The cradle of Indian renaissance and the national freedom movement, West Bengal has long since been the cultural centre of India. Born of its geography and history, the colourful state is indeed a land of violent contrasts. The cool northern uplands and the parched Pargana lands, the flat riverbeds and swampy coastal regions, the dense tropical and Alpine forests, the natural wealth and industrial progress of the land combine to produce a melodious representation of the Bengali’s essence and character. The variations in altitude are responsible for the great variety in the nature and climate of West Bengal. Shaped like a sea horse, West Bengal is also the triple gateway-opening eastward to the seven north-eastern states, northward into Sikkim and westward into the gangetic plains.

The state is extending from 85°50' East to 89°50' East and from 21°38' North to 27°10’ North. Though the state ranks twelfth in respect of area (88,752 sq.km.), the density of population (904 per sq.km.) puts a crown on the state. At present (January 01, 2002) there are nineteen districts in the state.

The state is divided into four major landforms namely Mountains (2.27%), Hills (1.14%) Plateaus (11.34%) and Plains (85.25%). The mountains and hills are on the extreme northern boundary. This part is called the crown of West Bengal. Sandakphu (3,630 meter) is the highest peak of West Bengal. The whole of Purulia district and western parts of Burdwan, Bankura and Paschim Medinipur districts comprise western undulating Highlands and Plateaus of West Bengal. The Gargaburu of Ayodhya hill is the highest peak (677 meter) of the region. The rest below 300 meter is the Plain covering mostly the southern parts of the state drained mainly by the Ganges and other tributaries.

Drainage of West Bengal consists of a number of perennial (snow-fed), non perennial (rain-fed) and tidal rivers and tributaries and distributaries. The Ganges and her tributaries the Damodar, the Ajay, The Mayurakshi etc. flow through the plain. Two snow-fed rivers, namely The Tista and the Mahananda – originating from the northern Himalayas flow southward. Matla, Batala, Saptamukhi, the distributaries of Bhagirathi–Hooghly river are called tidal rivers. As the region falls under the lower and deltaic course of the river Ganges, the drainage pattern is anastomotic.

West Bengal experiences a hot and humid monsoonal climate. Tropic of Cancer (23½° North) passes through the middle of the Southern Bengal influencing and moulding the climate. The northeast monsoon and the southwest monsoon are the principal features in the meteorology of West Bengal. A year is conveniently divided into the following four principal seasons. (i) **Winter season** (December to February) : Temperature averages between 15°C to 18°C. There is no rainfall but the coastal region experiences cyclonic rain; (ii) **Summer** (March to May) : The state experiences average temperature between 20°C-30°C; (iii) **Rainy season** (June to September) : Southwest monsoon flows over the Bay bringing rain ranging between 100 cm
and 455 cm depending on relief; (iv) Autumn (October to November): The Bay cyclone forms in this season giving rise to moderately disturbed weather.

India is endowed with vast and varied aquatic resources amenable for fisheries and aquaculture. The marine resources are spread in the oceans encompassing the 8041 Km. coastline. It has a continental shelf of 0.5 million sq.km. After the declaration of Exclusive Economic Zone (EEZ), the area available to India is estimated at 2.0 million sq.km. on the east west coast and 0.60 million sq.km. around the Andaman and Nicobar Islands. The total length of the rivers and canals has been estimated at 1.7 lakh km. The various estuaries systems cover an area of 2.7 million ha. The floodplain lakes constitute an area of about 2 lakh ha. to the available statistics, the reservoir area is estimated at 2.1 million ha. The area under tanks and ponds has been estimated at 22.54 lakh ha. and the resources are widely spread throughout the length and breadth of the country. The potential area identified for brackish water aquaculture has been estimated about 0.9 million ha. (Gopakumar, 2000).

The total fish production of the country has increased from 7.52 lakh tonnes in 1950-51 to 56.96 lakh tonnes in 1998-99. Out of total fish production the marine sector contributed 30.31 lakh tonnes whereas the contribution from inland sector is 25.65 lakh tonnes (Gopakumar, 2000). At present India holds sixth position in the world in terms of total fish production and first among commonwealth countries (Kamal, 2000). But according to inland production India is second largest producer of fish in the world after China (Gopakumar, 2000).

According to the recommendations of the working group on fisheries, the projected need of fish for 2002 AD, the country has to produce another 1.2 million tonnes of fish additionally. This is in order to make a per capita availability of fish 11.24 kg per man, the current level of availability being 9.85 kg (Kamal, 2000).

The state of West Bengal is bestowed with wide range of fishery resources right form the Himalayan foot hills in the north to the Bay of Bengal in the south with 2.76 Lakh ha. area of ponds and tanks, 0.42 lakh ha. of beels and baors, 1.72 lakh ha. of rivers, 0.82 lakh ha. of canals, 2.10 lakh ha. of brackish water, 0.16 lakh ha. of reservoir fisheries and 0.04 lakh ha. of sewage fed fisheries. The total fish production of the state has increased from 3.7 lakh tonnes in 1980-81 to 10.45 lakh tonnes in 1999-2000 with annual growth rate of 6.62% (Chakroborty, 2000). But, much is yet to be meet the increasing demand of fish of the state. It has been estimated that the requirement of fish of West Bengal at the end of 2010 would be about 14.0 lakh tonnes. For being self reliant on fish food it would be necessary to raise the present production level by adaptation of various aquaculture technologies.

The success of implementation of various fishery development programmes depends to a great extent on the intensification of the fish parasitological research as the improvement of fish yield can mainly be achieved from healthy fish stock.

Natarajan and James (1977) are of the opinion that studies on pathology of fish have to be increased greatly as intensive method of fish culture and composite fish culture techniques are being practised in the country.
Fishes are parasitized by different organisms, namely viruses, bacteria, algae, fungi, protozoans, helminths, acanthocephalans, nematodes, annelids, molluscs, crustaceans and cyclostomes. Parasites affect fish population in a variety of ways including stunting, emaciation, sterility, mortality etc. Large fish mortality or fish kill frequently occurs in rivers, ponds and tanks due to environmental stress and heavy parasitic infections. So, researches on ichthyoparasitology are of immense significance from the academic and applied points of view.

Among the ichthyoparasites, protozoans constitute a major and probably the most important group which include representatives from flagellates, rhizopods, sporozoans, myxozoans, microsporans and ciliates. Incidences of heavy fish mortality or irreparable loss in fish industries due to protozoan infestation are very common.

The myxozoans are parasitic protozoans that inhabit primarily the tissues and organ cavities of cold-blooded (exothermic/poikilothermic) vertebrates, especially fish and have an importance in ichthyopathology (Sakiti et al. 1990, 1996; Diamant, 1992; Lom and Dyková, 1992; Fomena et al. 1993). Moser and Kent (1994) remarked that this has been an exciting decade in the study of the myxosporea. The discovery that myxosporeans require an alternate host in their life cycle has changed the way we view the evolution of this group and its taxonomy. In many respects workers have begun to fully appreciate the uniqueness of the Myxosporea among the Protozoa. Those organisms, for example, unlike other protozoa, have specialized cells which give rise to distinct structures and thus in a sense are multicellular.

**LIFE CYCLE**

Since Thélohan discovered the first myxosporean, in 1895, the life cycle of these organisms has remained enigmatic and poorly understood. Several workers have attempted to elucidate the life cycle by means of direct infection, most attempts were unsuccessful. The first positive results were obtained by Markiw and Wolf (1983) with Myxobolus cerebralis Hofer, 1906 using tubificids as intermediate hosts. Following this approach, more recently, several authors have reported similar results.

