Myxosporeans and myxosporidiosis of common carp and gibel carp in China

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Hungary
2015 June.3

Brief history of fish myxosporean research in China

IV developmental stages

I. Initial stage: 1949-1959;
description solely based on morphology of myxospores

II. Developmental stage: 1960-1998;
traditional taxonomy, epidemiology, histopathology
Hallmark work: Publication of Fauna Sinica, Myxozoa, Myxosporea in 1998

III. Mature stage: 1998-2013;
combined morphological and molecular characteristics, host, tissue tropism; molecular epidemiology; life cycle, ecology, host-parasite relationships;

IV. Progressive stage: 2013 afterwards;
Genomic era; evolution; phylogenomic anlysis; functional genomics
Hallmark work: available of full genome data of *Thelohanellus kitauei*; ongoing genomic project of Myxobolus honghuensis

Prof. Chen

Prof. Ma

Recorded 575 species in 23 genera 1998

2.7 millon tons/year;
third among freshwater cultured fish;
About 70 myxosporean species reported

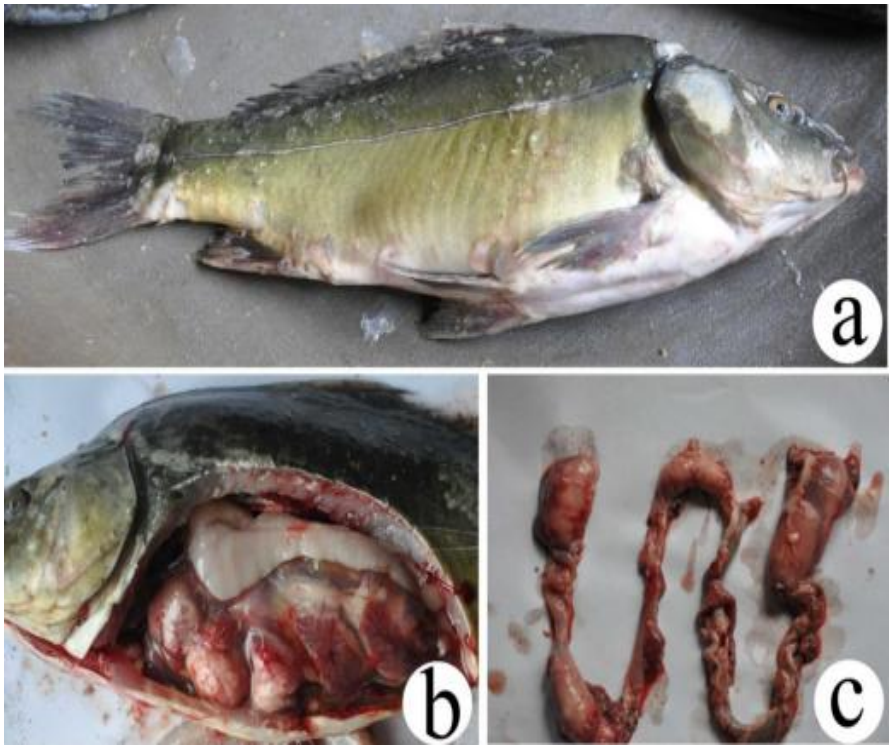
2.2 millon tons/year;
Fifth;
100 species

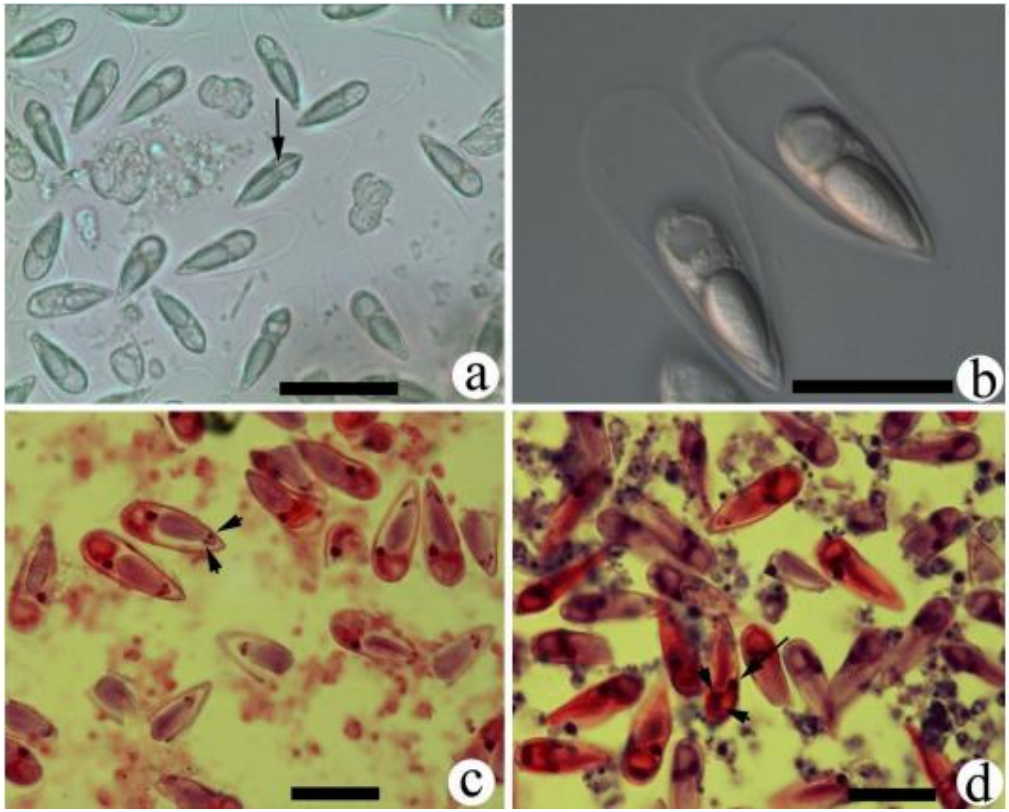
Most only with simple morphological description

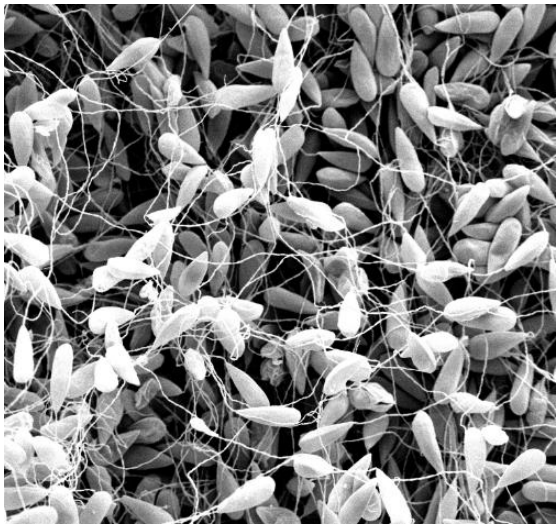
Outline

1. **Myxosporean infecting common carp**
2. **Myxosporean infecting gibel carp**
3. **Life cycles of fish myxosporean in China since 2009;**

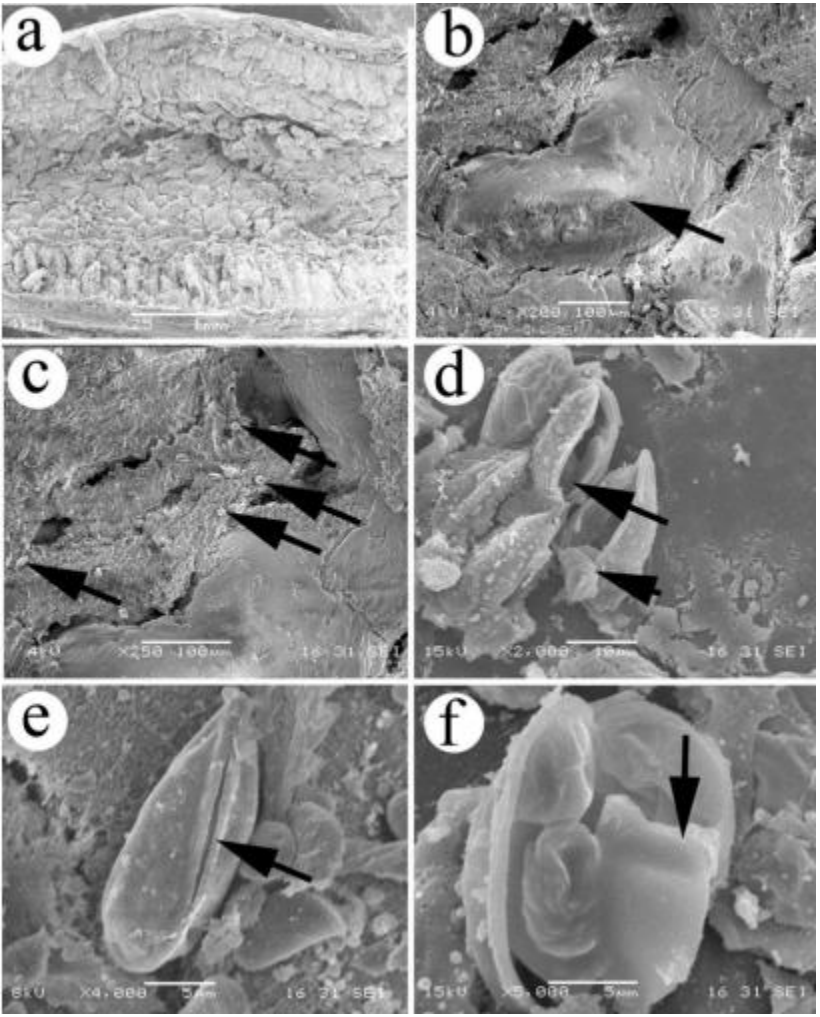
Thelohanellus kitauei







Clinical signs,
Giant cystic diseases,
also in Japan, Korea,
Israel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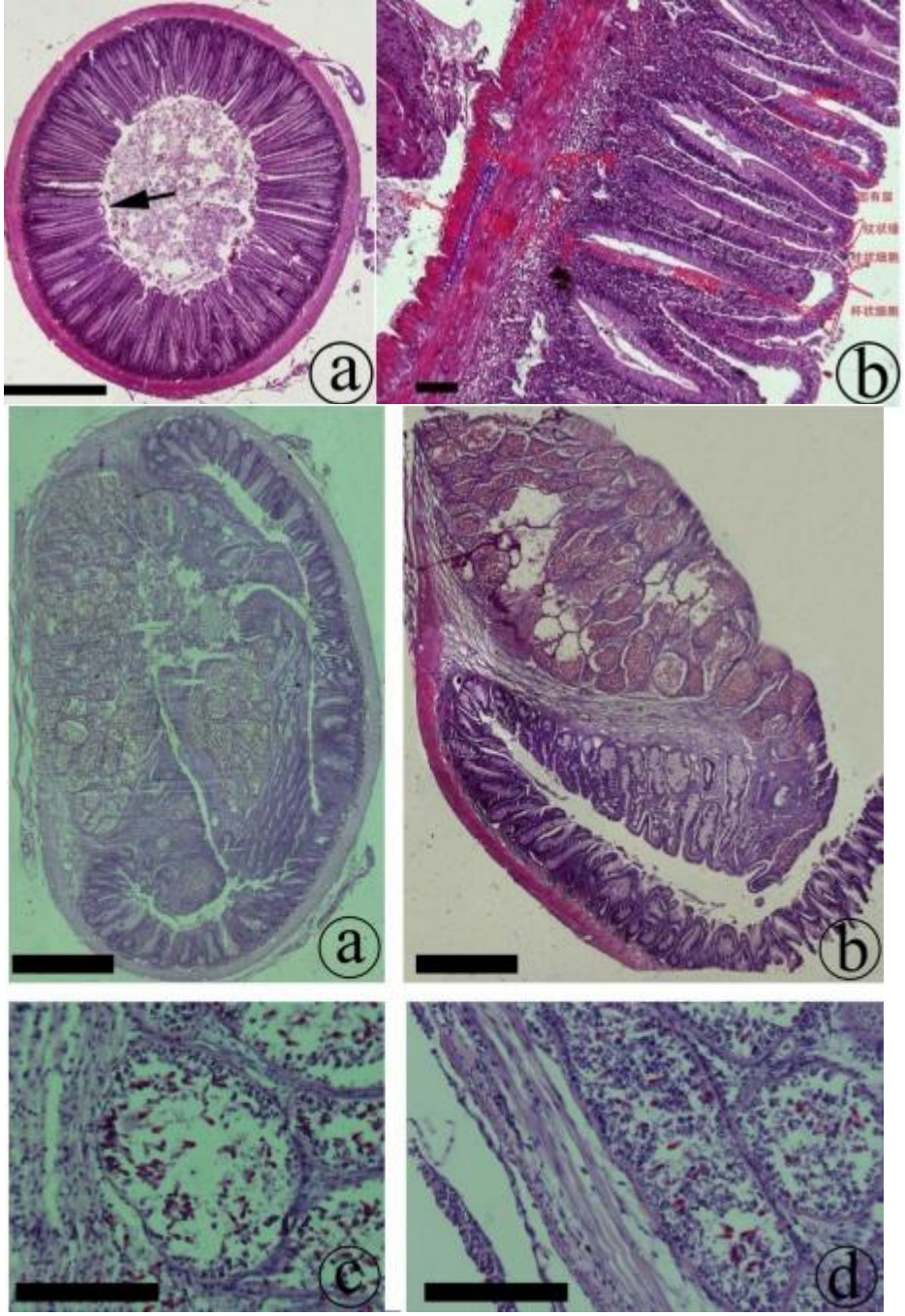
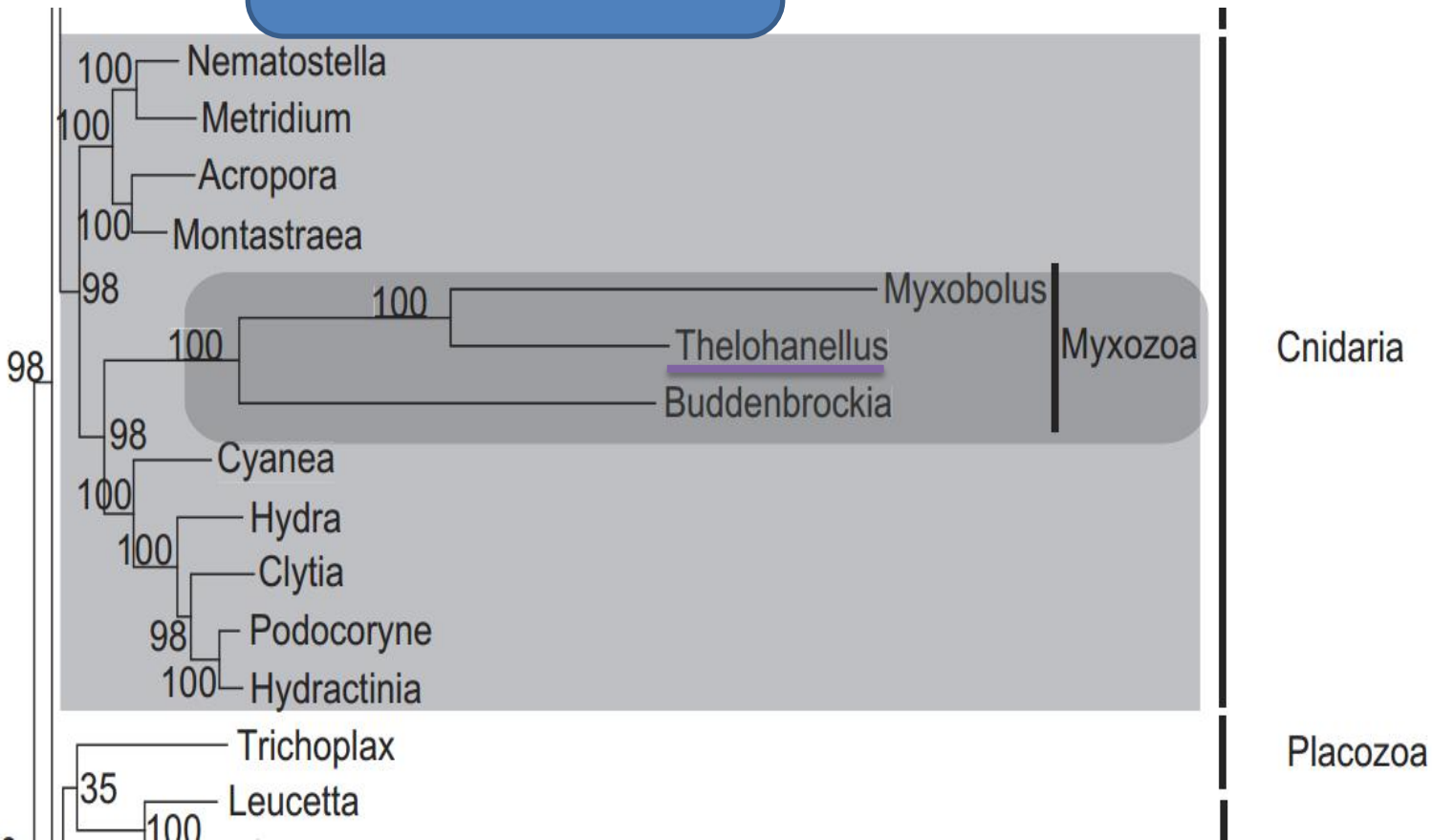

a
b
a
b
c
d

The Genome of the Myxosporean *Thelohanellus kitauei* Shows Adaptations to Nutrient Acquisition within Its Fish Host

