross-infection experiments, but found the nasal schistosomes of cattle and buffalo origins to be morphologically quite alike. He gave a detailed account of the life cycle of *S. nasale,* and his studies indeed made important additions to the contributions made earlier by Rao (l.c.).

Dutt and Srivastava (1958) continued the studies on *S. nasale* and made important observations on its molluscan and mammalian hosts. They found only *I. exustus* to serve as its vector in nature. Experimentally, too, they established its infection in laboratory-bred *I. exustus*. They never found *L. luteola* collected from the enzootic area to harbour cercariae of *S. na-*

sale. Further, in their infection experiments, this limnaeid snail showed a refractory behaviour when exposed to the miracidia of *S. nasale*. Their results, however, did not corroborate the finding of Rao (1933b, 1934) who, as stated before, found, besides *I. exustus*, *L. luteola* to serve as a vector of nasal schistosome in Madras State. In cross-infections that they established, cattle developed the usual clinical symptoms of nasal schistosomiasis when cercariae reared from blood flukes of buffalo origin were introduced into them by the nasal route, but in the reverse case, the recipient animal (buffalo) developed non-clinical nasal schistosomiasis. Thus the possibility of two different strains of *S. nasale* affecting cattle and buffalo is totally ruled out. They are inclined to attribute the difference in the pathogenicity of *S. nasale* in the two host animals to "innate tolerance of the parasite by the host".

Meanwhile, Sen-Gupta and Sinha (1966) reported the occurrence of *S. nasale* in goat in west Bengal. This report has an importance from distributional point of view.

In the next decade (1967-1977), several veterinarians made varied contributions to our knowledge of animal schistosomiasis in India.

Niphadkar and Rao (1967) reported the finding of *S. spindale* in bandicoot in Bombay. This is a new host record of this species. Rodents are known in Africa, America and Formosa to be parasitized by human schistosomes, but this is the first report of a schistosome from a rodent in India. Satyanarayanacharyulu et al. (1969) found schistosome eggs in the faeces of an elephant at Tirupati (A.P.) and they tentatively identified the eggs as being those of *S. indicum* and not of *B. nairi* for they were considerably larger. Achuthan et al. (1973) reported the occurrence of *S. nasale* in sheep and goats in Tamil Nadu. Muraleedharan et al. (1973) studied the incidence of infection of *S. nasale* in sheep in Bangalore and Mandya Districts, Karnatak State, and found it to be quite low — 3.2 per cent in Bangalore and 2.2 por cent in Mandya District. Hiregaudar (1975) reported the finding of schistosome eggs in the faeces of lions of the Gir Forests, and identified them as being those of *S. spindale*. This is the first report of schistosome infection in a carnivore in India. Muraleleedharan et al. (1976) again studied the incidence of infection of *S. nasale* but this time in cattle and buffaloes

in two places in Karnatak State, and found in it to be much higher in cattle — up to 53.4 per cent — than in buffaloes which showed the incidence up to 35.7 per cent.

The upshot of the foregoing discussions of the works done by various investigators is that only one species of human schistosome causing urinary schistosomiasis has been found in India, whereas infections of as many as seven species of animal-infesting schistosomes are enzootic in this country. The animal-infesting schistosome are:

Schistosoma indicum Montgomery, 1906

Schistosoma spindale Montgomery, 1906

Schistosoma incognitum Chandler, 1926
syn. *S. suis* Rao and Ayyar, 1933

Schistosoma nasale Rao, 1933

Orientobilharzia dattai (Dutt and Sriv., 1952) Dutt and Sriv., 1955
syn. *Ornithobilharzia dattai* Dutt and Sriv., 1952

Orientobilharzia turkestanicum (Skrjabin, 1913) Dutt and Sriv., 1955
syn. *Schistosoma turkestanicum* Skrjabin, 1913
Ornithobilharzia turkestanicum Price, 1929

Bivitellobilharzia nairi (Mud. and Raman., 1945) Dutt and Sriv., 1955
syn. *Schistosoma nairi* Mud. and Raman., 1945
Ornithobilharzia nairi Bhalerao, 1947

Some of the species of animal schistosomes viz., *S. indicum*, *S. spindale* and *S. incognitum* are quite common and are widely distributed in this country and they constitute, on account of the close association of man with the host-animals, a problem from zoonotic viewpoint. Dutt (l.c.) has already pointed out, by experimental infection of monkeys, the zoonotic importance of *S. incognitum*. Future researches quite likely to reveal some of these animal schistosomes in human subjects in India as Pitchford (l.c.) has reported such incidence in Eastern Transvaal, South Africa. Nelson's (1960) work on schistosome infections as zoonoses in Africa is noteworthy here.

RESUMEN

En esta revisión el autor presenta un análisis crítico de los trabajos realizados en la India sobre los esquistosomas del hombre y animales desde 1878 hasta la fecha.

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