As revealed in the pioneering publication of Wolf and Markiw (1984) and later confirmed by a series of experimental papers (e.g. El-Matbouli and Hoffman 1989; Hedrick et al. 1989; Kent et al. 1991, 1994; El-Matbouli et al. 1992, 1995; Benajiba and Marques, 1993; Yokoyama et al. 1993, 1995b; Uspenskaya, 1995; Andree and Hedrick, 1997; Lom and Dyková, 1997), the life cycle of representatives of the Phylum Myxozoa Grasse, 1960 consists, at least in some of its members, of two phases. The first is represented by organisms known as myxosporeans (Class - Myxosporea) developing almost exclusively in fish. The second is represented by organisms of which relatively few species have been known to date – developing mostly in oligochaetes. Until recently, they have been considered to constitute an independent Class Actinosporea, the sister Class of Myxosporea within the Phylum Myxozoa. A thorough comparison of structure and their morphogenesis of the two respective groups is still missing, although much desired to reveal the diversity manifested during the life cycle of myxozoan organisms.
Myxozoan life cycle, according to Lom and Dyková (1997), is quite complicated. The actinosporean spore, end product of the Actinosporean phase taking place in the oligochaete host and eventually released from it, floats in the water column. It is supposed, upon contact with the fish surface, to adhere chemotactically to it (Yokoyama et al. 1995a). It discharges sticky polar filaments serving for better attachment to the host tissue, the spore shell opens and the usually large, multinucleate sporoplasm emerges. It contains numerous small uninucleate cells, the infective cells proper, which pervade the host tissue and start first the development in the integument. This process was observed first by Daniels et al. (1976) and followed in detail by Markiw (1989). The released infective germs engage in a presporogonic development, intracellular and intercellular, in which inside a primary (mother) cell, secondary and tertiary cells are formed and then released to continue their growth and proliferation (El-Matbouli et al. 1995). These inner cells; like those inside Myxosporean sporogonic plasmodia or Actinosporean sporoplasm; reside inside a tightly fitting membrane bound space, as if in a closely adhering vacuole, within the mother cell cytoplasm.

Prior to the appearance of spore-forming, sporogonic stages in the target (final) site of infection, several cycles of presporogonic proliferation may occur. In addition, proliferative cycles which use to be termed extrasporogonic, continue to proceed during sporogenesis. Cells of both pre- and extrasporogonic cycles divide by endogenous budding, inner secondary cells may produce tertiary, quaternary or even quinquenary cells inside them. These purely proliferative cycles take place in tissues and organs other than the target sites and their cells may be intercellular in tissues (or bloodstream) and / or intracellular, irrespective of whether the sporogonic stage in the target site is histozoic or coelozoic.

Myxosporeans sporogonic stages in form of multinucleate plasmodia may reach large size (upto many millimeters). Very many inner cells are contained in tightly fitting vacuoles in their cytoplasm, i.e., generative cells and in some cases large cells of unknown function [= lobocytes of Grassé and Lavette (1978), who interpreted them as scavenger cells]. Histozoic plasmodia tend to be compact, roundish or ovoid; coelozoic ones may be extremely elongated, even branched and with many lobes or tips.

Generative cells produce Myxosporean spores in two ways: either directly, dividing into a number of cells corresponding to those which after transformation composed the mature spore, or within a pansporoblast. The latter is mostly accepted to be a product of a pair of cells joined together, one (the pericyte) enveloping the other (sporogonic cell) which divides to give generally rise to two spores within a pericyte. Pericyte does not divide, although exceptionally it has been reported to be binucleate (Schubert, 1968).

Although the germination of myxosporean spores in the fish digestive tract has been observed as early as 1895 by Thélohan, the only rather trustworthy reports on successful experimental infection of fish by myxosporean spores are by Johnston (1985) in Parvicapsula and by Odening et al. (1989) in Sphaerospora renicola. According to prevailing evidence, myxosporean spores are only infective for the invertebrate. Within the digestive tract of e.g., a
tubificid worm, the shell valves separate, releasing the sporoplasm. In binucleate sporoplasm the nuclei are known to fuse accomplishing autogamy (Shulman, 1966). Behaviour of sporoplasm of other types is not known. Earliest stages found in the intestinal epithelium [intercellularly, exceptionally intracellularly (Lom et al. 1997)] are uni- to binucleate, thus possibly capable of repeated division.

A real presporogonic Actinosporan phase proliferation in form of radial merogony has only been reported once by Marques (1984) in Neoactinomyxon eiseniellae. This problem has to be resolved by more observations, the same applies to the way of origin of pansporocyst. This is a structure in which the spores are produced within the shelter of two or four thinly spread enveloping cells, actively engaged in transport of nutrients from the host to the developing sporoblast cells.

Pansporocyst has been supposed to develop either by union of two uninucleate cells and their later differentiation (Ikeda, 1912; Marques, 1984; Lom and Dyková, 1992a) or from a binucleate cell (Léger, 1904) which divides and also produces the enveloping and sporogonic cells.

Once the pansporocyst has been formed, the inner enveloped cells divide producing eventually 8 gametes $\alpha$ and 8 gametes $\beta$ (both slightly differ morphologically), plus 32 tiny cells, the actual polar bodies of the well proven meiotic process (Janiszewska, 1955). Each of the resulting 8 zygotes produces by an intricate way of cell division and cell differentiation invariably 8 valvogenic and 32 capsulogenic cells, while the sporoplasm develops as a multinucleate plasmodium containing inner cells, the actual infective germs. (The genus Tetraactinomyxon with binucleate sporoplasm has been postulated to be a myxosporan by Kent et al. 1994).

Mature pansporocysts released from the infected tissues along with the excrements disrupt in water, the generally long projections of their spores instantaneously imbibe water and inflate to real floaters to keep the spore afloat in the water column. According to Markiw (1989) the spore's infectivity does not exceed two days.

Myxozoan life cycle has been exemplified by different workers using different genera. In the following few paragraphs some evidential experiments related with life cycle are discussed briefly.

The studies of Wolf and Markiw (1984), Wolf et al. (1986), El-Matbouli and Hoffman (1989) have shown that Myxobolus cerebralis has a two-host life cycle involving fish and an oligochaete (Tubifex tubifex) and two alternated different sporogonic stages in the life cycle. They demonstrated that Myxobolus cerebralis spores were ingested by T. tubifex and transformed into an actinosporan Triactinomyxon after a vegetative multiplication within 3 months. Then rainbow trout (Oncorhynchus mykiss) become infected either by intestino infected tubificids or by contact to waterborne triactinomyxon spores, that actively penetrate fish skin and gills (Markiw, 1989 and El-Matbouli et al. 1992).
El-Matbouli and Hoffman (1989) showed that *Myxobolus cotti* infecting the nervous system of bullhead (*Cottus gobio*) transformed in *T. tubifex* into a *Triactinomyxon*, which is infectious to bullheads.

Kent *et al.* (1990) also suggested that the infection of the brain of sockeye salmon (*Oncorhynchus nerka*) with *Myxobolus arcticus* involved the aquatic oligochaete *Eclipidrilus* sp. (*Lumbriculidae*).

El-Matbouli and Hoffman (1991) and Ruidisch *et al.* (1991) reported that *Myxobolus pavlovski* from the gills of silver carp (*Hypothalmichthys molitrix*) transformed in *T. tubifex* into an *Hexactinomyxon*, which infects silver carp.