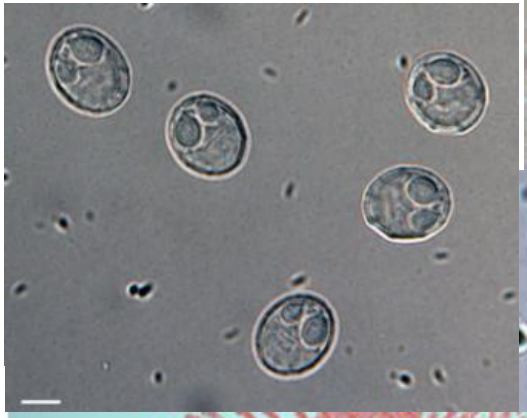
Yalin Yang[1,†], Jie Xiong[2,†], Zhigang Zhou[1,*], Fengmin Huo[1], Wei Miao[2], Chao Ran[1], Yuchun Liu[1], Jinyong Zhang[2], Ji[illegible] Wang[4], Lei Wang[4], and Bin Yao[1,*]

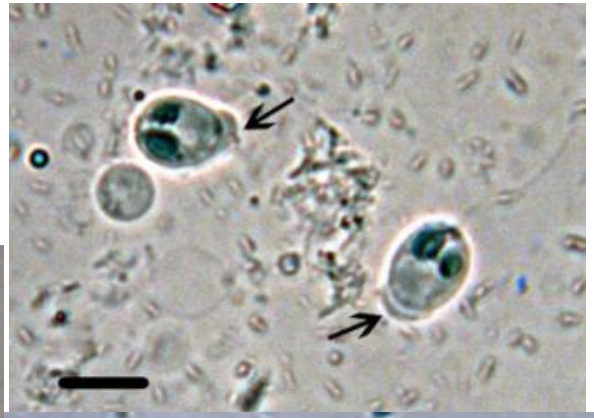
150.7 Mb, 5610 scaffords

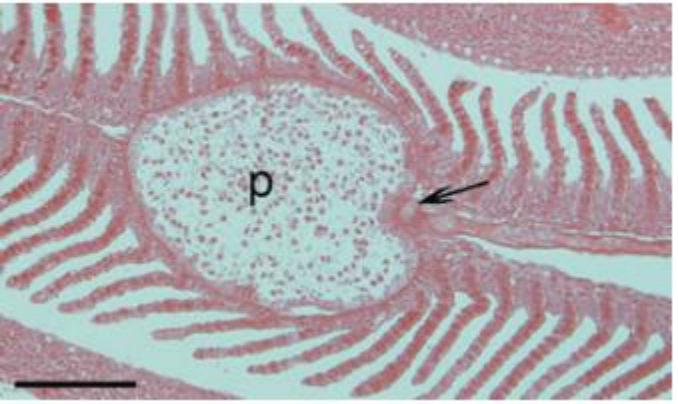


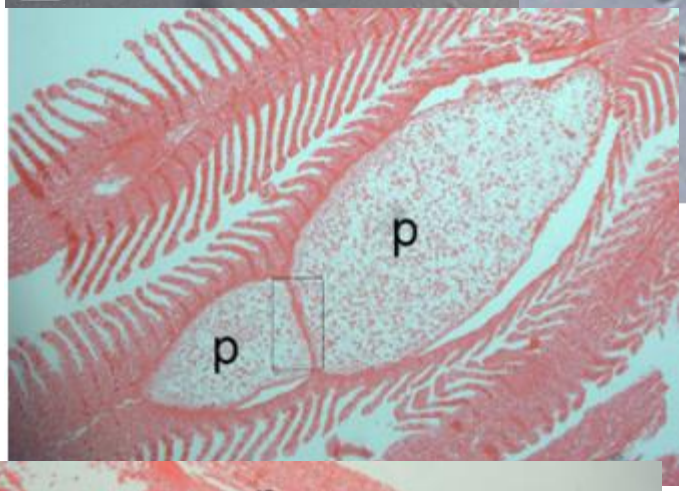
Myxobolus musseliusae

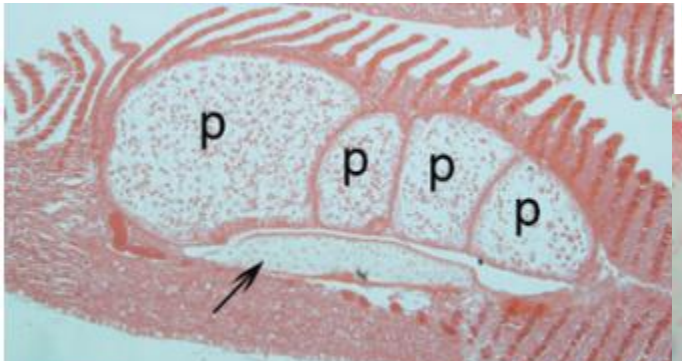
Correction of *M. dispar as M. musseliusae* Yakovchuk, 1979
Infection site: gill filament
Molecular data: JQ040301

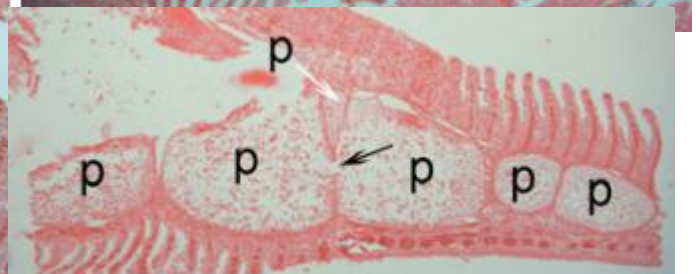


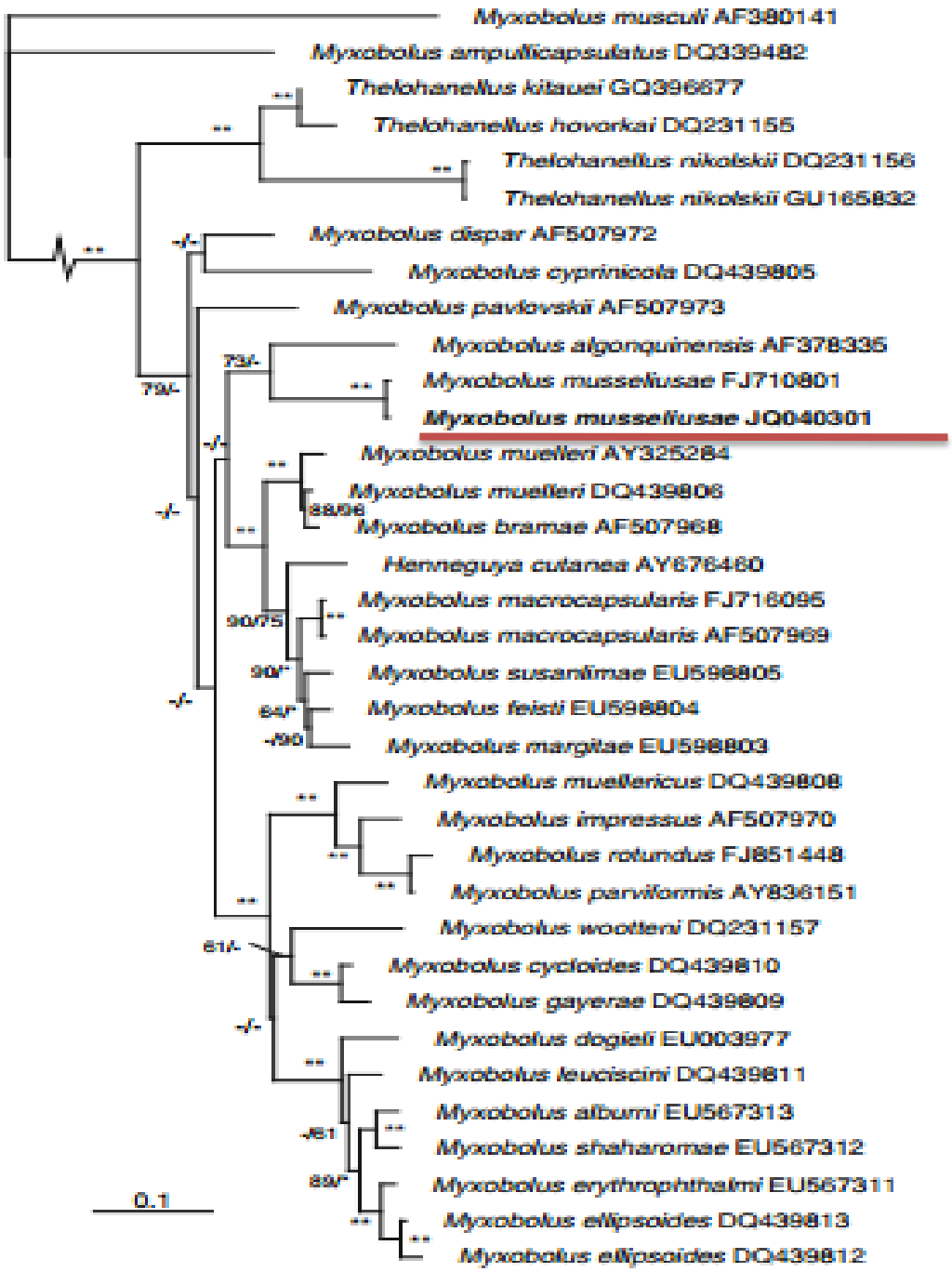






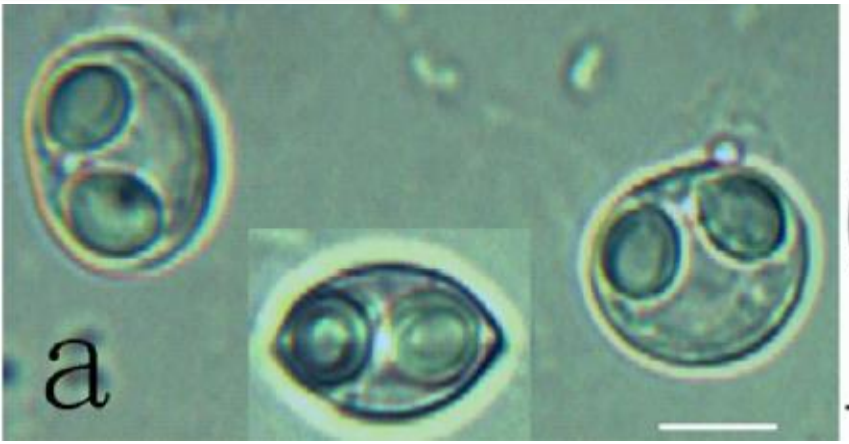


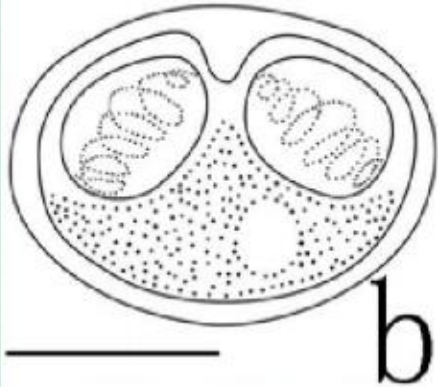


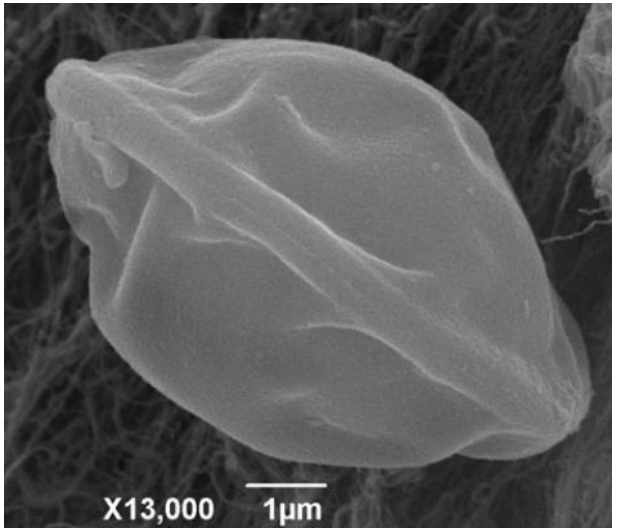

Myxobolus musculi AF380141
Myxobolus ampullicapsulatus DQ339482
Thelohanellus kitauei GQ396677
Thelohanellus hovorkai DQ231155
Thelohanellus nikolskii DQ231156
Thelohanellus nikolskii GU165832
Myxobolus dispar AF507972
Myxobolus cyprinicola DQ439805
Myxobolus pavlovskii AF507973
Myxobolus algonquinensis AF378335
Myxobolus musselusae FJ710801
Myxobolus musselusae JQ040301
Myxobolus muelleri AY325284
Myxobolus muelleri DQ439806
Myxobolus bramae AF507968
Henneguya cutanea AY676480
Myxobolus macrocapsularis FJ716095
Myxobolus macrocapsularis AF507969
Myxobolus susanimae EU598805
Myxobolus feisti EU598804
Myxobolus margitae EU598803
Myxobolus muellericus DQ439808
Myxobolus impressus AF507970
Myxobolus rotundus FJ851448
Myxobolus parviformis AY836151
Myxobolus wootteni DQ231157
Myxobolus cycloides DQ439810
Myxobolus gayerae DQ439809
Myxobolus dogieli EU003977
Myxobolus leuciscini DQ439811
Myxobolus albumi EU567313
Myxobolus shaharomae EU567312
Myxobolus erythrophthalmi EU567311
Myxobolus ellipsoides DQ439813
Myxobolus ellipsoides DQ439812
0.1

Myxobolus shangtungesis

Redescription*: M. shantungesis* Hu, 1965;
Infection site: gill arche;
Molecular data: KJ725079

