Argulus
(crustacean: branchiuran)

Overview

Arthropods are coelomate metameric invertebrate animals with a chitinous exoskeleton and jointed limbs. They undergo protostomial embryonic development and most grow by cuticular moulting (ecdysis). Three main subphyla are recognized: Chelicerata, Crustacea and Hexapoda. Crustaceans have a very strong cuticle strengthened by calcium salts; thus their growth must proceed through repeated moults. Most species are aquatic with internal or external gills, two pairs of antennae, mouthparts comprising one pair of mandibles and two pairs of maxillae, and each heteronomous body segment usually bears a pair of ventral biramous extremities (podia). Maxillopods lack appendages on abdominal segments and the nauplius larval stage has a unique maxillopodan eye. Branchiurans have dorsoventrally flattened bodies with a head, thorax and abdomen. The head has a flattened bilobed cephalic fold incompletely fused to the first thoracic somite, and the carapace expands laterally to form respiratory alae. They undergo direct (rather than metamorphic) development with eggs releasing juveniles. They are blood-sucking ectoparasites on marine and freshwater fishes, and occasionally amphibians. Argulids (fish lice) have discoid bodies and attach to hosts using hooks, suckers and barbs. Infestations by *Argulus* spp. on the skin and gills may cause lesions, haemorrhage, lethargy and erratic aversion behaviours in afflicted fishes.

Classification:

Domain:	Eukaryota (membrane-bound nucleus)
Supergroup:	Amorphea (unikonts with single flagellum, or nonflagellated amoebae)
Kingdom:	Metazoa (multicellular eukaryotes, heterotrophs, notably animals)
Group:	Protostomia (triploblastic, spiral cleavage)
Subgroup:	Ecdysozoa (cuticle moulted = ecdysis)
Phylum:	Arthropoda (chitinous exoskeleton, segmented body, jointed limbs, haemocoel)
Subphylum:	Crustacea (mandibular mouthparts, gills, two pairs antennae, biramous podia, larval nauplius/zoea)
Class:	Maxillipoda (nauplius with maxillipodan eye)
Subclass:	Branchiura (head with bilobed cephalic fold, carapace expands laterally, respiratory alae, blood suckers)
Order:	Argulida (single order)
Family:	Argulidae (fish lice, discoid body, attaches using hooks/suckers/barbs, stylus inserted to feed on blood)
Genus:	*Argulus* (parasitic on skin/gills of fish)
Species:	various species cause skin and/or gill lesions in fishes

Parasite biodiversity and host range: Most Metazoa are multicellular triploblastic animals with differentiated tissues, many being bilaterally symmetrical with a body cavity. Most invertebrate animals are protostomes as their embryonic development involves spiral determinate cleavage. Those that moult their external cuticles during their life-cycles (process known as ecdysis) are grouped together in the unique clade Ecdysozoa, including the nematodes (roundworms), onychophorans (velvet worms), tardigrades (water bears) and arthropods (myriapods, chelicerates, crustaceans and hexapods). Arthropods have small segmented bodies encased in chitinous exoskeletons with articulated limbs. Most species are free-living in terrestrial and aquatic habitats, although a small range are ectoparasitic on other animals, some feeding on the blood or skin of vertebrates. Five subphyla are recognized: Chelicerata, Crustacea, Hexapoda, Myriapoda and Trilobita. Crustaceans have very strong cuticles strengthened by calcium salts, so they moult periodically as they grow and metamorphose through different types of larval stages before forming adults. Most species are aquatic and have internal or external gills, while terrestrial species have internal gills which are kept moist. Crustaceans have mouthparts with two pairs of maxillae (to handle food) and paired mandibles (with opposing biting and grinding surfaces). They have two sets of antennae and each body segment usually gives rise to a pair of ventral biramous appendages (podia). Six crustacean classes are recognized: Brachiopoda, Cephalocarida, Malacostraca, Maxillipoda, Ostracoda and Remipedia. Maxillopods usually have a body plan comprising 5 cephalic, 6 thoracic and 4 abdominal segments followed by a telson. The thoracic segments bear biramous (sometimes uniramous) limbs, but the abdominal segments lack appendages. The carapace is present or reduced, most feed using maxillae, and the nauplius larval stages have unique eyes with three cups, each with tapetal cells (= maxillopodan eye). Six maxillopodan subclasses are recognized: Branchiura, Cirripedia, Copepoda, Mystacocarida, Pentastomatida and Tantulocarida.