Yokohama *et al.* (1991) achieved similar results by coexistence of uninfected goldfish with a stock of naturally infected oligochaetes (*Branchiura sowerbyi*) shedding spores of several actinosporeans resulted in infections with *Zschokkella, Myxobolus* and *Thelohanellus* spp.

El-Matbouli *et al.* (1992) were unable to transmit *Hoferellus carassii*, the causative agent of kidney enlargement disease of goldfish (*Carassius auratus*) directly. But by using tubificid oligochaetes as intermediate host in which *H. carassii* spores developed to an actinosporean of the genus *Aurantiactinomyxon* they succeeded in infecting myxosporean free goldfish with spores of *H. carassii* in 130 days after exposure to *Aurantiactinomyxon*.

A similar result was obtained again by El-Matbouli and Hoffman (1993) where they failed to transmit *Myxobolus carassii* directly to myxosporea-free golden orfe but achieved to infect the same host fish experimentally, in laboratory condition by using tubificid worm as an intermediate host.

Benajiba and Marques (1993) have also showed the life cycle of *Myxidium giardi* takes four months to complete through tubificid oligochaetes as intermediary host where spores of *Aurantiactinomyxon* type of class Actinosporea developed and upon contact with elvers (*Anguilla anguilla*) these spores transformed in *M. giardi*.

Although, not all workers have accepted the two stage life cycle proposal. Hamilton and Canning (1987) presented results that did not support the proposed actinosporean component in life cycle of the Myxosporea, but a further series of studies reinforced this two-host life-cycle in a number of myxosporeans.

Accepting that the **Myxosporea has a two-host life-cycle**, it would create many taxonomic and nomenclatural problems (Corliss, 1985). Combining the Myxosporea and Actinosporea will result in changes at all levels in their taxonomic ranks and would force biologists to reconsider their views of the evolutionary relationship of these two groups. The greatest change would be the merger of the two Classes into which the Phylum Myxozoa is divided (Myxosporea and Actinosporea), as these Classes would then only be stage in life cycle of one type of parasite.
Odening (1991) suggested that the actinosporean should be regarded as adults, the myxosporeans, however, as developmental stages. Even if this question cannot be answered definitely a new classification of myxosporeans and actinosporeans, which at present are arranged in different Classes of the Phylum Myxozoa, should be established.

**LENGTH OF THE LIFE CYCLE AND ITS SEASONAL FLUCTUATION**

*Myxobolus cerebralis* requires four months to produce mature spores (Wolf and Markiw, 1984). Although other experimental results are missing, additional data arise from observations of spontaneous infections: mature spores can be found in three week old *Rutilus rutilus* fry (Shulman, 1966), and mature spores of *Sphaerospora renicola* in one month old *Cyprinus carpio* fry. Histozoic trophozoites finally either discharge the mature spores into the host organism or to the outside and/or become encapsulated and destroyed by the host. In coelozoic species, the infection may be limited in time (*Sphaerospora renicola*) or it may persist indefinitely (*Myxidium lieberkuehni*).

Long-lasting myxosporean infections (e.g., with *Ceratomyxa shasta* or *Myxidium salvelini*) may span the oceanic phase of the life of anadromous fishes. In *M. salvelini*, the infection is retained in the trophozoite stage, sporogenesis being only resumed after the salmon have returned to spawn (Lom and Dyková, 1992).

While some myxosporeans seem to thrive in the host irrespective of the season, some exhibit a marked seasonal fluctuation. According to Lom and Dyková (1992), infection of perch (*Perca fluviatilis*) with *Henneguya psorospermica* to be limited to early spring.

**ULTRASTRUCTURAL MORPHOLOGY**

Ultrastructural studies, initiated by Grasse (1960) have been elucidating myxosporean cell structures, unique in many respects. Recently, ultrastructural findings confirm that the actinosporean and myxosporean stages do constitute together a single myxozoan life cycle (Lom, 1995) and are strongly in favour of metazoan nature of myxozoans (e.g., presence of desmosomes – Desportes and Théodoridès, 1982; Desser et al. 1983a). Ultrastructural evidence also helps to understand the interaction of myxosporeans with host cells (Lom et al. 1989a) or tissues (Current and Janovy, 1976; 1978) and hence the myxosporean pathogenicity.

Thus far, myxosporeans of 17 genera and 78 species have been examined with the transmission electron microscope (Lom and Dyková, 1996). The genera most studied were *Ceratomyxa* Thélohan, 1892 (e.g., *C. globulifera* Desportes and Théodoridès, 1982 [these are also the authors and the date of description]); *Henneguya* Thélohan, 1892 (e.g., *H. adiposa* Minchew, 1977 – Current, 1979); *Myxidium* Bütschli, 1882 (e.g. *M. gadi* Gergevitch, 1916 – Feist, 1995); *Myxobolus* Bütschli, 1882 (e.g., *M. cerebralis* Hofer, 1903 – El-Matbouli et al. 1995); *Sphaerospora* Thélohan, 1892 (e.g., *S. testicularis* Sitja-Bobadilla and Alvarez-Pellittero 1993a [these are also the authors and date of description]); *Zschokkella* Auerbach, 1910 (e.g., *Z. pleomorpha* Lom and Dyková, 1995 – Lom and Dyková, 1996) and *Ortholinea* Shulman,
1962 (e.g., *O. fluviatilis* Lom and Dyková, 1995 – Lom and Dyková, 1996). Although the essential features of myxosporean structures and their morphogenesis have been established, many structures and phenomena have not been understood to our satisfaction and additional data are needed.

Moser and Kent (1994) have summarized a general description of the ultrastructure of myxosporeans of various genera. According to them electron microscopy of trophozoites of several species confirm the light-microscopic examination that trophozoites are truly multicellular. Early differentiation into distinct somatic and generative elements may be observed in the developing trophozoite. The generative units appear as discrete cells in the multinucleate somatic plasmodium.

In the coelozoic genus *Sphaeromyxa*, the outer surface of the trophozoite is covered by a simple pellicular membrane with well-developed microvilli. Amorphous mucin-like strands, that apparently are secreted by the trophozoite, coat the pellicle. Pinocytotic vesicles have been noted in histozoic genera including *Myxobolus*, *Thelohanellus* and *Henneguya*, and to a lesser extent in coelozoic forms (*Sphaeromyxa* and *Myxidium*) where most feeding is accomplished through general surface absorption. Meshworks of fine fibrils and scattered ribosomes occur in the ectoplasm of several genera. Lom (1969a) detected fine internally folded membrane-bound tubules (0.5 μm long x 500 μm diameter) in the ectoplasm of *Sphaeromyxa*, these elements occur in bundles and may be unique in protozoan ultrastructure. The endoplasm is granular and highly vacuolated; among the vacuoles of *Sphaeromyxa* are found mitochondria, golgi complexes, lipid droplets, a well-developed smooth endoplasmic reticulum, and somatic nuclei associated with the vegetative activities of the trophozoites. In addition, the cytoplasm may contain cells in various stages of sporogenesis, such as early generative cells, sporoblasts and mature or developing spores. Generative cells of *Sphaeromyxa* form active amoeboid cells with filiform pseudopodia.

In many myxosporeans, sporogony is initiated when the folded surfaces of two uninucleate generative cells adhere. To form a sporoblast, one of these cells envelopes the other; the enveloping cell and its nucleus remain visible until the spores are completely formed but they do not participate directly in sporogenesis. The generative cell divides until a sporoblast containing 5 or 10 cells that are destined to become the cellular components of the spore is produced. Sporoblasts with 5 cells produce one spore; those with 10 cells are disporoblastic. Within the sporoblast those cellular units that are destined to become the sporoplasm are binucleate. As the generative cells divide, ribosomes and mitochondria become numerous in the sporoblasts. These organelles decrease in number as the full complement of cells is attained and sporoblastic differentiation begins. In the latter process, spore structures begin to appear in the sporoblast as cells destined to become valves of the spore spread around the capsulogenic cells and sporoplasm.