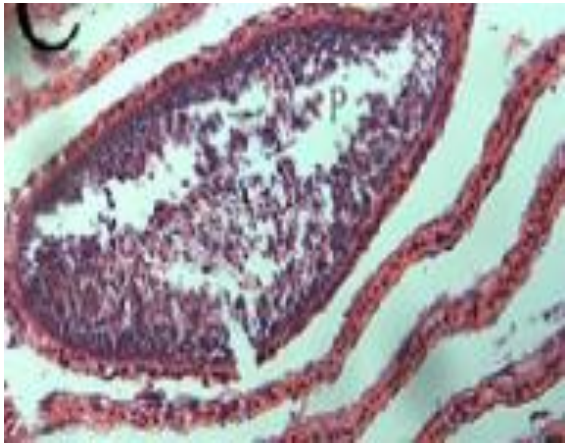






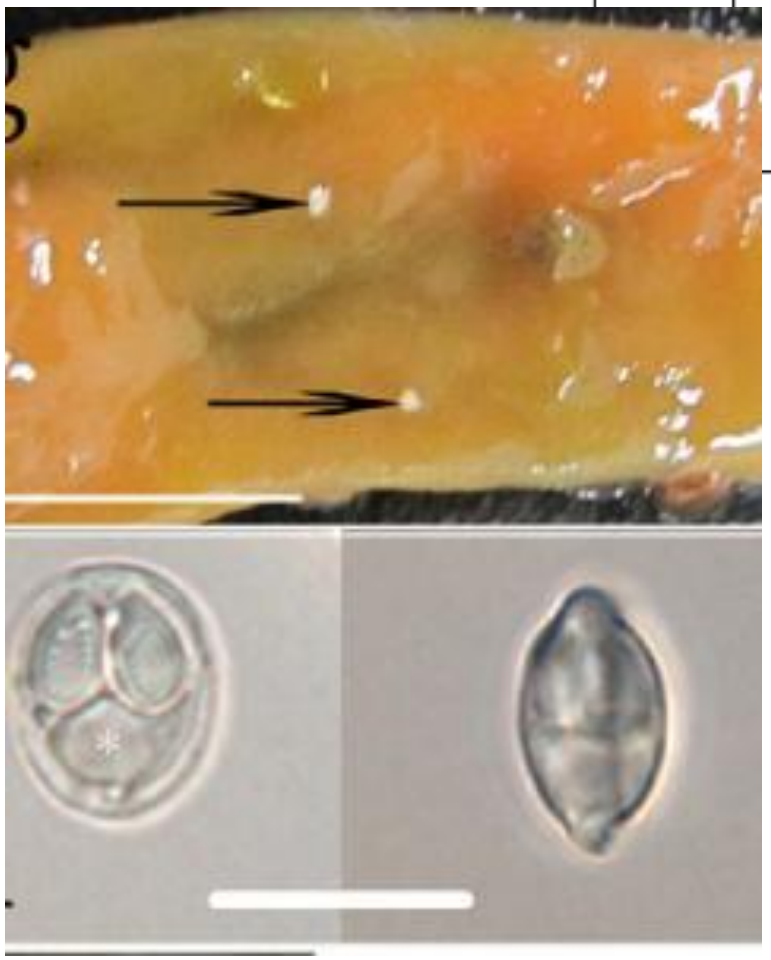
Myxobolus koi

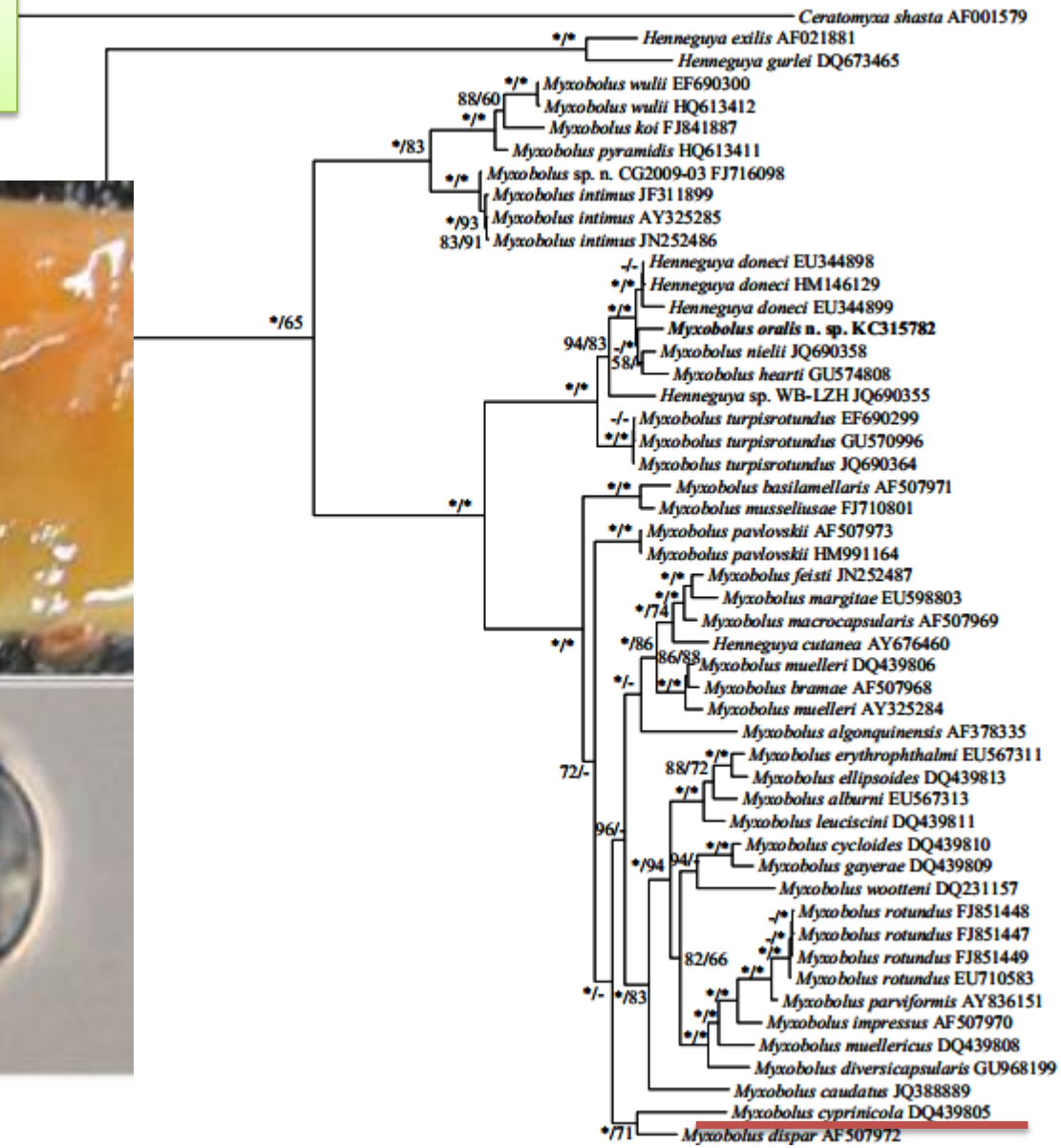
Redescription*: M. koi* Kudoa, 1919
Infection site: gill lamellae;
Molecular data: KJ725077



Myxobolus cyprinicola

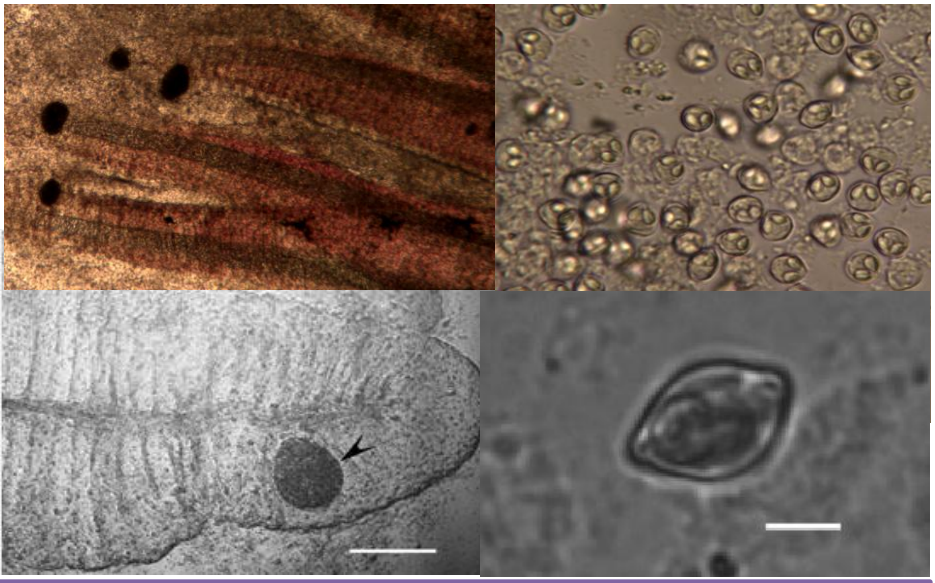
Redescription: *M. cyprinicola* Reuss, 1966
Infection site: intestine wall
Molecular data: KJ725080



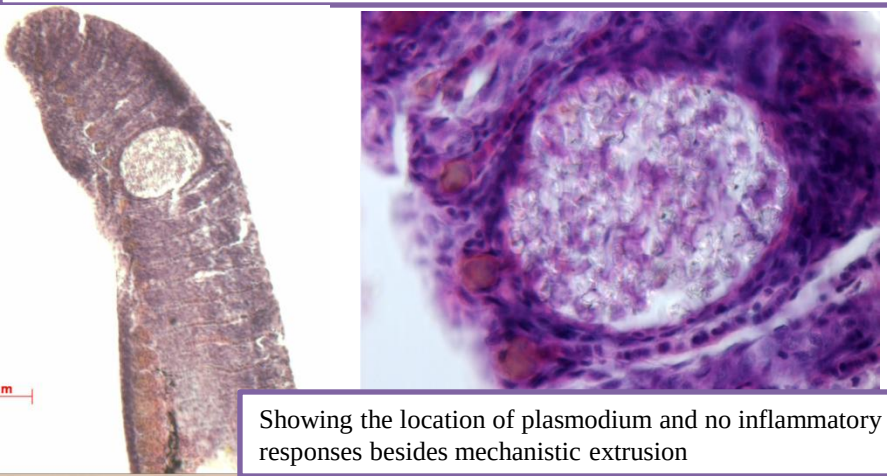


Myxobolus pyramidis

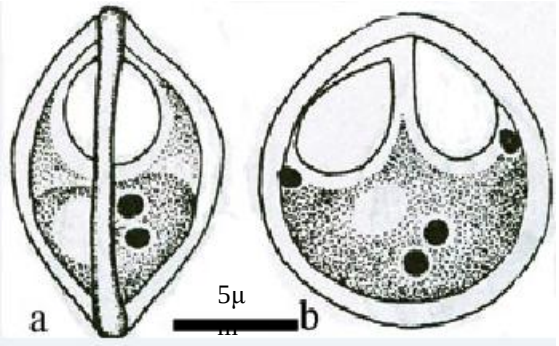
Redescription *M.pyramidis* Chen, 1958;
Infection site: gill lamellae
Molecular data: HQ613411

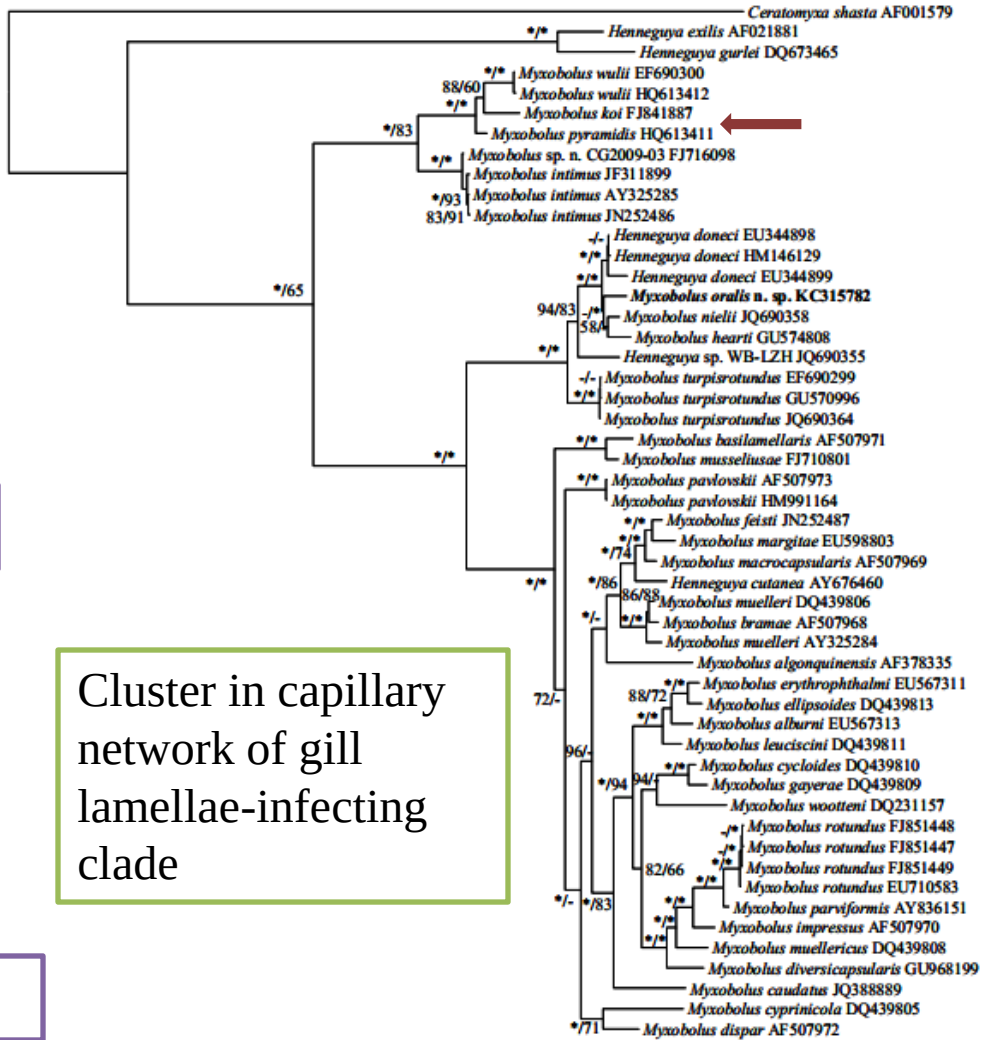


Showing plasmodium locating at the tip of gill filaments and spore in frontal and sutural view



Showing the location of plasmodium and no inflammatory responses besides mechanistic extrusion

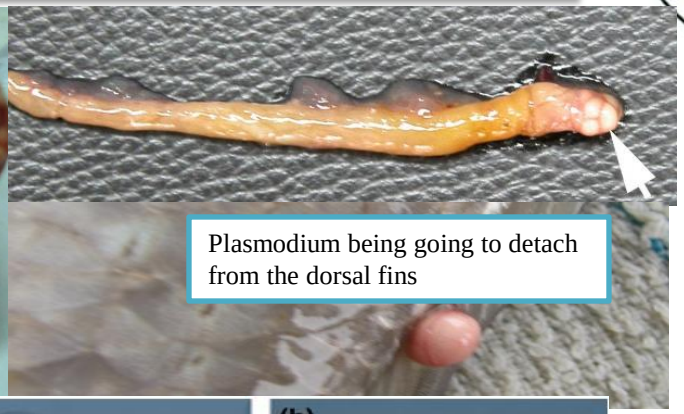




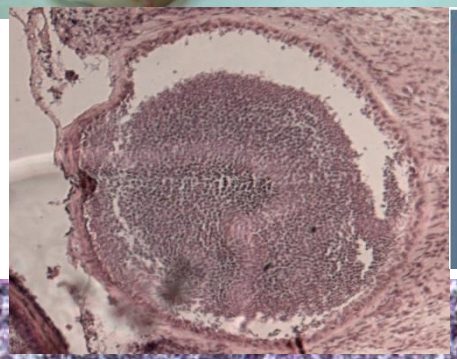
Cluster in capillary network of gill lamellae-infecting clade

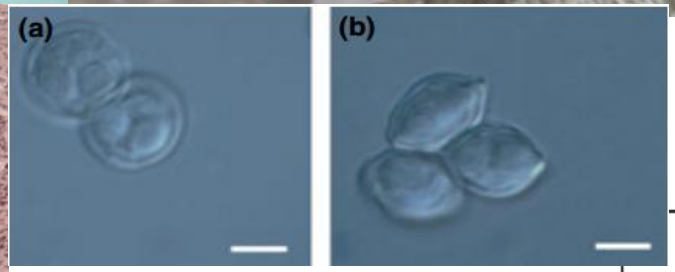
Myxobolus turpisrotundus n.sp.

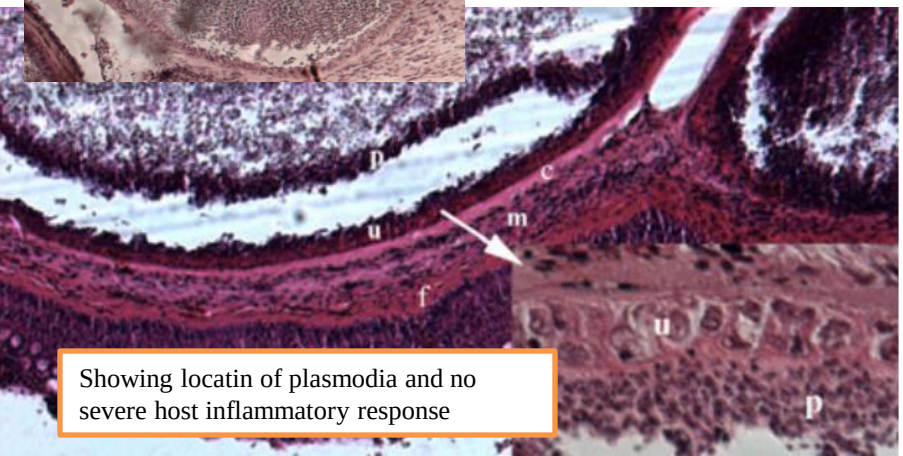
Correction of *M. rotundus* recorded in China;
Infection site: connective tissue of gill arch, fins, intestine and body surface
Molecular data: EF690299, GU570996



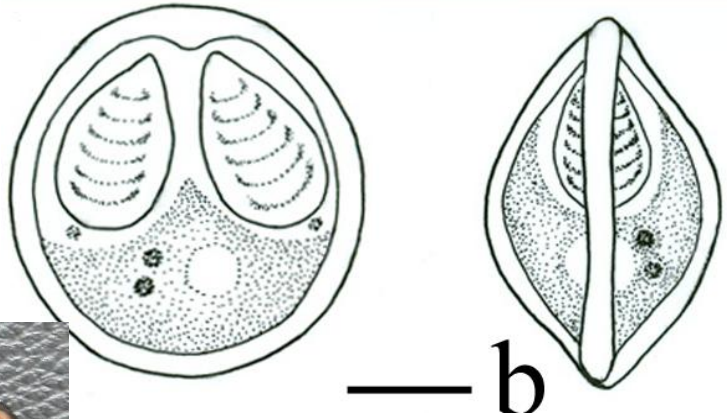
Plasmodium being going to detach from the dorsal fins

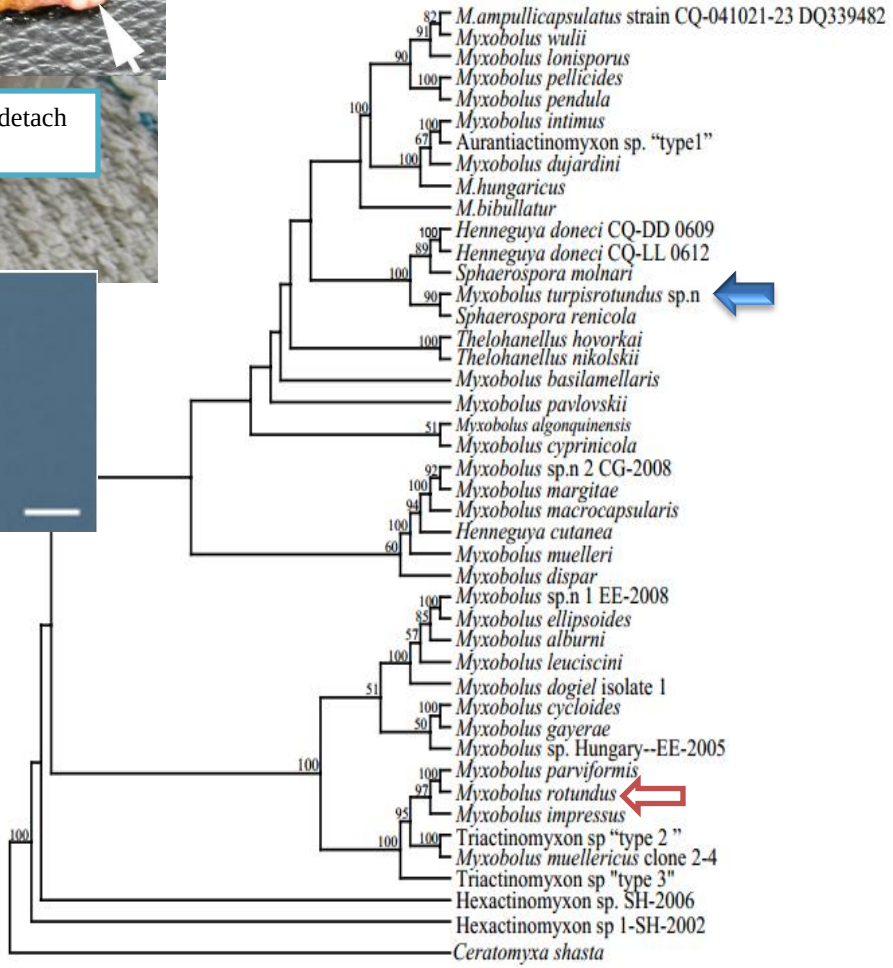






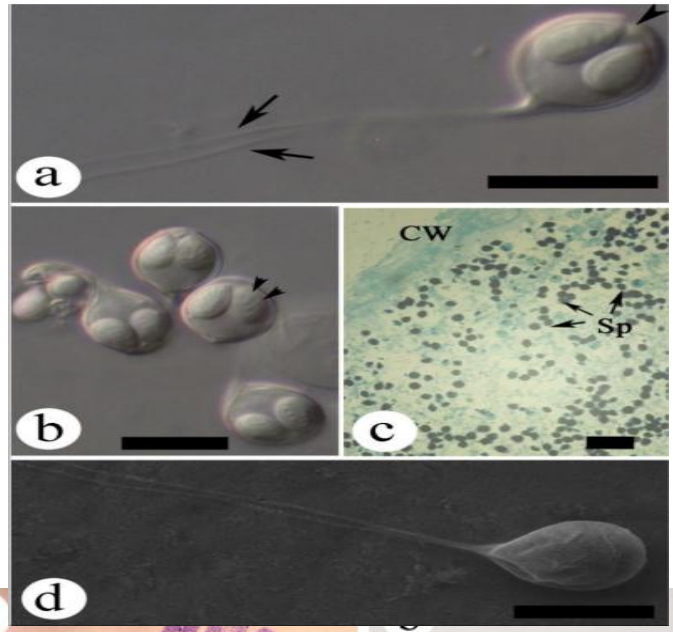
Showing locatin of plasmodia and no severe host inflammatory response