Major parasitic crustacean families	Biodiversity	Hosts	Parasitic stages	Patho-genesis	Disease transmission
Class: Maxillipoda					
Subclass: Copepoda (copepods)					
Order: Cyclopoida (open buccal cavity)					
Family: Lernaeidae (anchor worms)	19 genera, 114 spp.	freshwater fishes	copepodids and adults	skin lesions	direct (water)
Former order: Poecilostomatoida (slit-like buccal cavity)[now a "poecilostome" lineage within the Cyclopoida]					
Family: Ergasilidae (gill lice)	27 genera 61 spp.	freshwater and marine fish	adult ♀	gill/skin lesions	direct (water)
Subclass: Branchiura (head with flattened bilobed cephalic fold, carapace expands laterally)					
Order: Argulidea (discoid bodies, attach using hooks, suckers and barbs)					
Family: Argulidae (fish lice)	4 genera, 150 species	marine and freshwater fish	juveniles, adults	skin lesions	direct (water)
Subclass: Pentastomatida (tongue worms, elongate annulated bodies, 2 pairs tiny anterior claws near mouth)					
Order: Porocephalida (mouth between/below anterior hooks)					
Family: Porocephalidae	5 genera, 10 spp.	snakes (rodent IH)	adults	lung lesions	indirect (via IH*)
Family: Linguatulidae	1 genus, 4 spp.	carnivorous mammals (mammal IH)	adults	naso-pharyngeal lesions	indirect (via IH*)

*IH = intermediate host

Branchiura (commonly referred to as fish lice) are blood-sucking ectoparasites of freshwater and marine fishes, sometimes amphibians and aquatic invertebrates. One family is recognized, the Argulidae whose adults have dorsoventrally-flattened discoid bodies with a head, thorax and abdomen. The head has a flattened bilobed cephalic fold incompletely fused to the first thoracic somite, and the carapace expands laterally to form respiratory alae. They attach to external surfaces of their fish hosts using modified maxillae bearing hooks or suction discs, and insert a stylus to feed on blood, mucus and/or extracellular material. They undergo direct (rather than metamorphic) development with eggs releasing juveniles. Over 150 spp. have been described in 4 genera: 129 *Argulus* spp. with a worldwide distribution (except Antarctica); 13 *Dolops* spp. and one *Dipteropeltis* sp. from South America; and 14 *Chonopeltis* spp. from Africa. Argulids are transient ectoparasites (semipermanent, intermittent feeders) or micropredators characterized by their ubiquity in natural ecosystems, their low host specificity and their pathogenic potential, especially to overcrowded cultured or aquarium fishes. Several *Argulus* spp. are considered to be serious pests in aquaculture (both freshwater and marine) with heavy infections on cyprinids and salmonids causing traumatic lesions with significant morbidity and mortality. A growing number of species have also proven problematic to the aquarium trade with infections causing mortalities particularly in small ornamental fishes.