The formation of the polar capsules is similar in all myxosporeans that have been examined. Each polar capsule forms as an elongate sinuous tube with an attached sac like
polar capsule primordium within the capsulogenic cell. Within the tube and sac, fine granules gradually aggregate to form the inverted coiled filament (Lom and de Puytorac, 1965; Lom, 1969a; Schubert, 1968).

Electron microscopy has revealed no clear evidence of sexual processes in those species examined. As a result of examination by light microscopy, it was believed that in certain species pairs of early generative cells developed into haploid gametes, which fused to form a binucleate zygote which then underwent sporogenesis. In this view, which has not been substantiated, it is proposed that all nuclei of the sporoblast are haploid. It is well established that the two nuclei of the sporoplasm fuse before spore hatching, and a reduction division is thus assumed to occur at some stage in the life cycle; it is not clear when meiosis occurs, however, or whether nuclei other than those forming the sporoplasm undergo reduction division (Moser and Kent, 1994).

In *M. cerebrails* the two spore valves are often of different volumes. A deep furrow in each valve parallels the suture. Fine mucus strands extend over the surfaces of the valves; there are more of them toward the posterior. The furrow and mucus strands present in the spores of *M. cerebrails* have not been observed in several other species including the closely related *M. cartilaginis* (Lom and Hoffman, 1971). Morrison and Pratt (1973) observed that several parallel longitudinal furrows, visible as faint striations with the light microscope, extend from end to end on each side of the spore in *Sphaeromyxa maiyai*. Canals through which filament extrusion occurs have been observed on each valve in the sutural ridge in *M. cerebrails* and in *M. muelleri*. The canals appear to be capped in *M. muelleri* but open in *M. cerebrails*.

Electron micrographs of sectioned spores show that the ridge is formed by the sutural joining of the valves. When present, the intercapsular appendix is formed of the sutural ridge which extends posteriad between the polar capsules. This organelle is apparently present only in *Myxobolus*. Extruded filaments are hollow, surrounded by a double membrane, and covered with an adhesive material presumably secreted from their lumen. When coiled inside its capsule, a filament appears spirally twisted along its long axis. The filament is continuous with the anterior surface of the polar capsule which appears to be capped by a proteinaceous plug formed by the capsulogenic cell and by an overlying electrondense mass, the “stopper mechanism” of the valve. Upon discharge, the filament everts from the remains attached to the apex of the capsule (Lom, 1964).

According to Lom and Dyková (1996) myxozoan ultrastructure can be described as follows.

**Spore Formation**

Coelozoic myxosporeans (e.g., *Zschokkella, Ortholinea, Myxidium, Chloromyxum*) can produce either one, two or several to many spores per sporogonic plasmodium. In the suborder Platycteronina under the order Bivalvulida, pansporoblasts are always formed and in the order Multivalvulida they never occur. However, in some of the genera having species with
mictosporic plasmodia spore formation in pansporoblasts may alternate with sporogony without pansporoblasts. In the genus *Zschokkella* (suborder *Variisporina*), some of the species (e.g., *Z. nova* [Lom and de Puytorac, 1965] and *Z. leptatherinae* [Su, 1996]) form pansporoblasts while others (e.g., *Z. mugilis* [Sitja-Bobadilla and Alvarez-Pellitero, 1993b] and *Z. pleomorpha* [Lom and Dykova, 1995]) do not. In some species of *Myxidium*, e.g., *M. gadi* sporogenesis can also take place both through direct cell division and in pansporoblasts (Fiest, 1995). In *Chloromyxum*, some species form pansporoblasts (*C. lenorae* – Lom *et al.*, 1988), some not (*C. leydigi* Naville, 1927). However, *Ortholinea fluviatilis* produce spore in both ways.

**Attachment**

Four ways of attachment to the host cells were observed in the myxosporeans. The most simple was the junction between the tips of the microvilli and the surface of plasmodium of *O. fluviatilis*. Such junctions are also known in pseudoplasmidia of *Sphaerospora* species (e.g., *S. renicola* Lom *et al.*, 1982). Plasmodia of *Z. pleomorpha* inserted their finger-like projections between the host cell microvilli and were firmly attached to them by rather elaborate junctions of a type reminiscent of junctions found in *Hoferellus gilsoni* (Lom *et al.*, 1986). In the complex host-parasite interface of this species, there are areas of contact between the plasmodium and epithelial cell membranes in form of septate junctions, the gaps between membranes being spanned by bridges spaced at a similar distance, 17 nm (compared to 19 nm in *Z. pleomorpha*). Junctions of plasmodial projections in *Myxidium gadi* and host cell microvilli are similar but lack this septate appearance and have an interposed layer of amorphous material (Feist, 1995). In other species (*Sphaerospora truttae* McGeorge, 1995) the projections were reported to simply interdigitate with the microvilli. In other myxosporean species the plasmodial projections are attached directly to the epithelial cells. They simply adhere to the host cell surface in either *Leptotheca* or *Ceratomyxa* (Desportes and Théodoridés, 1982). Surface indentations in host cells, occupied by plasmodial projections similar to those observed in *O. fluviatilis* were observed in *Myxidium giardi* (Paperna *et al.*, 1987). In the latter case the area of contact was actually represented by attachment points spaced at regular intervals rather then being flat.

In both *Z. pleomorpha* and *O. fluviatilis*, additional holdfasts occurred in form of cytoplasmic projections attached or inserted into the gap between neighbouring epithelial cells. This was reported before (El-Matbouli and Hoffman, 1994) in *Sinuolinea tetraodoni* occupying renal tubules of *Tetraodon palembangensis*, a fish which is congeneric with the host of *O. fluviatilis*. Similar attachment to junctions between epithelial cells was demonstrated in *Zschokkella mugilis* by Sitja-Bobadilla and Alvarez-Pellitero (1993b) and quite recently in plasmodia of *Hoferellus carassi* attached to the epithelium of the urinary bladder of goldfish (Trouillier *et al.*, 1996)

Thus it is obvious that a given type of attachment is by no means typical of a certain myxosporean species or genus. The reasons for such a variety of ways of attachment (or no attachment at all as in *Z. leptatherinae* Su, 1996) can perhaps be interpreted in terms of
adaptation to conditions prevailing in each given case (type of the host surface at the site of infection, developmental stage) rather than as a feature of the parasite.

Cytological Structures

Cell structures of plasmodia as well as of developing spores confirm the great variability of myxozoan cells. The wide diversity of cytoplasmic constituents in large plasmodia is opposed to the simple structure of secondary or tertiary cells in which the nucleus is surrounded by just a thin layer of cytoplasm with a few mitochondria and small fragments of endoplasmic reticulum.

In mitochondria, there is a great variability in the shape of cristae and in the density of mitochondrial matrix, while mitochondria in the inner (generative) cells have a lucent matrix, the matrix tends to be dark in e.g., capsulogenic cells of Z. pleomorpha and especially in large plasmodia of O. fluviatilis. These states can be compared with what has been designated as orthodox and condensed mitochondrial structure. Mitochondria with equally striking dense matrix were reported in Myxidium lieberkuehni and Chloromyxum cristatum (Lom and de Puytorac, 1965), Myxidium giardi (Paperna et al. 1987), Z. icterica (Diamant and Paperna, 1992) or M. gadi (Feist, 1995). Transformations of mitochondrial structure are obviously associated with not yet understood changes in metabolic activity and ion traffic at different stages of myxosporean development.