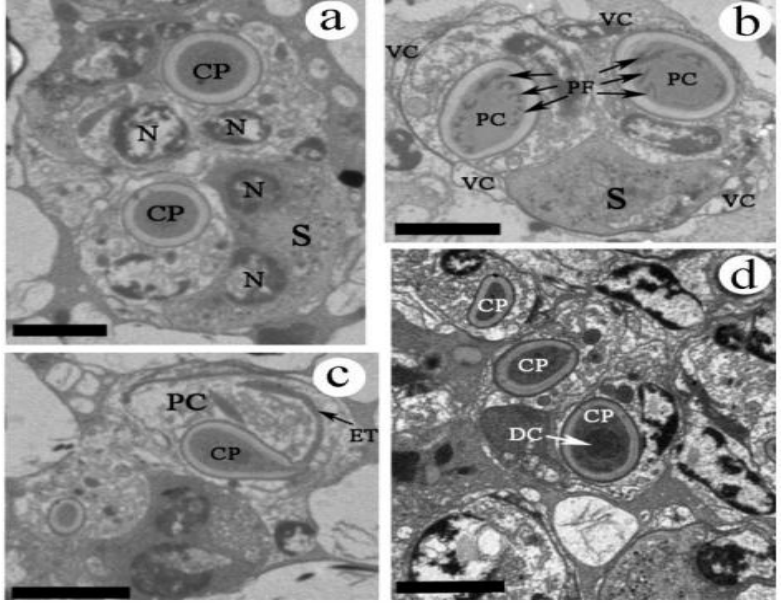


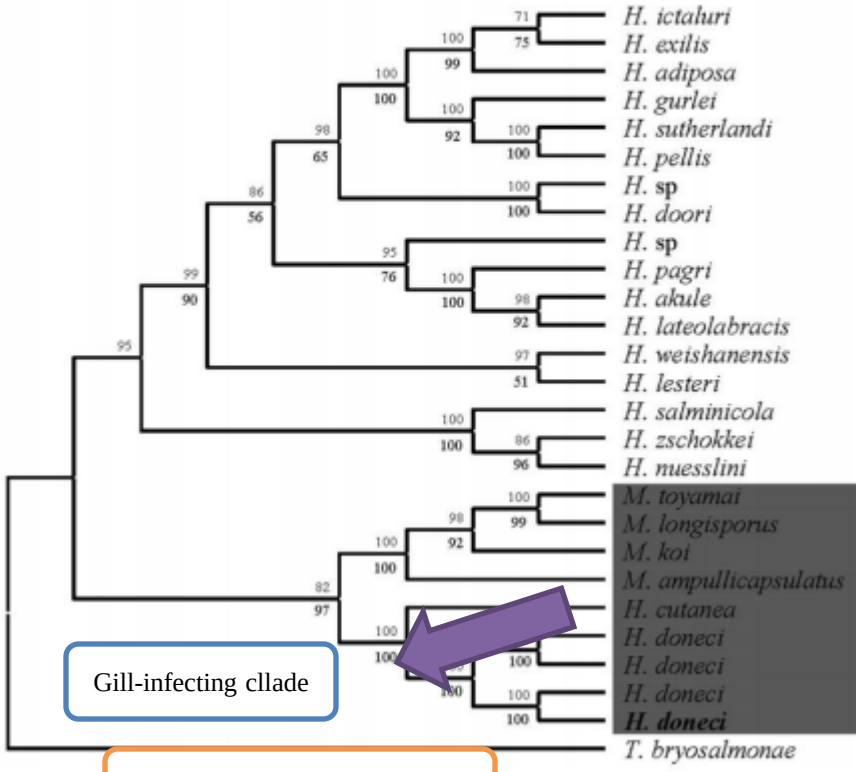


Henneguya doneci n. sp.

Redescription *M.doneci* Schulman, 1962;
Infection site: gill filaments
Molecular data: EU344898 ; HM146129; LC011456, JQ690376



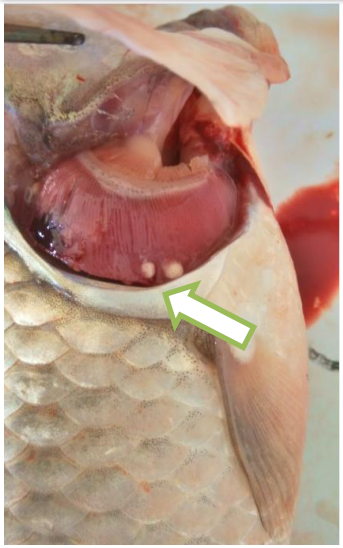


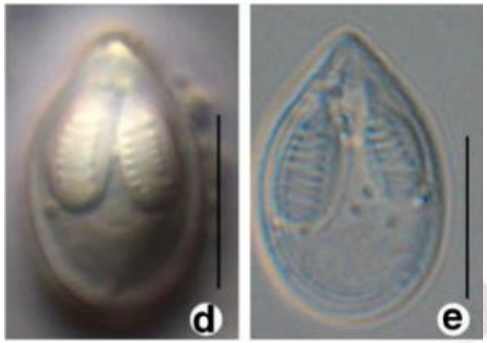


Cited from Ye et al. 2012

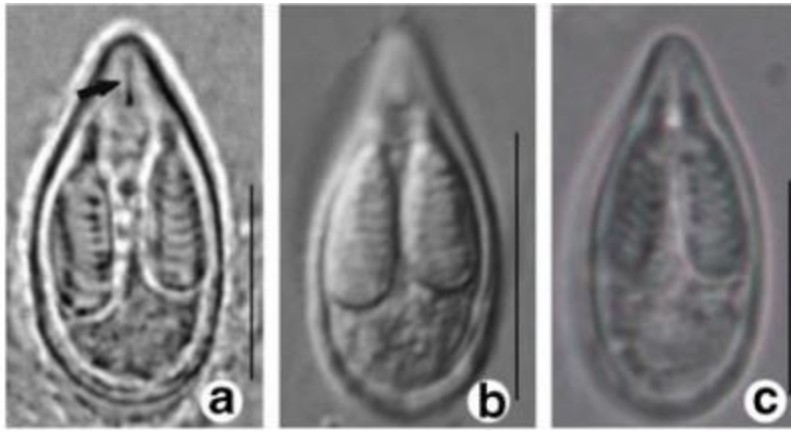
Myxobolus ampullicapsulatus n. sp.

Infection site: gill filaments
Molecular data: DQ339482, KJ725082, KC425225

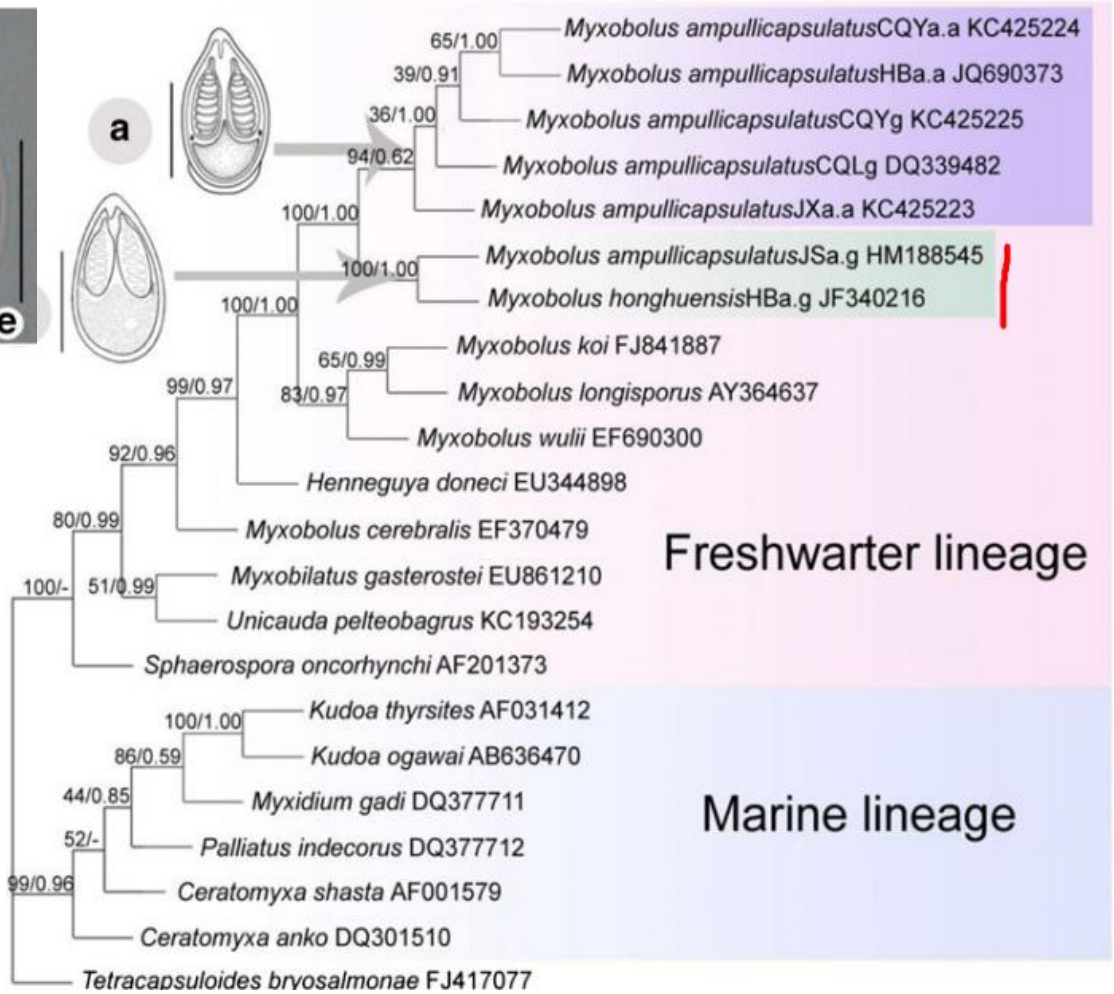




M.honghuensis



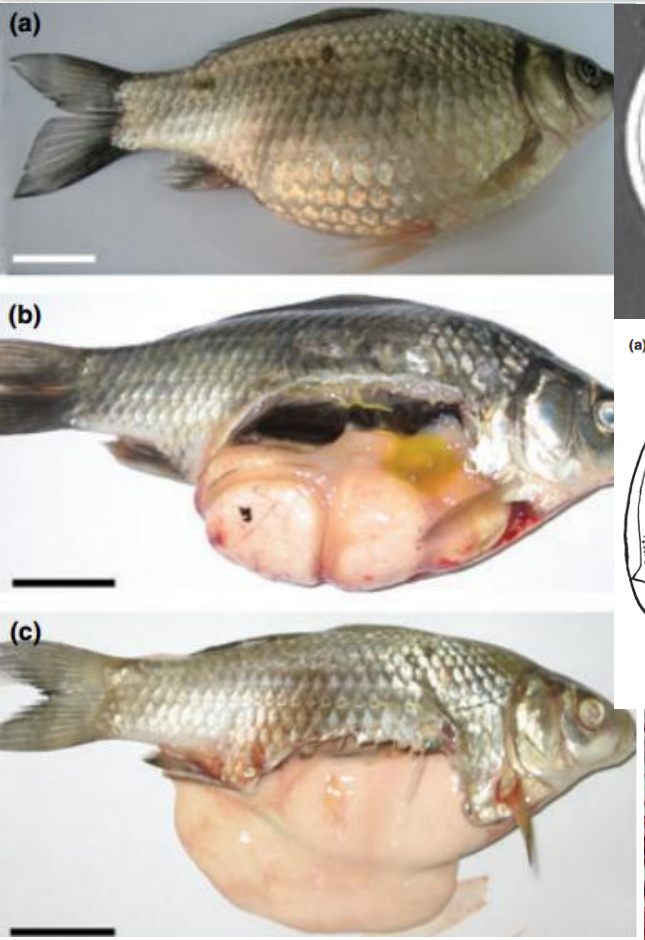
M. ampullicapsulatus

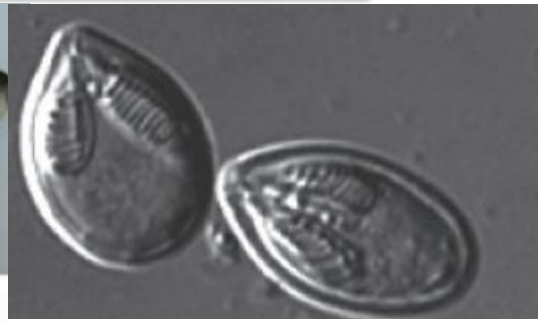


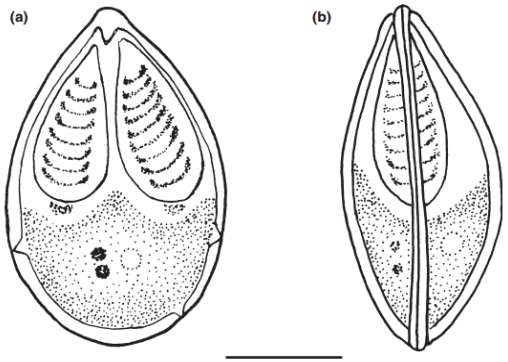
Showing tiny morphological and molecuar difference between *M. ampullicapsulatus* and *M. honghuensis*

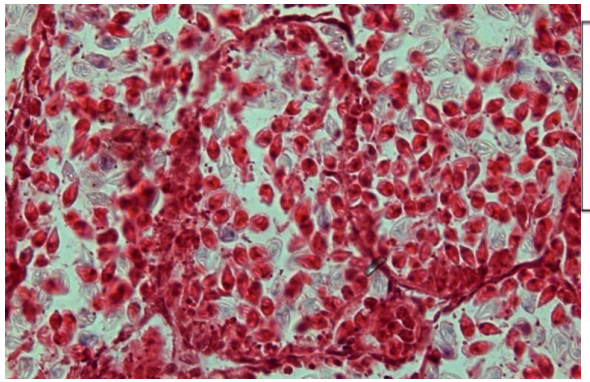
Myxobolus wulii

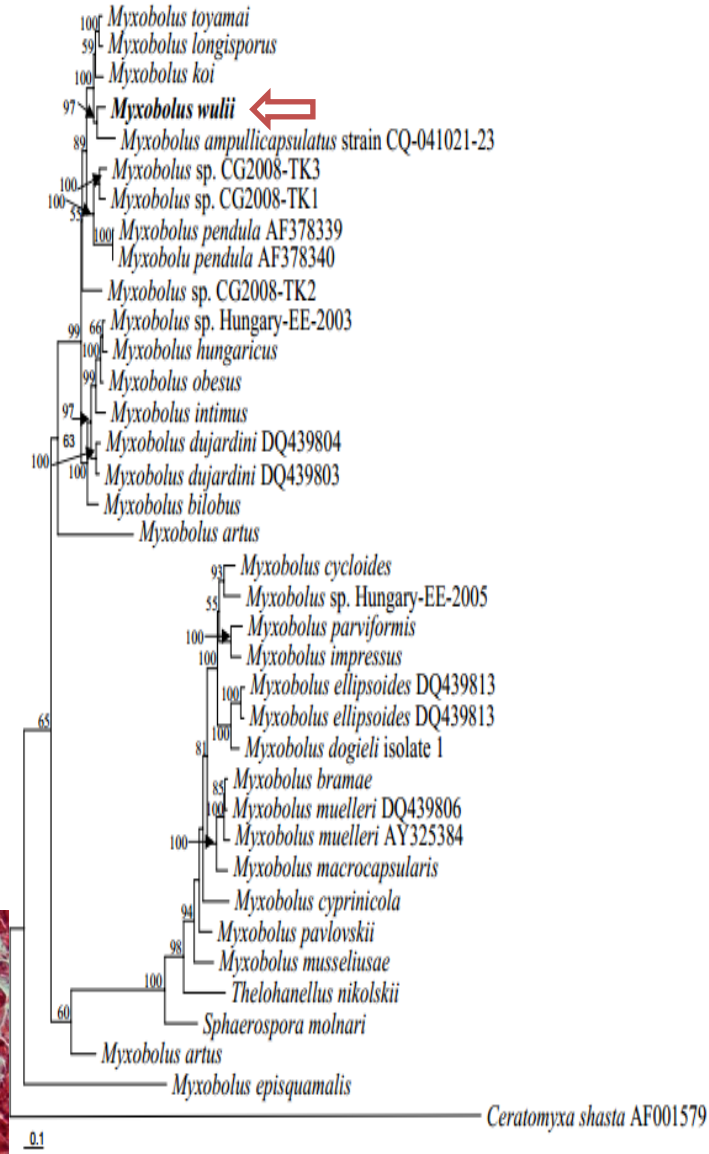
Synonyms: *Myxosoma magna* wu & Li, 1986; *Myxobolus quanqiaoensis* Wu & Wang, 1997;
Infection site: hepatopancreas
Molecular data: EF690300