Although there are no microtubular structures in Z. pleomorpha and O. fluviatilis plasmodia' (at variance with e.g. Myxidium lieberkuehni Lom and de Puytorac, 1965; Sphaeromyxa sabrazesi Grassé and Lavette, 1978; Kudoa lunata Lom and Dyková, 1988 or Leptotheca / Ceratomyxa Desportes and Théodoridès, 1982) there is a rich variety of vesicles, vacuoles and dense bodies. These organelles are supplemented by several types of rather unusual inclusions. First there are bodies with stacks of membranes in plasmodia of Z. pleomorpha. They are to some extent reminiscent of multilamellar bodies in plasmodia of Myxidium gadi (Feist, 1995) rather than of myelin figures in Z. mugili plasmodia mentioned by Sitja-Bobadilla and Alvarez-Pellitero (1993b). Further riddles are found in the cytoplasm of O. fluviatilis. Finally, the undulated membranous profiles bear some resemblance to stacks of annulate lamellae; however, they are linked with RER and not the nuclear membrane; perhaps a more reasonable suggestion would be a kinship with stacks of cisternae of Golgi apparatus.

These organelles expand the list of cytoplasmic constituents of unknown functions such as lobocytes (Grassé and Lavette, 1978) or generative cells mutually interlocked with each other by their cell projections (Dyková et al. 1987).

Somatic nuclei of plasmodia, adhering to the surface of generative cells in O. fluviatilis plasmodium strongly resemble similar complexes in the sporoplasm of some actinospores. In Neoactinomyxon eiseniellae, somatic nuclei of the sporoplasmic plasmodium are similarly attached to the actual infective cells inside it (Marques, 1984). Such association also exists in the pair of sporoplasmic cells of Kudoa lunata (Lom and Dyková, 1988), the nucleus of the outer cell is closely attached to the surface of the inner sporoplasmic cell.
Although the functional significance of this coupling is unknown and may differ in the myxosporean plasmodium and actinospore sporoplasm it clearly shows general patterns common to both myxosporean and actinosporean phase of the life cycle (Kent et al. 1994).

In the course of capsulogenesis in both *O. fluviatilis* and *Z. pleomorpha*, the primordium and external tube have the appearance found in most myxosporeans studied i.e. are filled with finely or coarsely granular dense substance, without containing peculiar dense structured formations such as those found in *Myxobolus tanduli* (Current et al. 1979) or *M. cotti* (Lom et al. 1989b). Within the external tube, the dense granular lumps are eventually replaced by nascent filament profiles. In *Z. pleomorpha*, the almost mature capsule is encased with a dense envelope set at a certain distance from the capsule surface. This boundary was not found in any other myxosporeans.

The fine fibres on the surface, of the almost mature polar filament have also been found in *Sphaerospora angulata* (actually *S. renicola*) (Desser et al. 1983a). They obviously constitute a basic element in filament morphogenesis. They tend to disappear in all species observed before the filament transforms into a mature one with a dark core inside a lucent outer layer. At that time the matrix of the capsule also appears uniformly dense and structureless. Morphogenesis of the polar filament proceeds from simple S-shaped double walled profiles first seen within the external tube to more massive, dense and twisted profiles and, eventually, to submature dumbbell- or 8-shaped profiles with denser core and lucent envelope within capsular primordium.

**CLASSIFICATION**

The position of the myxosporeans in the animal kingdom is under considerable question. Both the spore and the trophozoite show true multicellularity well advanced over the protoplasmic or colonial levels of organization characteristic of the Protozoa (Mitchell, 1977). Recent electron microscopy has shown that the ontogenesis and functional morphology of myxosporian spores are profoundly different from all other protozoans. Several authors do not consider the Myxosporidans true Protozoa (Lom, 1973).

The striking similarity between myxosporian cnidocysts or polar capsules and nematocysts of the Phylum Cnidaria indicates a possible relationship between these two groups (Lom, 1969, 1973).

Recently, molecular analyses of a few myxozoan species have indicated that the place of Myxozoa is with metazoans rather than in the protistan realm. The results of Smothers *et al.* (1994) and of Schlegel *et al.* (1996) suggested their grouping with Bilateria, specifically nematodes while Siddall *et al.* (1995) postulate the inclusion of myxozoans as a branch of greatly derived parasitic cnidarians, as a sister group of the fish infecting narcomedusan *Polypodium hydriforme*. This is thus far the final step of considerations of metazoan affinities for Myxozoa starting with Štolic (1899) a century ago and focusing later on cnidian relationships (especially Weill, 1938; Siddal *et al.* 1995). But Lom and Dyková (1997)
recommended that the elucidation of the problem warrants further studies on cytology and sequence data of both groups as well as sequence analysis of cnidocyst and polar capsule proteins.

Now, it is evident from above discussion that there lies a lot of controversy in the phylogenetic relationships of Myxozoa. The same controversy is present in the system of classification of Myxozoa too. In the present dissertation we follow the classification of Lom and Noble (1984). Lom and Dyková (1992) and Moser and Kent (1994) also recommended the above said classification of Lom and Noble (1984). It represents the results of thoughtful consideration of the present knowledge of this group and provides an excellent basis for future revision. A summary of this classification, with minor modifications, is given here under.

<table>
<thead>
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<th>Phylum</th>
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<td>Bipteria Kovaleva, Zubchenko and Krasin, 1983</td>
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Genus  : Leptotheca  Thélohan, 1895
Ceratomyxa  Thélohan, 1892
Family : Sphaerosporidae  Davis, 1917
Genus  : Sphaerospora  Thélohan, 1892
Hoferellus  Berg, 1898
Wardia  Kudo, 1919
Palliatius  Shulman, Kovaleva and Dubina, 1979
Myxobilatus  Davis, 1944
Family : Chloromyxidae  Thélohan, 1892
Genus  : Chloromyxum  Mingazzini, 1890
Caudomyxum  Bauer, 1948
Agarella  Dunkerley, 1915
Family : Auerbachiidae  Evdokinova, 1973
Genus  : Auerbachia  Meglitsch, 1960
Globospora  Lom, Noble and Laird, 1975
Family : Alatosporidae  Shulman, Kovaleva and Dubina, 1979
Genus  : Alatospora  Shulman, Kovaleva and Dubina, 1979
Psuedoalatospora  Kovaleva and Gaevskaya, 1983
Family : Parvicapsulidae  Shulman, 1953
Genus  : Parvicapsula  Shulman, 1953
Neoparvicapsula  Gaevskaya, Kovaleva and Shulman, 1982
Suborder  : Platysporina  Kudo, 1919 emend
Family : Myxobolidae  Thélohan, 1892
Genus : *Myxobolus* Bütschli, 1882

*Henneguya* Thélohan, 1892

*Thelohanellus* Kudo, 1933

*Unicauda* Davis, 1944

*Dicauda* Hoffman and Walker, 1978

*Phlogospora* Qadri, 1962

*Neohenneguya* Tripathi, 1953

*Trigonosporus* Hoshina, 1952

*Hoferellus* Berg, 1898

*Laterocaudala* Chen and Hsieh, 1984

*Spirsuturia* Chen and Hsieh, 1984

Order : Multivalvulida Shulman, 1959

Family : Trilosporidae Shulman, 1959

Genus : *Trilospora* Noble, 1939

*Unicapsula* Davis, 1924

Family : Kudoidae Meglitsch, 1960

Genus : *Kudoa* Meglitsch, 1947

Family : Pentacapsulidae Naidenova and Zaika, 1970

Genus : *Pentacapsula* Naidenova and Zaika, 1970

Family : Hexacapsulidae Shulman, 1959

Genus : *Hexacapsula* Arai and Matsumoto, 1953

Family : Septemcapsulidae Hsieh and Chen, 1984

Genus : *Septemcapsula* Hsieh and Chen, 1984

CULTIVATION

Little success has been attained in maintaining the Myxosporida outside of hosts (Mitchell, 1977). *In vitro* culture of sporulating trophozoites of a single species, *Myxobolus cerebralis*, has been reported by Wolf and Markiw (1976). Spores of several species have been maintained for long periods outside hosts. Those of *M. cerebralis* may remain viable after freezing at -20 °C for at least 2 months (Hoffman and Putz, 1969); it is likely that many other
species are comparably resistant. Spores appear morphologically unchanged after long frozen storage, but infectibility tests with frozen spores have been performed only for *M. cerebralis*. Spores of at least some species seem to require a period of aging or maturation outside the host. Temperature probably has a major influence in the aging process. Patashnik and Groninger (1964) observed that spores of *Kudoa* in microsamples of milky halibut disappeared and were replaced by active amoeboid trophozoites following exposure to cycling temperatures (4°–20°C), freezing at -16°C, and gradual (8 hours) return to room temperature.

**HOST – PARASITE RELATIONSHIPS**

A marked degree of host and tissue specificity has been described for a number of myxosporidans. However, several species are known to infect a wide variety of hosts and to invade many organs and tissues in these hosts. The issue of specificity is confused by the status of taxonomic research in this class. New species continue to be named and distinguished primarily on the basis of the host species, organ, or tissue in which they are found. Analyses of intraspecific spore and trophozoite variability are insufficient and the true degree of specificity of most myxosporidans is not known.

The major known pathogens of the group exhibit varying degrees of host and tissue specificity. *Myxobolus cerebralis* appears to be limited to hosts of the family Salmonidae in which it invades and erodes cartilage supporting the central nervous system. *Ceratomyxa shasta* also appears to be limited to the Salmonidae but infects a wide range of tissues and organs in cases of severe disease.

The host range of other species is not as well defined. Some degree of host and tissue specificity seems to be apparent for the marine species of *Kudoa, Hexacapsula* and *Unicapsula*, although research is limited (Mitchell, 1977).

As a group, coelozoic species are less harmful to hosts than histozoic forms. It is possible that the gall bladder is the oldest site of myxosporidan infection. Most species which infect the gall bladder are not found elsewhere in their hosts. A highly advanced host-parasite relationship is indicated for several such species. Sindermann (1970) points out, however, that heavy infections in the gall bladder may result in major pathology. Electron microscopic studies of *Henneguya, Myxidium* and *Sphaeromyxa* indicate that trophozoites in the gall bladder feed primarily by pinocytosis or general surface absorption. The trophozoites of some species may attach by pseudopodia to the epithelial cells of the gall or urinary bladder, but most are free-floating in the contents of these organs. Changes such as bile discolouration and increase in viscosity, increase in thickness of the wall of the gall bladder, bile duct obstruction, and general enlargement of both the gall bladder and liver have been noted (Lom, 1970a). *Myxidium minteri* described from salmonids may be found in the gall bladder and liver (Sanders and Fryer, 1970) but may also concentrate within kidney tubules and cause tubular degeneration. *Chloromyxum majori* locates primarily in the glomeruli of salmonids and may destroy glomerular capillaries (Yasutake and Wood, 1957). *Sphaerospora tincae* invades the anterior haemopoietic portion
of the kidney and may induce consequent swelling in the pectoral region in young tench (Tinca tinca). Late in the course of infection the urinary kidney and peritoneal tissues surrounding various viscera also become infected. Death frequently results (van Duijn, 1973).

Of the hundreds of histozoic species of Myxosporida, relatively few are reported to cause significant harm to their hosts; but, this may reflect lack of knowledge of host-parasite relationship for the majority of species (Mitchell, 1977). As more information accumulates about the dynamics of wild fish populations and as more species of fishes become commercially significant, detrimental effects of particularly muscle- and gill-inhabiting Myxosporida are being more frequently recognized. The majority of pathogenic myxosporidans localize superficially in hosts – either on gills, cutaneous tissues, or in the musculature of the general body wall. Infections of myxobolid genera such as Myxobolus, Henneguya, and Thelohanellus on gills are very common in freshwater fishes. Cysts appear as white or yellowish opaque spheres or irregular masses. They range from microscopic size to those readily visible to the naked eye. Cysts may develop within and between lamellae or filaments of gills. In the intralamellar (intracapillary) form, spheroid or elongate ovoid cysts develop within blood capillaries of lamellae or gill filaments (Minchew, 1973). Interlamellar cysts which develop among epithelial cells between lamellae seem to be less restricted in growth potential; these may retain a definite shape or may become large irregular masses surrounded by a relatively weak host tissue capsule. Lamellar capillaries may be included in the capsule and this may result in loss of some blood upon cyst rupture. Tissue reactions to the interlamellar cysts are highly variable. Severe inflammation may induce fusion of lamellae of adjacent filaments. Heavy infections of either inter- or intralamellar cysts may seriously impair gill function. The interlamellar form of Henneguya exilis has been associated with heavy mortalities in cultured channel catfish. Up to 95% losses in young (less than 2 weeks old) fingerlings have been reported; older catfish may also be heavily parasitized (McCraren et al. 1975). Myxobolus exigus infections in the gills of mullet in the Black Sea have caused significant losses by general impairment of gill function and actual tissue damage resulting in bleeding and asphyxia (Shulman, 1957).

Many myxosporidans, but especially Henneguya and Myxobolus, frequently infect integumentary tissues and underlying muscles and connective tissue in freshwater fishes. Cysts may develop anywhere on the body surface, including the fins, opercula, snout, and barbels and are often prominent to the naked eye. Infections are usually situated in dermal connective tissue on or under the surface of scales, in the subcutis between the scale layer and superficial musculature, or in the musculature itself. It is sometimes not possible to distinguish the primary site of tissue invasion, for all layers of the body wall may be invaded. In many cases there is little or no inflammatory response to the trophozoites; host connective tissue merely forms a thin capsule around them; the capsule may rupture upon maturation of spores in the trophozoite. Sometimes small blood vessels may be included in the capsule and some haemorrhaging may occur as the parasite grows. The overlying epidermis is often thin and may appear to rupture as a result of pressure from the growth of cysts. Spores may be released abruptly or gradually
from such sites. In cases of diffuse infiltration spores may spread internally from the main site of infection to a wide variety of other tissues where further development may or may not occur.

No humoral responses against myxosporidans have been demonstrated. Antibody titers in host fishes could be expected to be temperature-influenced as is typical for poikilotherms. Lom (1970b) noted that when perch (Perca fluviatilis) heavily infected with Heneguya psorospermica were held at 8°-10°C, the parasites matured normally. However, when infected perch were held at 20°-24°C the trophozoites degenerated and were replaced by phagocytic cells and connective tissue. Host antibody response may also influence seasonal cycles of some myxosporidans.