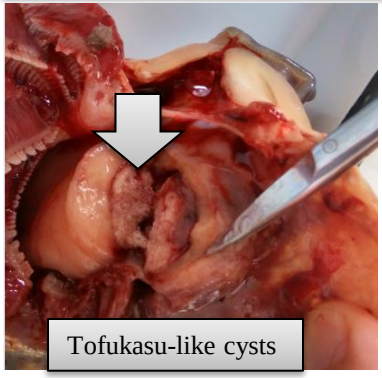


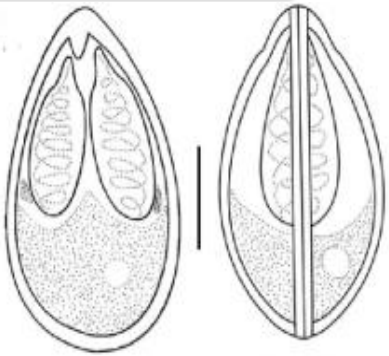


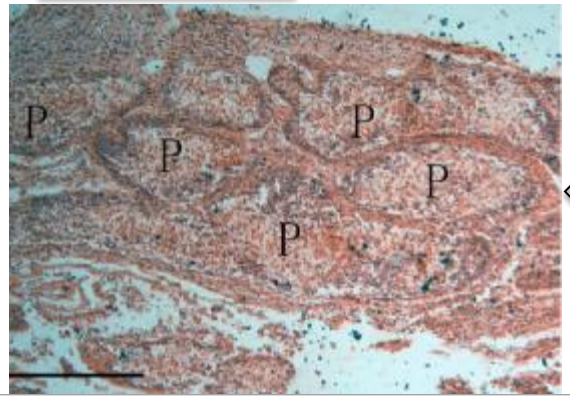
Honeycomb-like hepatocyte completely replaced by mature spores

Myxobolus honghuensis n.sp.

Synonyms: *Myxosoma pharynae* Xiu & Lu 2013;*M. ampullicapsulatus* Jsa.a
Infection site: phyarynx
Molecular data: KJ725074; JF340216

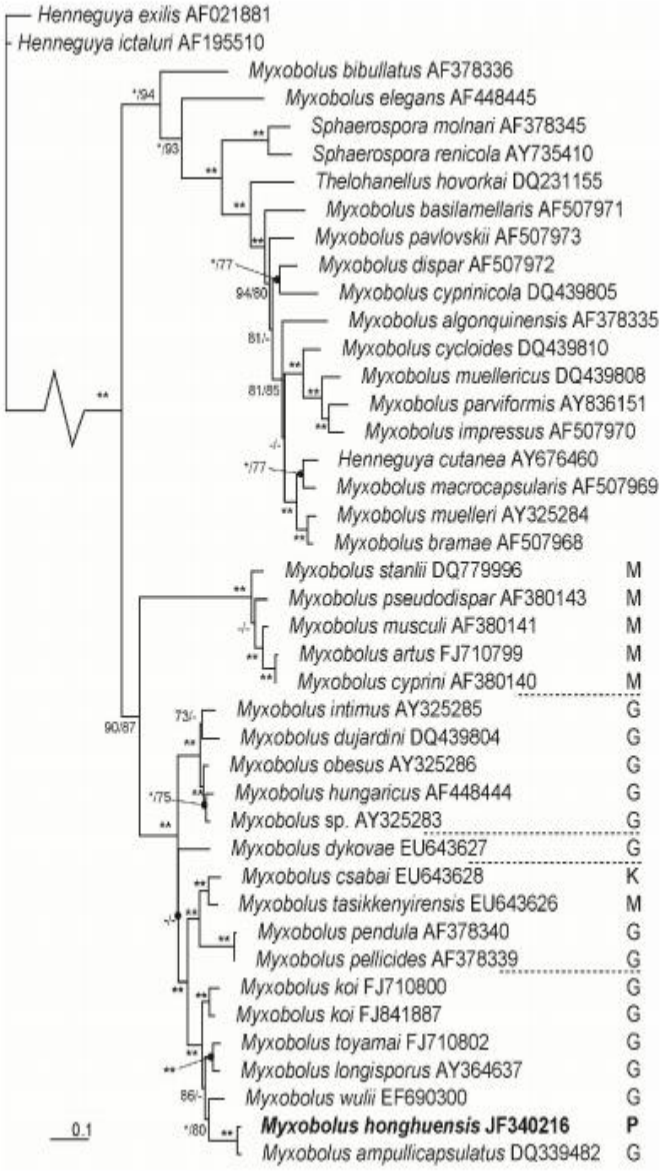






Many small plasmodia forming a big cyst

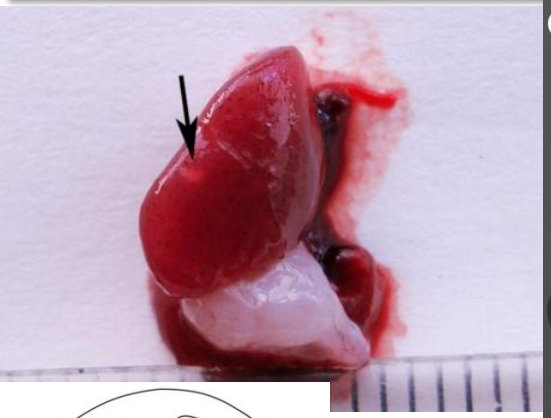
Parasite	*M. honghuensis* n. sp.	*M. wulii*	*M. ampulicapsulatus*
Source			Zhao et al. (2008)
Host	*C. auratus gibelio*	*C. auratus gibelio*	*C. auratus auratus*
Spore (body) shape	pyriform	pyriform	pyriform
Spore (body) length	16.9± 0.5 (15.1 - 17.8)	18.0± 0.8 (16.0 - 19.6)	18.0±0.9 (16.5-19.5)
Spore (body) width	10.4 ± 0.4 (9.8 - 11.3)	11.3 ± 0.6 (9.8 - 12.0)	9.3 ± 0.4 (8.5-10.0)
Spore (body) thickness	8.4 ± 0.4 (7.9 - 9.1)	8.9 ± 0.4 (7.8 - 9.8)	7.0
Large polar capsule length	8.4 ± 0.4 (7.6 - 9.2)	9.2 ± 0.6 (7.8 - 10.0)	8.5 ± 0.7 (7.0-10.0)
Large polar capsule width	3.9 ± 0.2 (3.1 - 4.2)	3.9 ± 0.2 (3.1 - 4.3)	
Small polar capsule length	7.9 ± 0.2 (7.0 - 8.3)	8.6 ± 0.5 (7.5 - 10.0)	3.0 ± 0.2 (2.5 - 4.0)
Small polar capsule length	3.7 ± 0.3 (3.0 - 4.1)	3.8 ± 0.3 (3.0 - 4.2)	
No. filament turns	7-8	7-9	9 - 10



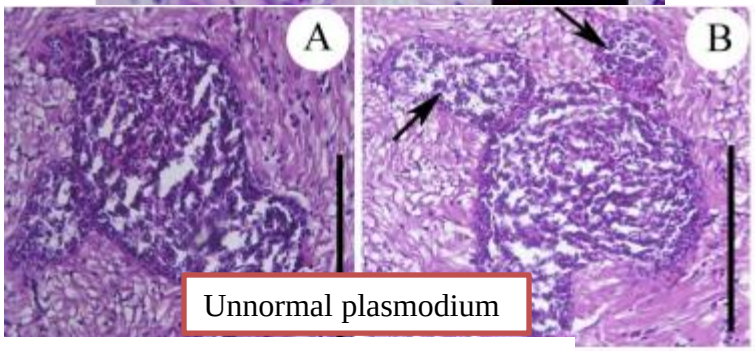
Cluster with species with elongate spore

Myxobolus hearti

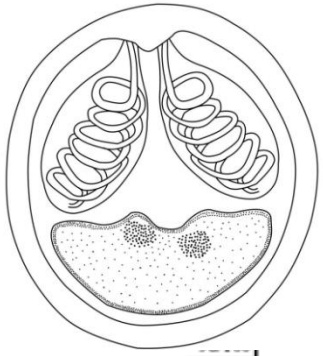
Redescription
Infection site: myocardium
Molecular data: GU574808

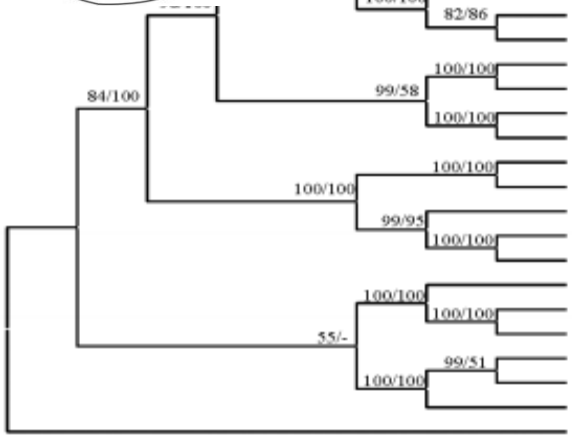


normal round plasmodium



Unnormal plasmodium



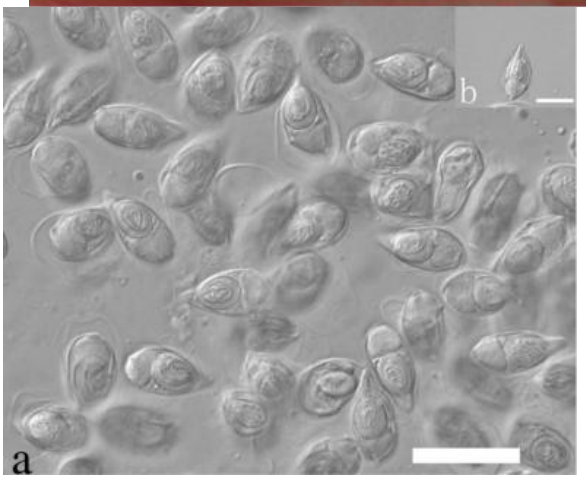


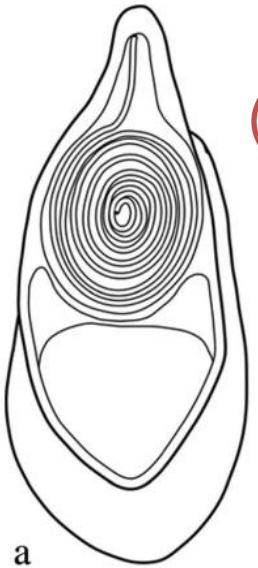
Species	Genebank accession no.	Host species	Infection organ	Location
M. erythrophthalmi	EU567311	*Scardinius erythrophthalmus*	renal interstitium	Balaton, Hungary
M. alburni	EU567313	*Alburnus alburnus*	fin	Balaton, Hungary
M. leuciscini	DQ439811	*Leuciscus cephalus*	gill	Danube, Hungary
M. dogieli	EU003978	*Abramis brama*	heart	Balaton, Hungary
M. gayerae	DQ439809	*Leuciscus cephalus*	intestine wall	Danube, Hungary
M. cycloides	DQ439810	*Leuciscus cephalus*	swimbladder	Danube, Hungary
M. diversicapsularis	GU968199	*Rutilus rutilus*	gill	Hungary
M. impressus	AF507970	*Abramis brama*	gill	Balaton, Hungary
M. rotundus	EU710583	*Abramis brama*	gill	Balaton, Hungary
M. basilamellaris	AF507971	*Cyprinus carpio*	gill	Hungary
M. musselusae	FJ710801	*Cyprinus carpio*	gill	Japan
M. pavlovskii	AF507973	*Aristichthys nobilis*	gill	Hungary
M. pavlovskii	HM991164	*Hypophthalmichthys molitrix*	gill	Hungary
M. turpisrotundus	EF690299	*Carassius auratus gibelio*	subepidermal tissues	Ezhou, China
M. turpisrotundus	GU570996	*Carassius auratus gibelio*	skin	Wuhan, China
M. hearti	**GU574808**	***Carassius auratus gibelio***	**heart**	**Honghu, China**
H. doneci	EU344898	*Carassius auratus auratus*	gill	Chongqing, China
H. doneci	HM146129	*Carassius auratus gibelio*	gill	Honghu, China
M. bilobus	DQ008579	*Notemigonus crysoleucas*	gill	[illegible]
M. koi	FJ710800	*Cyprinus carpio*	gill	[illegible]
M. toyamai	FJ710802	*Cyprinus carpio*	gill	[illegible]
H. lateolabracis	AB183747	*Lateolabrax* sp.	heart	Mie, Japan
H. akule	EU016076	*Selar crumenophthalmus*	heart	Hawaii, USA
H. pagri	AB183748	*Pagrus major*	heart	Mie, Japan
T. bryosalmonae	U70623	*Oncorhynchus mykiss*	kidney	France

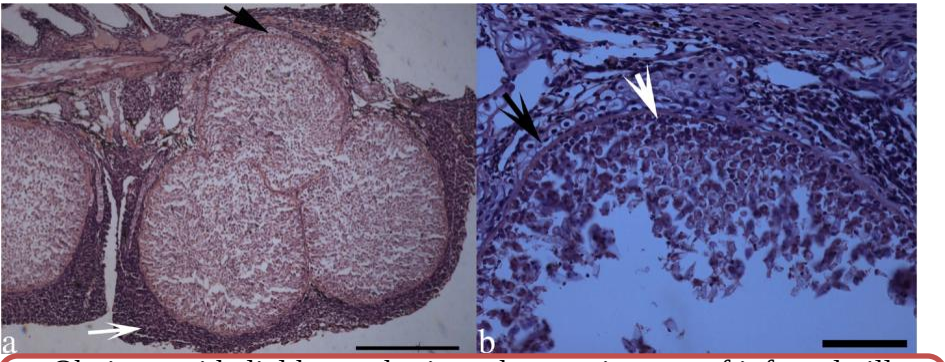
Cluster with species with round spore

Thelohanellus wangi n.sp.