Myxosporidan infections have also been associated with varying degrees of hypertrophic and hyperplastic growth of superficial and deep connective and epithelial tissues. Sphaerospora reichenowi elicits cauliflower like growths in the intestine of the eel, Anguilla anguilla (van Duijn, 1973). Myxobolus pfefferi found in barbels (Barbus spp.) in Eurasia primarily infects connective tissue of body musculature and may produce "boil" or tuberoulcer disease in these hosts. Growths 5-6 cm may protrude from the sides of hosts, and, in severe cases, more than twenty cysts or nodules may be seen on a single host. With maturation of the spores, these growths soften and ulcerate to release whitish spore-bearing exudate over a period of weeks. Secondary infection by bacteria and fungi usually occurs and leads to scale loss, integumentary haemorrhaging, general fatigue, and eventual death in most cases. Barbels seem to acquire no immunity; fish with scars indicating previous infection may become reinfected (Markevich, 1951). Internally, the cysts grow to their massive size by eroding muscle and normal connective tissue septae; small islets of degenerated host tissue may often be seen within the trophozoites. Parasitic masses may extend from the edges of vertebrae to the integumentary epithelium. The trophozoite comprises most of the size of the cysts, but hypertrophic and hyperplastic connective tissue forms a capsule of varying thickness. There are numerous other species that cause similar, though somewhat less, conspicuous conditions in the integument, musculature, and subcutaneous and visceral connective tissue of fresh water fishes. Hyperplastic connective tissue forms a thin pliable external capsule which extends inward to divide the entire parasitic mass into a multilocular growth. Often characteristic of this type of superficial infection is a temporary thickening of the overlying epidermis. Small blood vessels are frequently included in the capsules and limited bleeding may result as the cysts rupture. Inflammatory response is characteristically mild and mostly limited to the capsular tissue but surrounding normal muscle bundles often seem to show increased capillary supply. Phagocytic cells are frequently found in the connective tissue capsule of older cysts. After rupture and release of most of the contents of these cysts, connective tissue proliferates to fill spaces originally occupied by muscle bundles. Scattered spores usually remain in such sites long after healing has occurred. Cysts in muscle and deep connective tissue may expand to involve the connective tissue of the peritoneum. Massive cysts may also develop in the host coelom.
A thorough study by Nigrelli and Smith (1938) showed that *Myxobolus lintoni* may be associated with fibroblastic tumours in the skin and subcutis of the sheepshead minnow (*Cyprinodon variegatus*). Large pendant tumors measuring 8 x 10 mm were found on small (about 4 cm long) hosts. The epidermis was absent in most cases and melanophores formed the outermost covering of the growths. The stroma of the tumors consisted primarily of loosely arranged, often stellate fibroblasts; a mild inflammatory response was indicated by the presence of mast cells, lymphocytes, various polymorphonuclear cells, and melanophores scattered in the stroma. Vascular capillaries, small nerves, and eosinophilic serous or albuminous exudate which seemed to precede fibrosis were also present in the tumors.

Although tissue response is typically limited to the capsule, Nigrelli and Smith (1940) described hyperplasia of overlying epithelium with an infection of *Henneguya ameiurenis* in the brown bullhead (*Ictalurus nebulosus*). The parasite was localized in dermal connective tissue of the barbels. Resulting tumors appeared as warty papillae arising from the base of the barbels. The thickened epithelium was multilayered and involved hyperplasia of squamous and mucus cells, giant dermal gland (goblet) cells, and melanophores. Comparable papillomatous growths up to 1 cm in diameter have been associated with *Henneguya* infections in channel catfish, *Ictalurus punctatus* (McCraren *et al.* 1975), but these were localized in the epithelium covering the fins and did not extend into the underlying connective tissue. Nigrelli (1948) described subcutaneous infection of *Myxobolus moxostomi* associated with tumorlike growths of overlying epithelium in the redhorse sucker (*Moxostoma* sp.). In this case, abnormal cells characterized by distinct intercellular bridges (prickle cells) formed a stratified epithelium which was partly in contact with underlying dermal connective tissue. Degeneration of normal epithelial cells was evident.

It is assumed that most histozoic Myxosporida are capable of some tissue lysis and definite cases of necrosis of surrounding tissue have been described for several species in musculature, bone, and connective tissue. Enzyme proteolysis has been associated with myxosporidians which cause lysis of musculature (Patashnik and Groninger, 1964). Extensive muscle necrosis and postmortem liquefaction (milkiness) are characteristic of the marine species *Hexacapsula neothunni* in tunas and several species of *Kudoa* in a variety of hosts including herring, menhaden, tunas, mackerels, halibut, swordfish, and soles. Several species of *Henneguya* and *Myxobolus* are known to cause similar effects in many freshwater and anadromous trout and salmon. In these cases intermuscular cysts in living hosts are often accompanied by some local tissue necrosis (milky pockets). Surface ulceration may occur as a terminal phase of some infections. Emaciation and death may occur in severe cases (40–50 cysts per host). In harvested fish, softening and liquefaction of infected muscle tissue may occur soon after death, but most often these effects appear after several days of cold or frozen storage. It is thought that proteolytic enzymes active in muscle necrosis may be produced continuously during these infections but are diffused and denatured by the host blood system until death when they become locally active. It is also possible that vegetative stages of the parasites may emerge and secrete the enzymes upon death of the host. In at least some cases,
suitable temperature fluctuation may elicit spore hatching and trophozoite activation (Mitchell, 1977).

Many muscle-inhabiting myxosporidans, including some of those which invade connective tissue, may develop cytozically within muscle fibers (Davis, 1924; Mitchell, 1970). Cross sections show that these trophozoites replace the sarcoplasm and may eventually fill the space within the sarcolemma. Variable degrees of swelling of the fiber may occur. These intrafibrillar infections often occur with concurrent infections of intermuscular connective tissue; in such cases, as older intrafibrillar infections produce muscle degeneration, these areas of infection become indistinguishable from infected intermuscular connective tissue. *Unicapsula muscularis*, the causative agent of "wormy" halibut, appears to be an exclusively intrafibrillar form. Infected muscle fibers may double in size and appear as firm white vermiform opacities.

*Ceratomyxa shasta*, parasitic in anadromous and freshwater salmonoids, is a somewhat unique myxosporidan. Nearly all other species of *Ceratomyxa* inhabit the gall bladder or uriniferous tubules of marine fishes and appear to be relatively nonpathogenic. *Ceratomyxa shasta* is also found in these organs but it is primarily histozoic. In young rainbow trout the primary site of infection seems to be the intestine. Multinucleate prespore stages have been found in smears taken from the junction of the large and small intestine about 18 days after infection (Scafer, 1968). Whitish, opaque spots containing amoeboid stages appear in the large intestine about 20 days after infection (at about 12°C). Rate of development of the parasite is influenced by temperature; infection proceeds but at a slower rate when ambient temperature is less than 10°C. Eventually all tissue layers of the entire intestinal tract become infected; the intestine may swell and haemorrhage and trophozoites then develop throughout the visceral cavity. In more advanced infections practically all viscera and body musculature may contain spores and various stages of trophozoites. Large boils may develop and protrude from the body surface. Death frequently results in hatchery-reared fingerling rainbow trout about 40 days postinfection. Pathological changes include extensive destruction of tissue in the intestine, liver, and kidneys. In contrast to the typical cases in rainbow trout the most common site of infection in juvenile silver salmon seems to be the eyes (Scafer, 1968). Although juvenile hosts are most susceptible, there is some indication that considerable prespawning losses may result from infections in anadromous adult spring chinook and coho salmon (Sanders *et al.* 1970).

*Myxobolus cerebralis*, the causative agent of whirling disease in salmonoids, is one of relatively few myxosporidans which invade cartilage. Because of the predominance of cartilage in the skeleton, juvenile hosts are most affected. Fifty percent mortality is not uncommon among fry in hatcheries. Trophozoites invade and erode skeletal cartilage by about 40 to 60 days after infection. Major disease symptoms result from invasion and weakening of cartilage supporting the central nervous system. Invasion of the cartilaginous capsule of the semicircular canals is associated with loss of equilibrium, characteristic tail chasing, and often moribund weakening in fingerlings. Infection and consequent erosion of cartilage surrounding the spinal cord may cause compression of spinal nerves and consequent loss of pigment cell
control (blacktail) in the posterior one-third of the body. Lesions are also common in the gill arches. In rainbow trout, lesions appear in cartilage as vacuous areas measuring approximately 300 x 100 μm at about 3 months postinfection; these contain disintegrating cartilage cells and matrix, free cartilage cells, and usually several multinucleate trophozoites. By about 4 months after infection, trophozoites reach their maximum size of up to about 1 mm in greatest dimension; spores are evident at this point and the parasite fills most of the space in the lesions. Host tissue response becomes evident after about 4 months when sporogony is nearly completed. Epithelioid host tissue then surrounds the fully developed spores and forms a granulomatous cyst which permanently fills the lesion site in the supportive tissue. If the host survives, spores probably remain permanently entrapped in the granuloma; but it is possible that some vascular transport of spores from these sites may cause diffuse infiltration of the parasite into other organs. Spores have been found in the gall bladder, liver, intestinal wall and lumen, brain, bone and musculature of the head and body, and gills. In some cases, the epithelioid granulomas may also cause some harmful effects, such as excessive pressure on viscera and nerves. Survivors of whirling disease usually show permanent debilitating curvatures along the spinal axis, extreme deformities of the mandible, which may hinder feeding, and marked depressions in the cranium just posterior to the eyes. A marked decrease in growth rate has also been recorded for infected survivors. After skeletal ossification the parasite cannot cause massive infection or disease symptoms; older hosts thus are not prone to develop whirling disease, but they may act as carriers of the parasite (Hoffman et al. 1962).

**DISTRIBUTION AND EPIZOOTIOLOGY**

The prevalence of a myxosporean infection in a particular fish host in a given locality is the result of the interaction of many factors, physiological (e.g., host resistance) and ecological (host's environmental requirements, nutrition and manner of feeding). Benthic fish are generally more infected than pelagic ones. Environmental factors affect them mainly indirectly, being mediated by the host organism (Lom and Dyková, 1992).

A large amount of data has been collected on host specificity. Some species seem to be host specific (e.g., *Sphaerospora* spp. from the kidney) others are highly polyxenous (*Myxobolus cerebralis*, *M. muelleri*). Such extremes are also found in geographic distribution and salinity tolerance.

According to Lom and Dyková (1992), unsatisfactory knowledge of most species and their rather vague identification prevents scientists from obtaining a comprehensive estimate of the pattern of myxozoan distribution, but it appears that many species enjoy a wide distribution. For example, *M. lieberkuehni* is holarctic. *M. cerebralis* has, along with cultured trout (perhaps even in frozen meat, since spore withstand freezing) spread in both the Americas, Australia and Newzeland. Some of the myxosporeans of common carp were originally limited to only a part of the geographical area of their hosts (e.g., *Myxobolus koi*, *Thelohanellus nikolski* to East Asia) but, with transfers of East Asian fish, they were introduced to Europe. Parasites of ornamental fishes are also disseminated throughout several countries.
The prevalence of myxosporean infection in a locality can sometimes be detected as being extremely high (up to 100%) although sometimes only a few fish from a given stock are infected. This may be due to unsatisfactory diagnosis, since light infections are easily overlooked and the parasite are never found in their primary site of infection but only in the kidneys or spleen, to which organs the spores were transported from disrupted mature plasmodia elsewhere in the body (e.g., *Myxobolus cyprini*). Young hosts are usually most susceptible to infection and disease, and major epizootics most frequently occur in hatchery stocks of young fish.

**EVOLUTION**

Donets (1979) related the phylogeny of the Myxosporea to the geological history of their marine and freshwater hosts and to the evolution of fish. Donets suggests that the first myxosporeans appeared in marine perciform fishes in the Senonian epoch of the upper Cretaceous. During the Paleocene period, the hosts underwent wide adaptive radiation. By the end of this period, the orders Bipolaria and Eurysporea entered fresh water along with their hosts. The Platysporina evolved from the Bipolaria during the Oligocene and became associated with the widespread cypriniform hosts. Subsequently, the Platysporina spread to fish of numerous families and orders.

According to Shulman (1966) there is a correlation between the evolution of the Myxosporea, tissue specificity, and the floating capability of the spores. Shulman also believes that the first myxosporea infected the gall bladder and that they later developed the capacity to infect the urinary bladder and still later become histozoic.

Lom and Noble (1984) believed that the myxosporea show few readily apparent evolutionary lines. One of the more obvious lines is that which arises from *Myxobolus* and is characterized by the suppression of one capsulogenic cell. The line gives rise *Thelohanellus*. Another fairly obvious line results from changes in cell division which produced a lineage with supernumerary polar capsules and shell valves; this line would include *Ceratomyxa* (with two polar capsules and two shell valves), *Trilospora* (three), *Kudoa* (four), *Pentacapsula* (five), and *Hexacapsula* (six).

Moser (1977) suggested that spore size correlates with tissue specificity. A survey of more than 300 histozoic and 400 coelozoic species showed that the spores of coelozoic species were longer and wider than were those of histozoic species. This was also generally true even when histozoic and coelozoic species were of the same genus (Moser and Kent, 1994).

**IMPORTANCE OF THE PRESENT STUDY**

The success of implementation of various fishery development programmes depends to a great extent on the intensification of the fish parasitological research as the improvement of fish yield can mainly be achieved from healthy fish stock. Now, many alien fish species, in addition to the indigenous species, are also found in this region. Some of these species are widely distributed and well-established in natural water bodies. With the introduction of these
exotic species, it was inevitable that some parasites including myxozoans would also find their way into this region. Many of these myxosporidans could have pathogenic effects on the host fishes causing serious damage to various parts of body, and as such it results in heavy economic loss to the fish farmers and also threatening the existence of the biodiversity of the indigenous fish species from the locality. Thus, these organisms can prove valuable tools for fisheries scientists, as living tags, or labels, in population studies but only after they are accurately identified and their host specificity and zoogeography fully understood (Lom and Laird, 1969).

Fishes in India have been less thoroughly surveyed for their myxosporan fauna than those of other regions of the world (Haldar and Mukherjee, 1985). Thus the present study was undertaken responding to the need felt in bridging the widest gaps in our knowledge on the various aspects of myxozoan organisms – their occurrence in the edible fishes of West Bengal, morphology, life history, pathogenicity, prevalence, incidence and their control. It is hoped that the present investigation not only will lessen to a great extent the gap in our knowledge on the above stated aspects but also has a direct bearing on the economy of our country.

OBJECTIVES OF THE PRESENT STUDY

The primary objectives of the present study were as follows:

1. Identification of myxozoan species inhabiting freshwater and estuarine edible fishes of West Bengal.
2. Studies on the morphology and taxonomic status of these myxosporidans.
3. Determination of the frequency of occurrence, abundance and temporal variation of the myxosporidan organisms.
4. Determination of the pathogenicity of the myxozoans to their hosts.
5. Studies on the extent of parasitism incurred by myxozoan species in hybrid carps.
6. Studies on the surface morphology of some members of Phylum Myxozoa by Scanning electron microscope.
7. Preparation of a chronological list of the known species of myxozoan genera described from Indian piscine hosts.