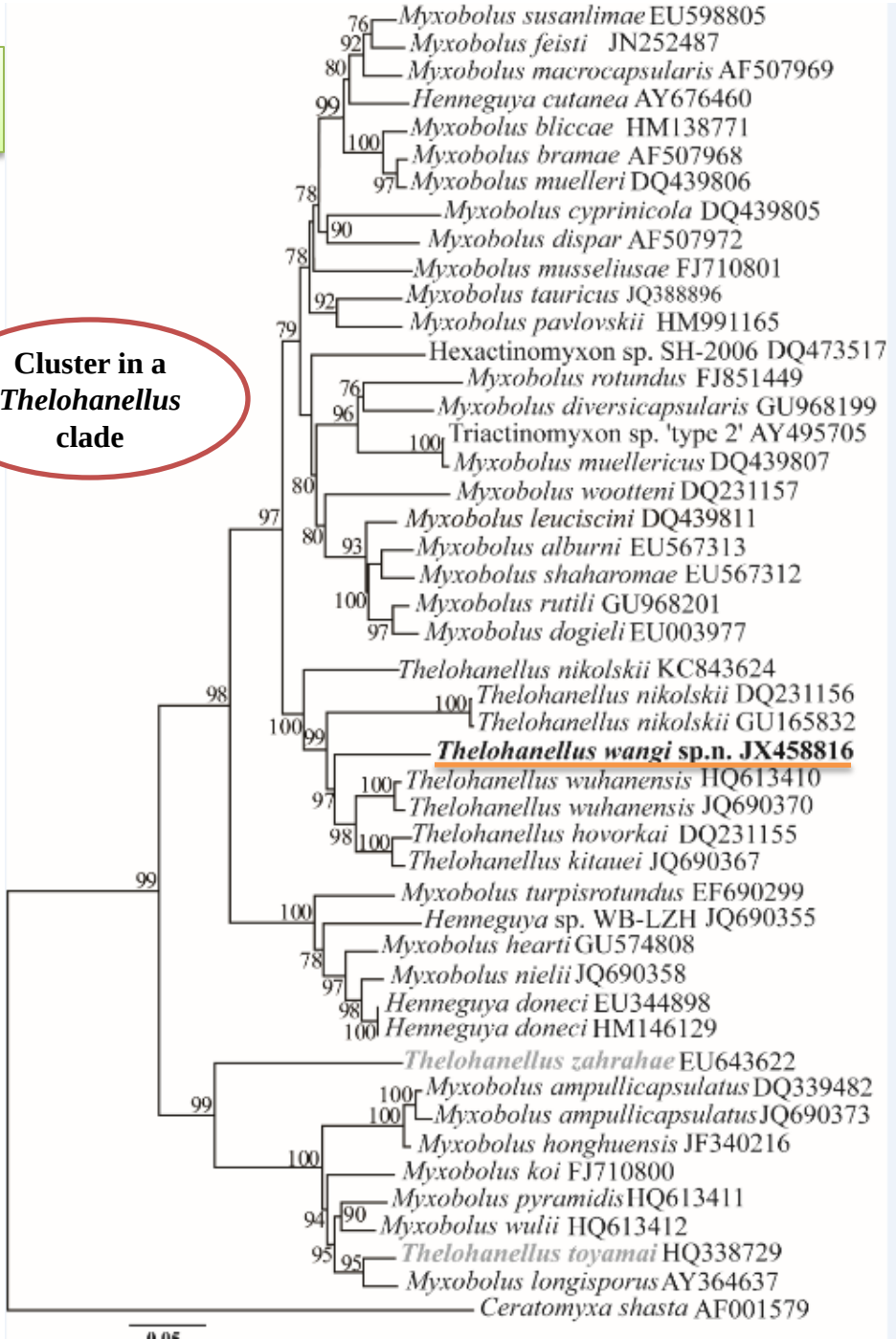
Infection site: gill filaments
Molecular data: JX458816





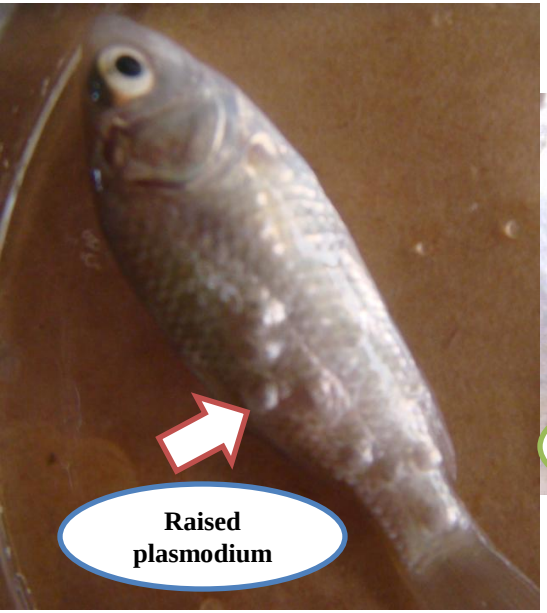


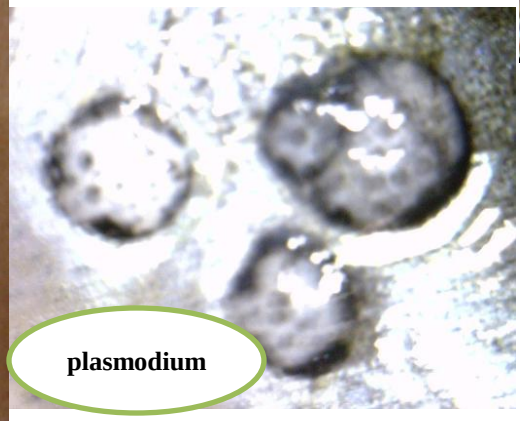
Obvious epithelial hyperphasia at the anterior part of infected gill filaments and a thin connective tissue membrane delimited the plasmodium from cartilage cells of gill filaments

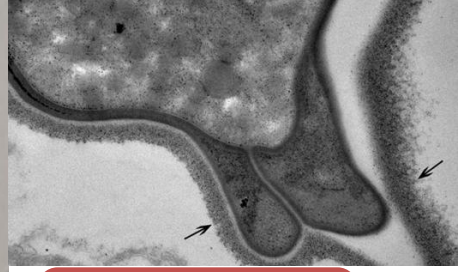


Thelohanellus wuhanensis n. sp.

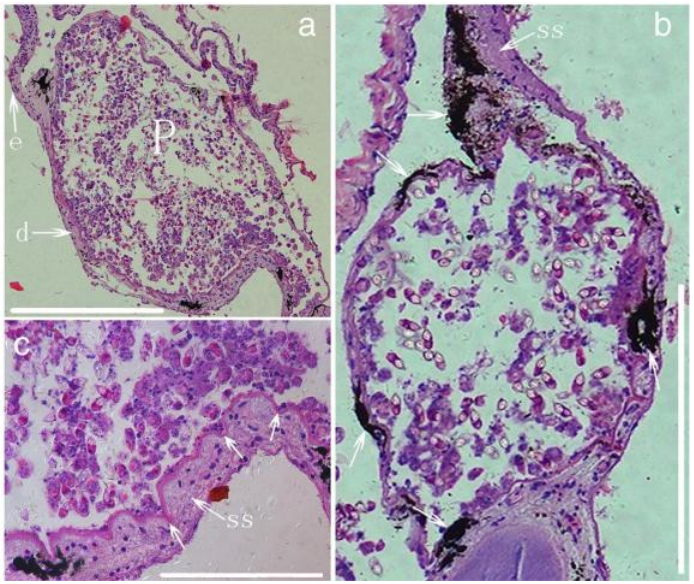
Infection site: skin
Molecular data: JQ968687; JQ088179; HQ613410



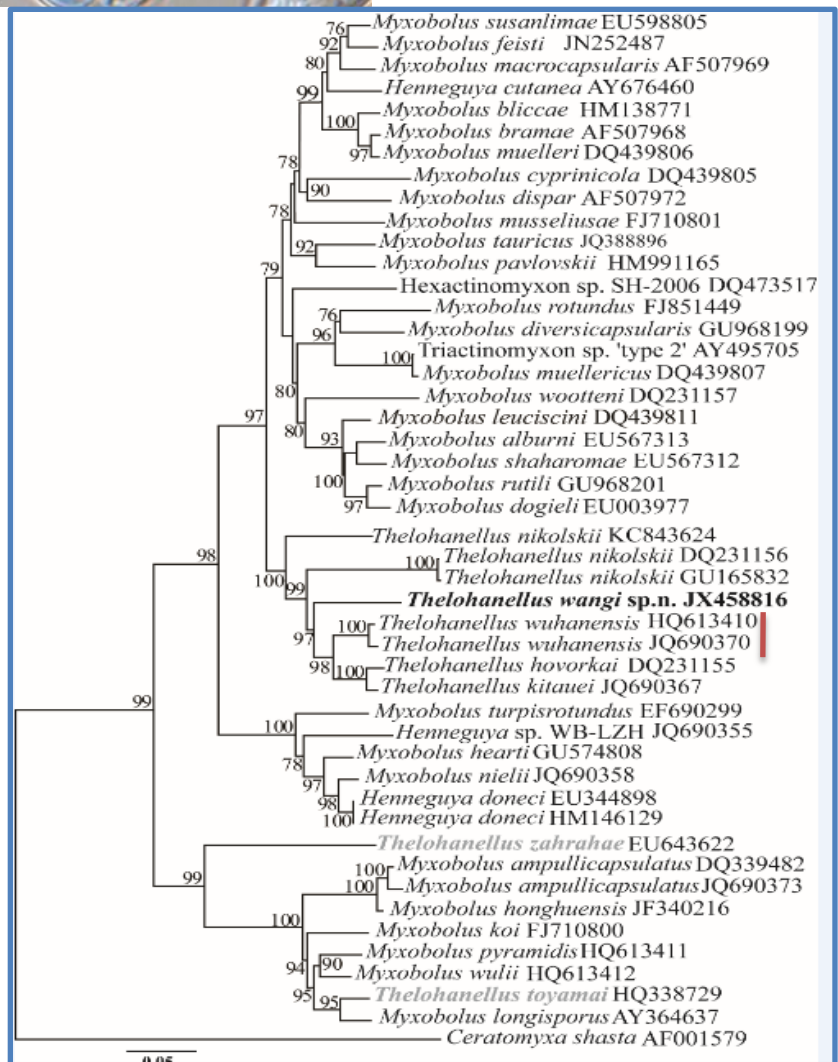




Membranous sheath surrounding spore cited from Liu et al. 2014

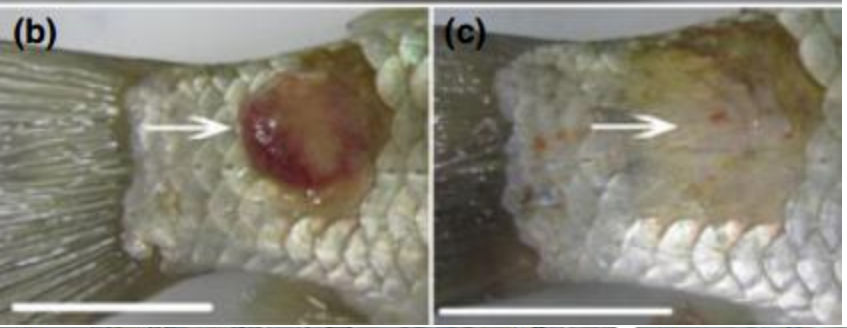


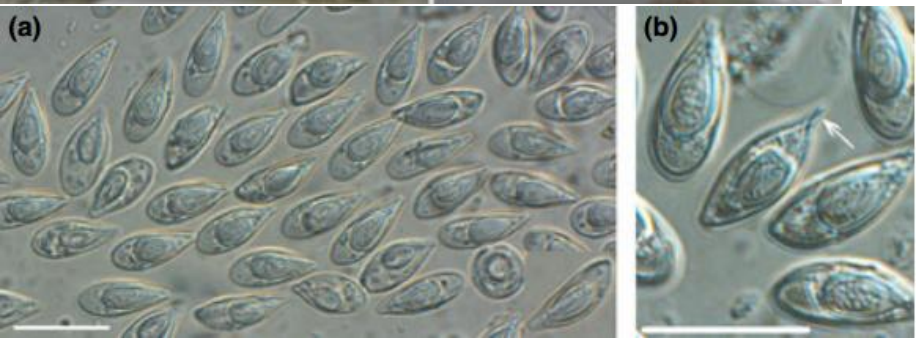
Showing plasmodium developing in the stratum spongiosum of dermis and many melanocytes gathering together around the plasmodia

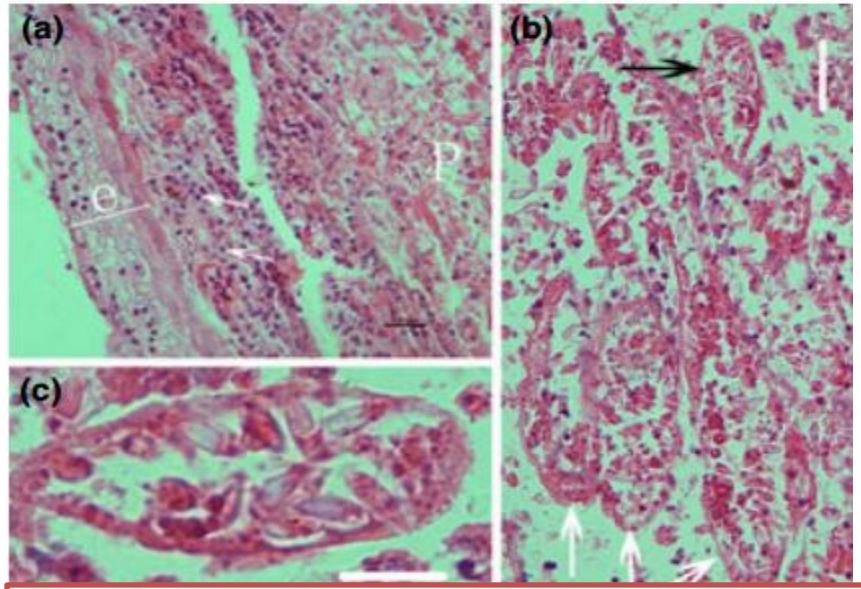


Thelohanellus testudineus n. sp.

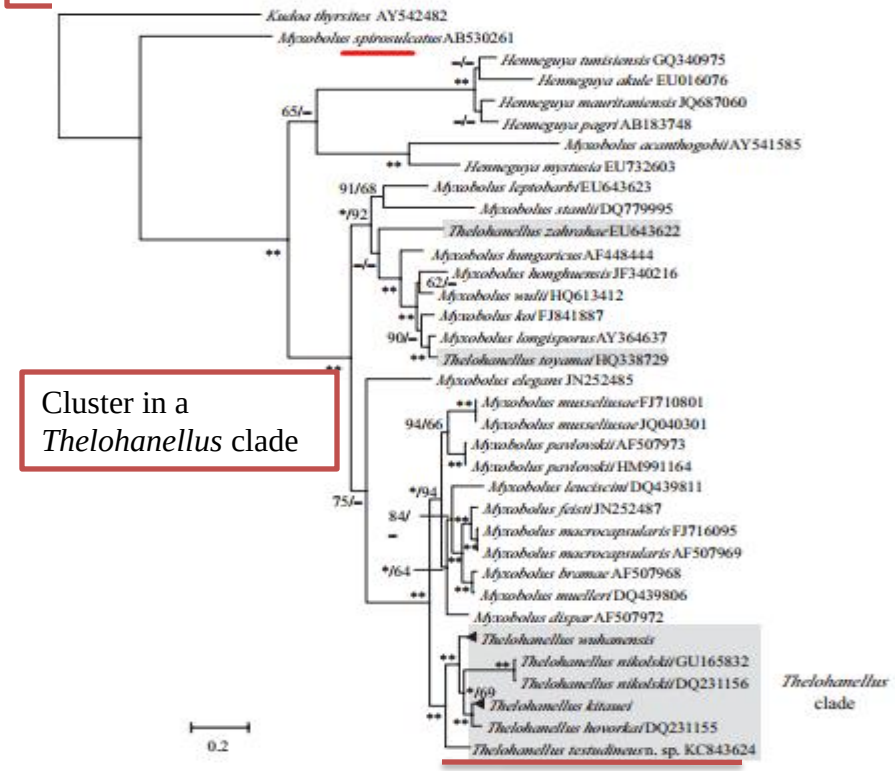
Infection site: skin
Molecular data: KC843624







Showing plasmodium developing in the dermis of the skin and distinct inflammatory infiltration,

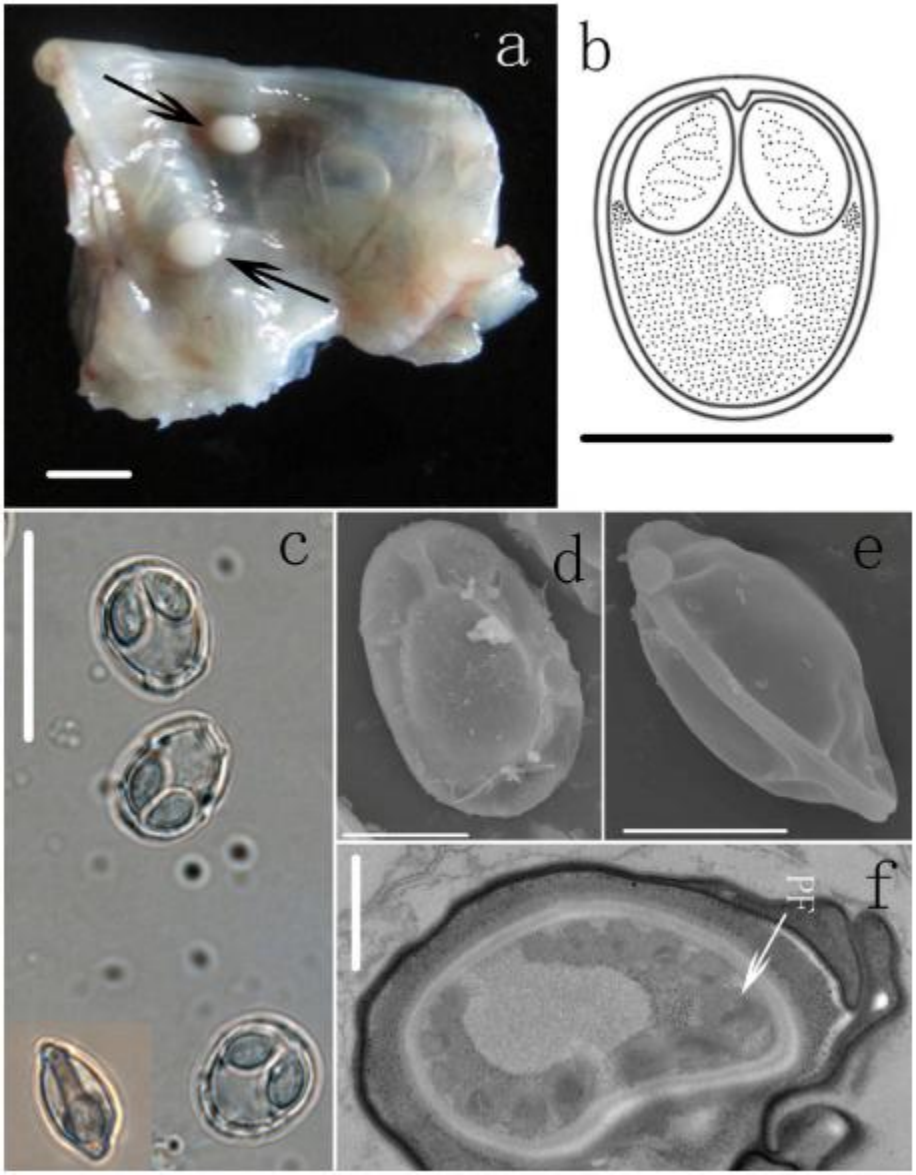


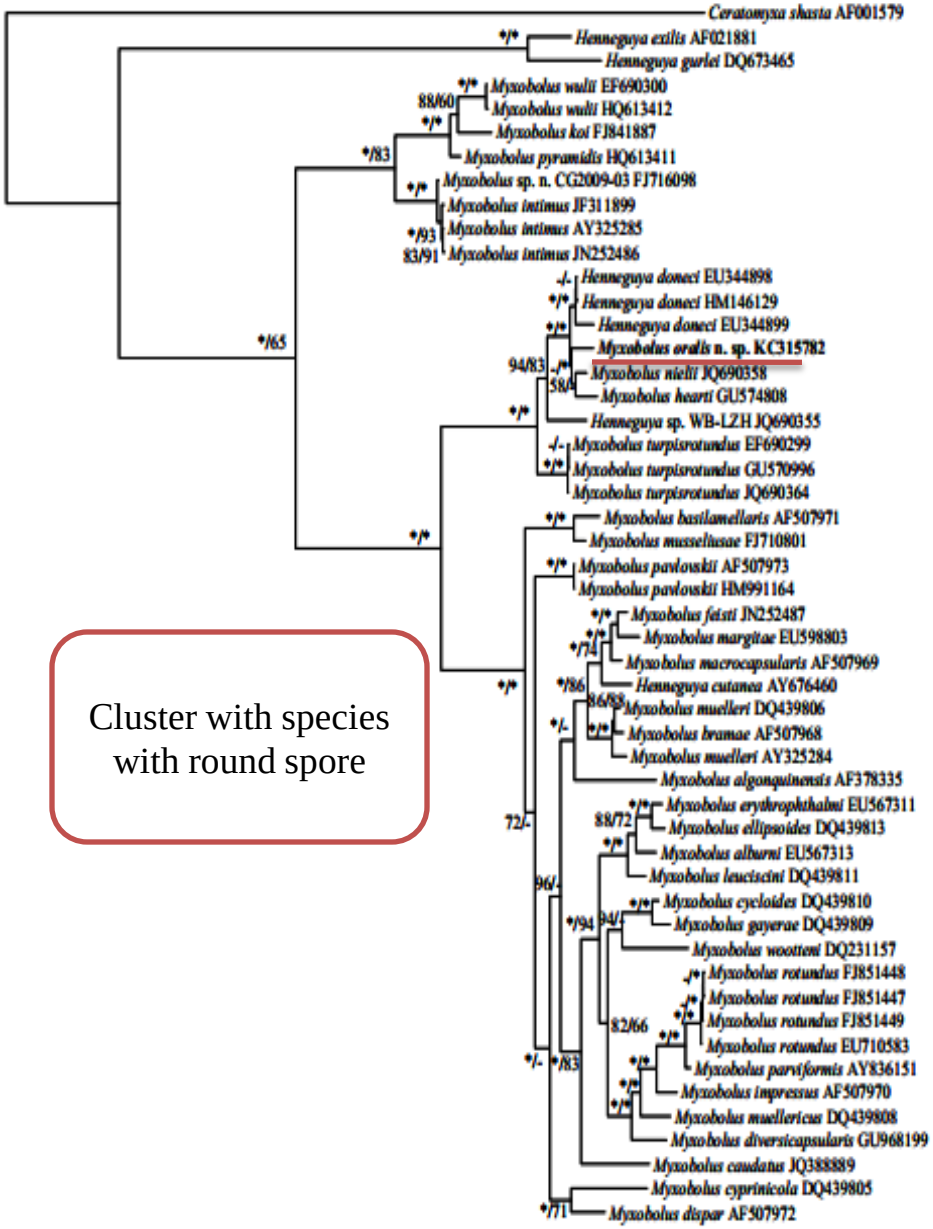
Cluster in a *Thelohanellus* clade

Cited from Liu et al. 2013

Myxobolus oralis n. sp.

Infection site: oral cavity
Molecular data: KC315782



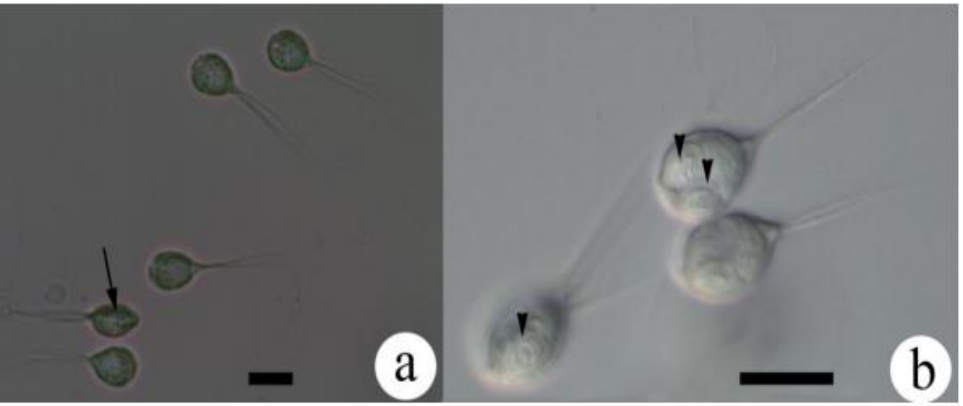


Cluster with species with round spore

Cited from Liu et al. 2014

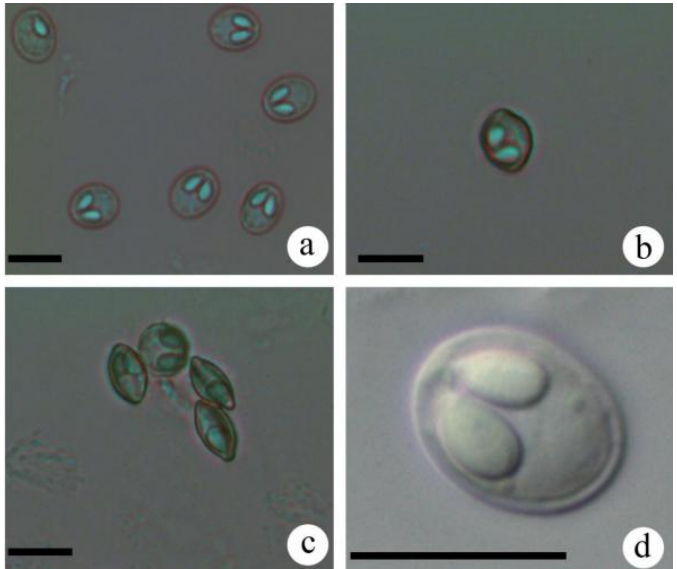
Henneguya globulata n.sp.

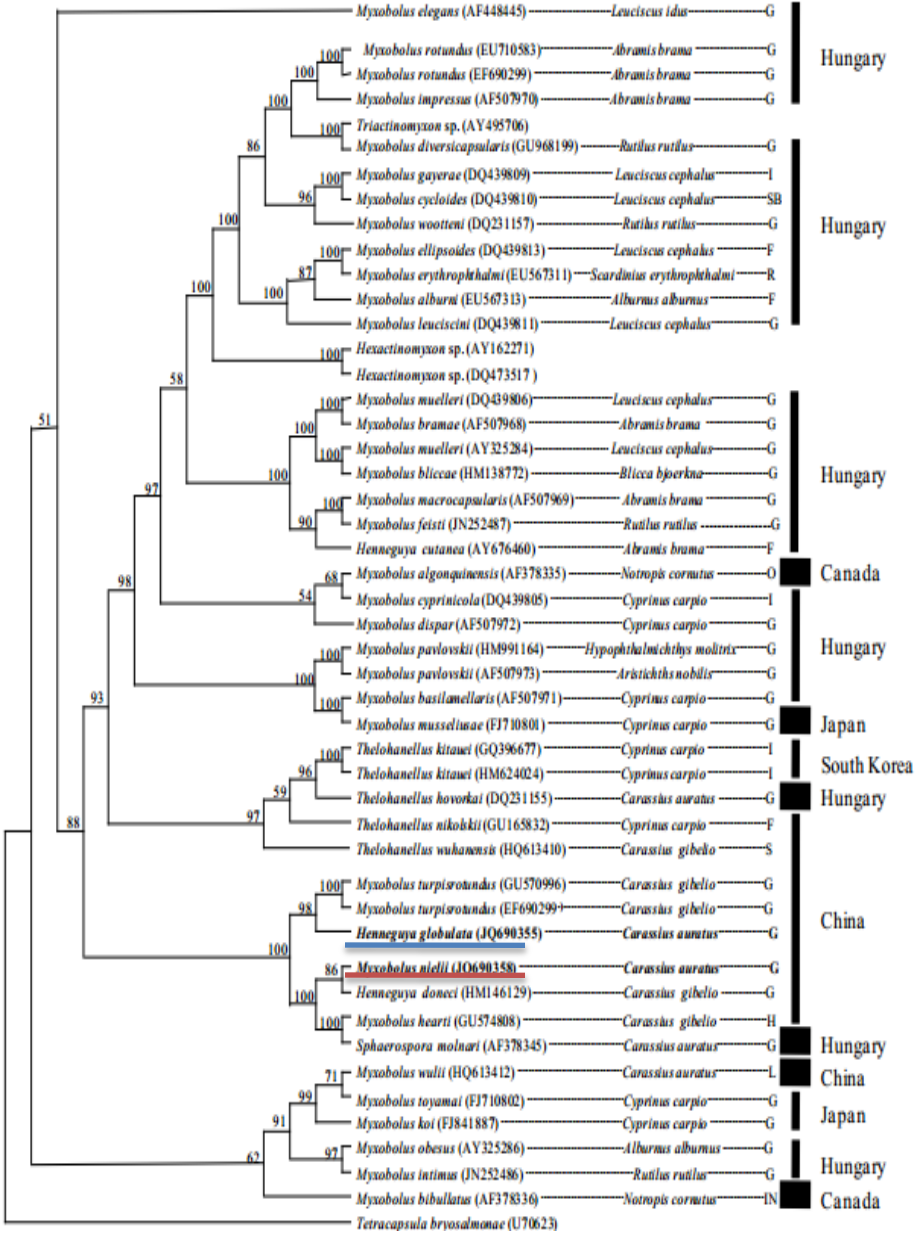
Infection site: gill filaments
Molecular data: KJ725074; JF340216



Myxobolus nielii (Nie et Li, 1973) Landsberg et Lom, 1991

Infection site: gill filaments
Molecular data: KJ725074; JF340216

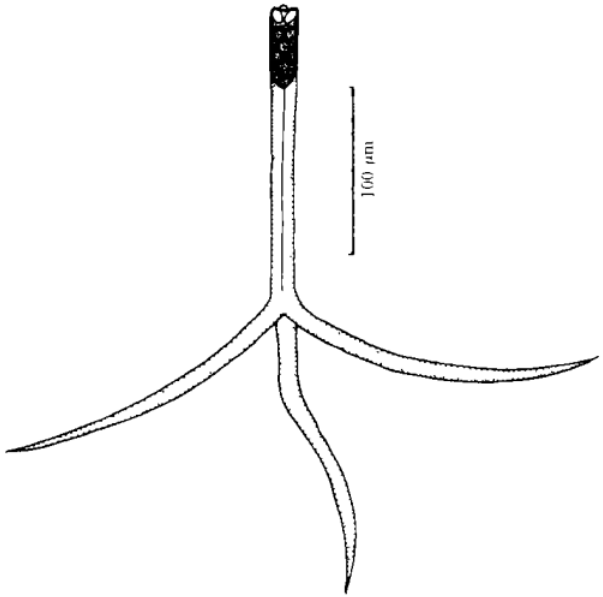




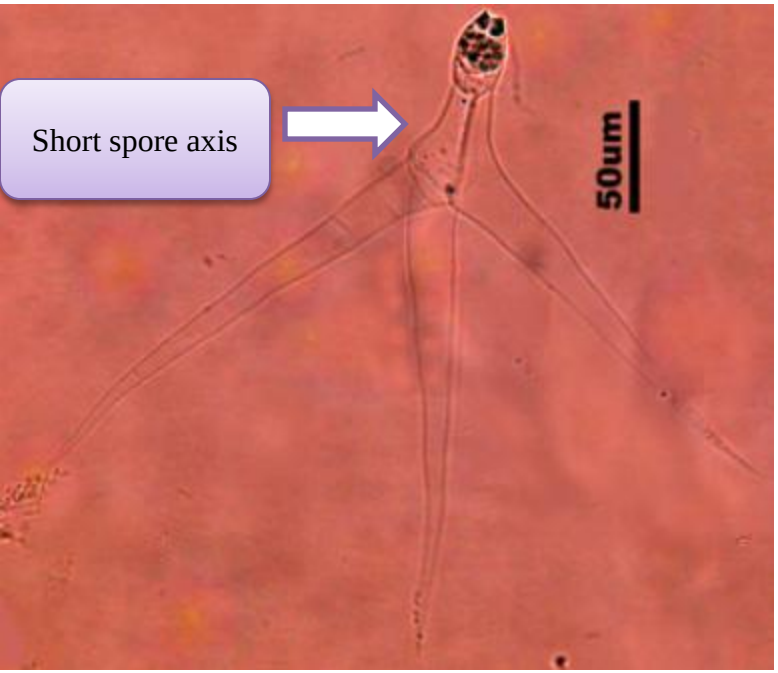
Phylogenetic relationship consistent with spore morphology (round spore body)

Life cycle study in China

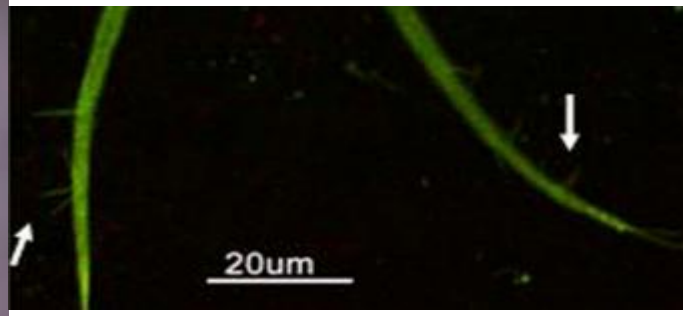
- **Firstly reported *Triactinomyxon* type from *Branchiura sowerbyi* (Wang et al. 2000)**
  no molecuar data



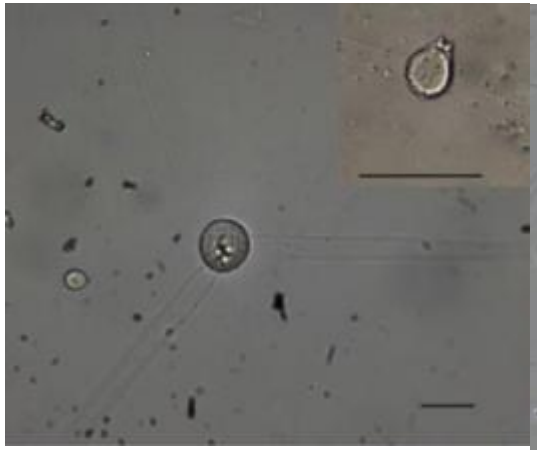
- **Secondly *Triactinomyxon* type from *Branchiura sowerbyi* (Zhai et al. 2012)**
  molecuar data: HM107112

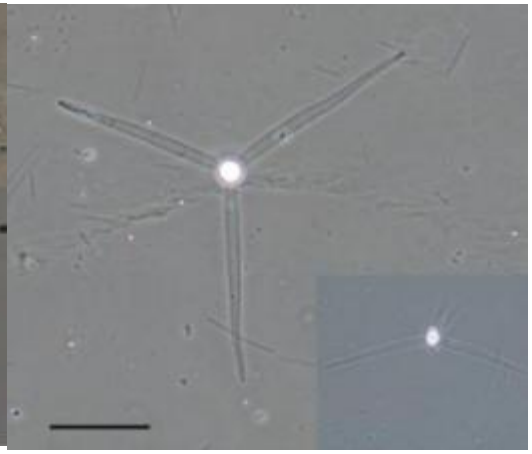


●**Firstly *Raabeia* type from *Branchiura sowerbyi* (Zhai et al. 2013; Xi et al. 2013) molecuar data:AB121146; HQ613409**

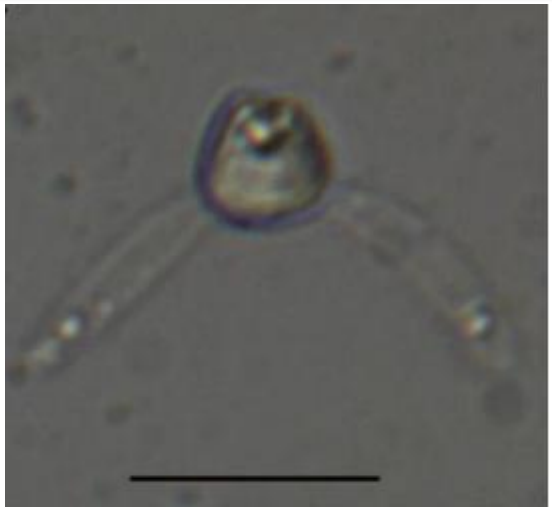


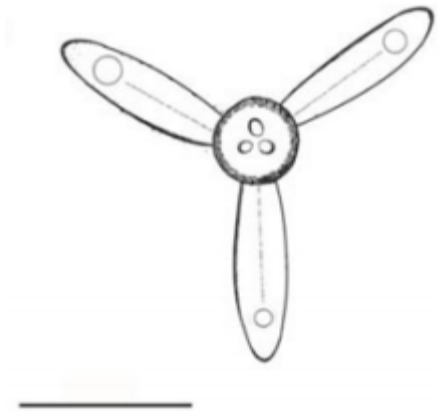
●**Firstly *Aurantiactinomyxon* type from *Branchiura sowerbyi* (Xi et al. 2013); molecuar HQ613406**



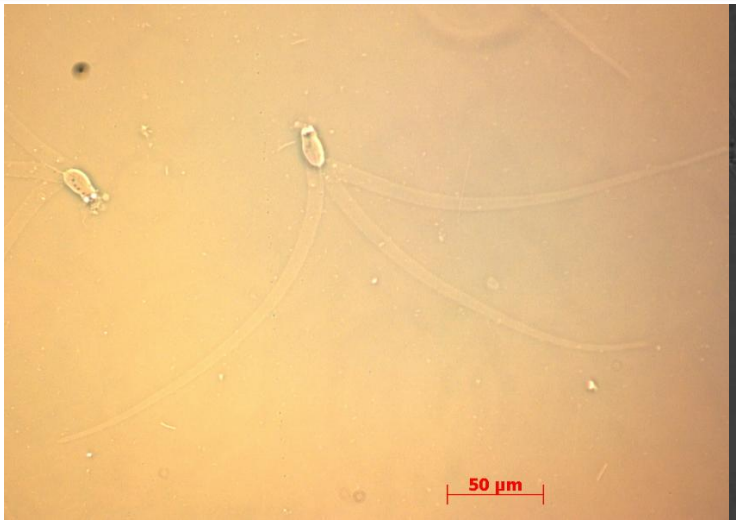


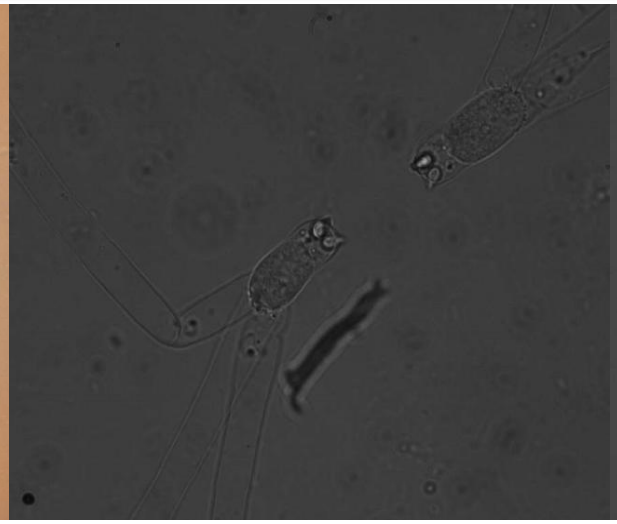
●**Firstly *Guyenotia* type from *Branchiura sowerbyi* (Xi et al. 2013); molecuar data unavailable**

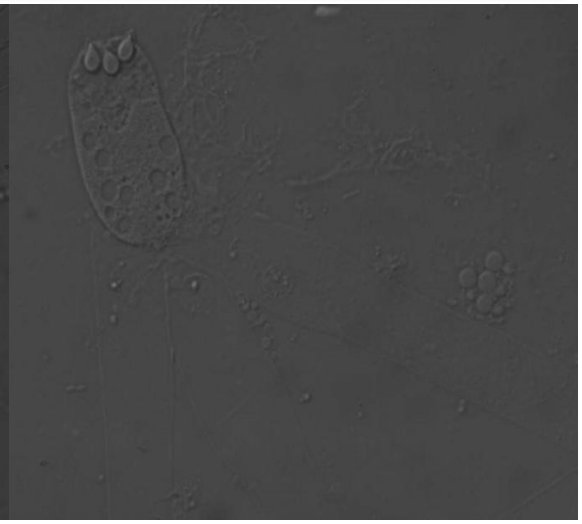




●**Secondly *Raabeia* type from *Branchiura sowerbyi***
molecuar data: HQ613410



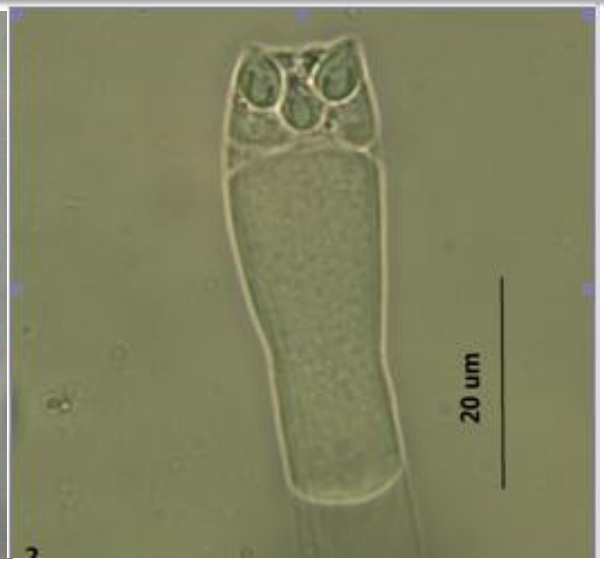


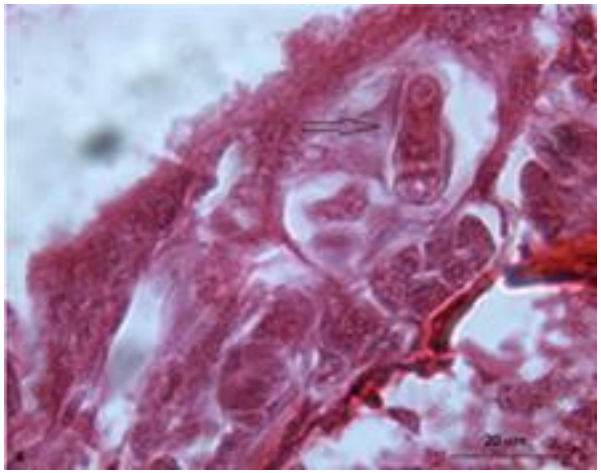


●**Firstly *Echinactionmyxon* type from *Branchiura sowerbyi*; molecuar data: EF690300**

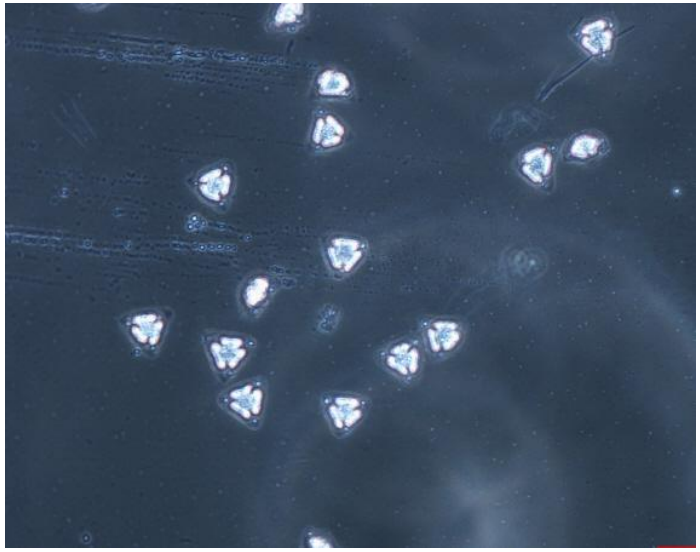
●**Secondly *Echinactionmyxon* type from *Branchiura sowerbyi*; molecuar data: unavailable**

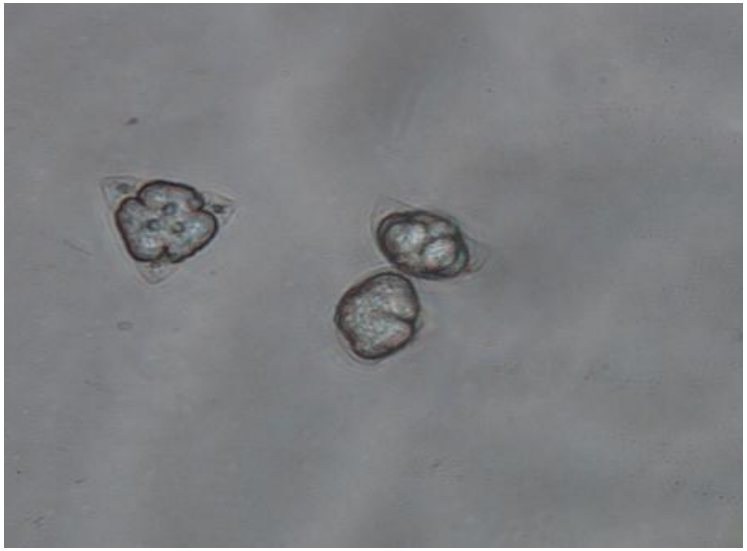
●**Thirdly *Triactinomyxon* from *Branchiura* molecuar data: JX477771**

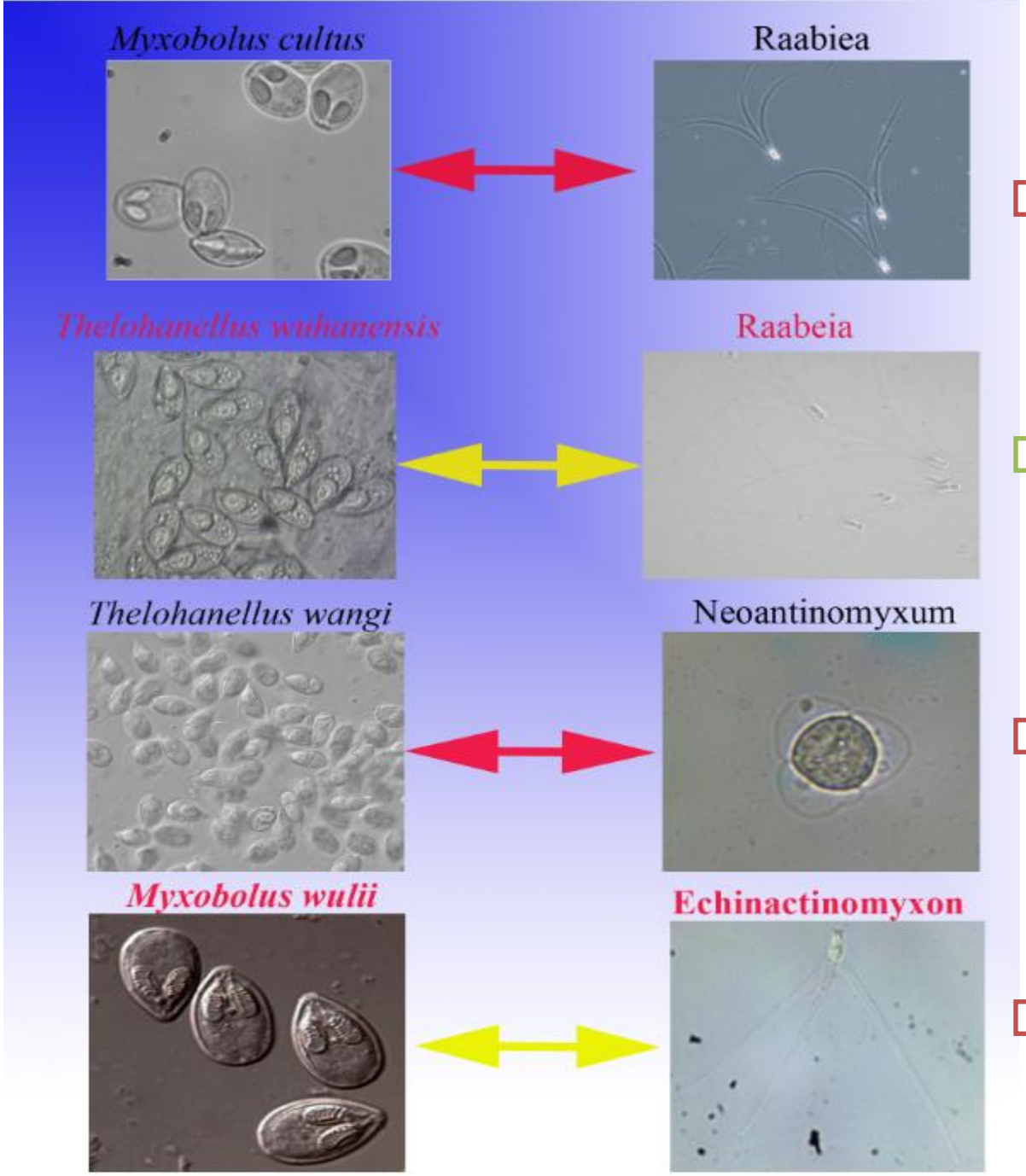




●**Firstly Neoactinomyxum type from *Branchiura sowerbyi;* molecuar data: KP642135, JX458816**







Molecuar data match

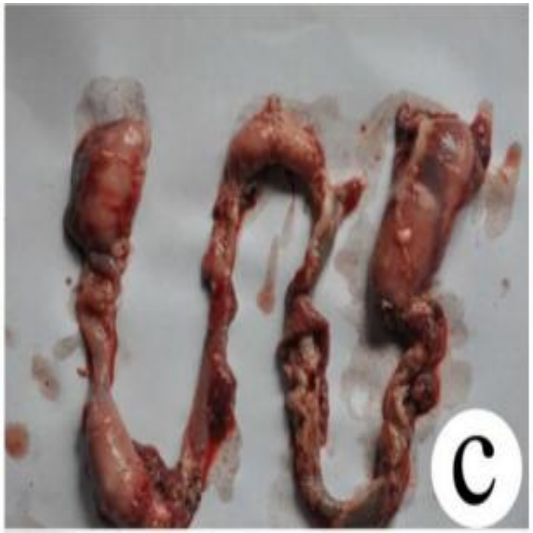
Experimental infection and molecular match

Molecuar data match

Molecuar data match

Current severe myxosporidiosis of common carp in China

Giant cystic diseases caused by *Thelohanellus kitauei*



Infection prevalence: 70%;
Mortality rate: up to 90%, especially Northern China;
Infection season: from early August to late October, especially Autumn;
Economic losses: 50 million per year;
Control strategy: no practical way

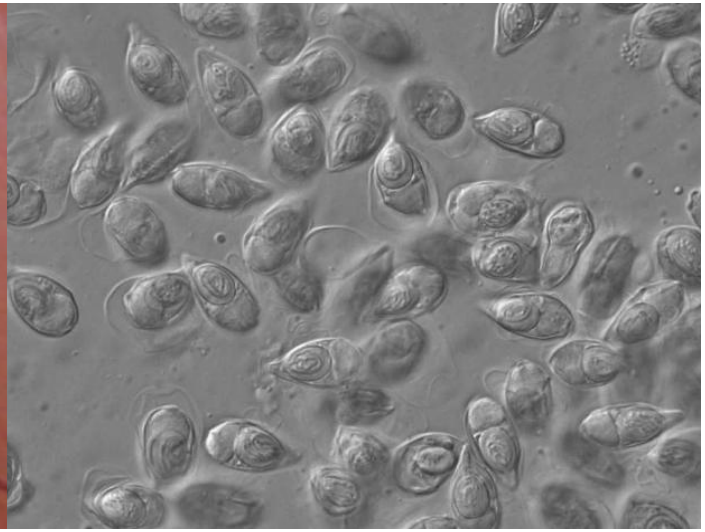
Current severe myxosporidiosis of gibel carp in China

1. Pharynx myxosporidiosis caused by *Myxobolus honghensis*



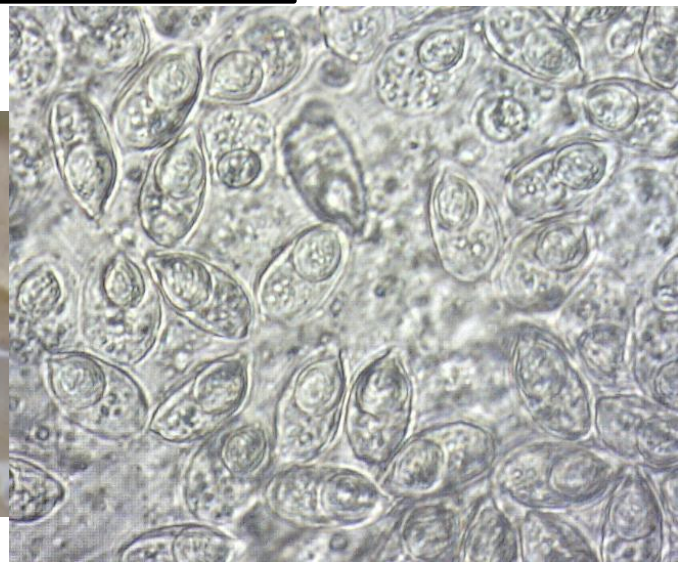

Infection prevalence: 70%;
Mortality rate: up to 100%, especially in Northern Jiangsu Province;
Infection season: from early May to late October, especially summer;
Economic losses: 2 billion per year;
Control strategy: blocking the transmission and inactivating the infective actinospores by Ino-org;

2. Gill myxosporidiosis caused by *Thelohanellus wangi*



Infection prevalence: 60%;
Mortality rate: up to 100%, especially under anoxia, crowded or other stress;
Infection season: only from early April to late June on fry fish below 7cm in body length;
Economic losses: 10 million per year;
Control strategy: blocking the transmission and inactivating the infective actinospores by Ino-org;

3.Skin myxosporidiosis caused by *Thelohanellus wuhanensis*



Infection prevalence: 70%;
Mortality rate: no directly lethal,but up to 100% under anoxia, crowded or other stress condition;
Infection season: only from early April to late June on fry fish below 7cm in body length;
Economic losses: 10 million per year;
Control strategy: blocking the transmission and inactivating the infective actinospores by Ino-org;

Acknowledge

Dr. Gu ZM and Dr. Liu Y from Huazhong Agricultural University, Wuhan, China;

Prof. Csaba Székely from institute for Veterinary Medical Research, Centre for Agricultural Research, HAS;

Dr. Zhai and Dr. Ye LT from Institute of Hydrobiology, Chinese Academy of Sciences;

Thank you for your attention