***Argulus* species**	**Hosts**	**Distribution**
A. africanus	Anguilliformes: anguillid (African mottled eel); Characiformes: alestid (African tigerfish); Cichliformes: cichlid (Singida tilapia, longfin tilapia, Nile tilapia, Victoria tilapia, thickskin haplo, guiarti haplo, obesus haplo, retrodens haplo); Cypriniformes: cyprinid (labeo); Dipnoi: lepidosirenid (marbled lungfish); Osteoglossiformes: mormyrid (Cornish jack, eastern bottle-nosed mormyrid); Perciformes: latid (forktail lates); Polyperiformes: polypterid (bichir); Siluriformes: bagrid (semutundu, kampango, degeni), clariid (African sharptooth catfish, eel-like fattyfin catfish, mudfish, vundu), claroteid (kibonde), schilbeid (golden barbel)	Africa, Asia
A. alexandrensis	Zeiformes: zeid (dory)	Africa
A. alosae	Batrachoidiformes: batrachoidid (toadfish); Clupeiformes: clupeid (alewife); Gadiformes: gadid (Atlantic tomcod); Gasterosteiformes: gasterosteid (three-spined stickleback); Osmeriformes: osmerid (rainbow smelt); Salmoniformes: salmonid (brook trout)	North America
A. amazonicus	Cichliformes: cichlid (speckled peacock bass), Amazon peacock bass)	South America
A. ambloplites	Anabantiformes: channid (obscure snakehead), Characiformes: alestid (African tigerfish); Siluriformes: clariid (African sharptooth catfish)	Africa
A. ambystoma	Urodela: ambystomatid (Lake Patzcuaro salamander)	Mexico
A. americanus	Amiiformes: amiid (bowfin); Esociformes: umbrid (central mudminnow); Siluriformes: ictalurid (yellow bullhead); Anura: ranid (river frog); Urodela: sirenid (southern dwarf siren)	North America

A. angelae	Characiformes: anostomid (three-spot leporinus, karp-jonn, lisa), curimatid (branquinha, boquiche, beiru, mocinha), cynodontid (biara), hemiodontid (halftooth), prochilodontid (flag-tailed prochilodus), triportheid (pechon)	South America
A. angusticeps	no host recorded	Africa
A. appendiculosus (syn. *A. biramosus*)	Acanthuriformes: sciaenid (freshwater drum); Amiiformes: amiid (bowfin); Clupeiformes: clupeid (American gizzard shad); Cypriniformes: catostomid (quillback, smallmouth buffalo, bigmouth buffalo, white sucker), cyprinid (Eurasian carp), leuciscid (emerald shiner); Esociformes: esocid (northern pike); Hiodontiformes: hiodontid (goldeneye); Lepisosteiformes: lepisosteid (longnose gar); Perciformes: centrarchid (largemouth bass, smallmouth bass, white crappie), moronid (white bass), percid (yellow perch, walleye, sauger); Salmoniformes: salmonid (cisco); Siluriformes: ictalurid (brown bullhead, black bullhead, flat bullhead, channel catfish, brindled madtom)	North America
A. araucanus	Atheriniformes: atherinopsid (neotropical silverside)	South America
A. arcassonensis (syn. *A. otolithi, zei*)	Eupercaria: sciaenid (longneck croaker); Zeiformes: zeid (John dory)	Africa
A. australiensis	Perciformes: sparid (bream)	Australia
A. belones	Beloniformes: belonid (flat needlefish); Istiophoriformes: sphyraenid (great barracuda)	Africa
A. bengalensis	Cypriniformes: cyprinid (carp)	India
A. bicolor	Beloniformes: belonid (redfin needlefish); Carangiformes: carangid (Florida pompano); Perciformes: moronid (striped bass), sparid (western Atlantic seabream)	Americas
A. borealis	Pleuronectiformes: pleuronectid (flathead sole, rock sole), Ovalentaria: embiotocid (shiner perch)	Americas
A. brachypeltis	Characiformes: alestid (African tigerfish); Siluriformes: clariid (African sharptooth catfish)	Africa
A. caecus	Cephalopoda: ommastrephid (Japanese flying squid); Tetraodontiformes: tetraodontid (coastal puffer)	Japan
A. capensis	Anabantiformes: anabantid (Cape kurper)	Africa
A. carteri	Characiformes: erythrinid (wolf fish)	South America
A. catostomi	Cypriniformes: catostomid (white sucker, quillback, longnose sucker, lake chubsucker, northern hogsucker, shorthead redhorse), cyprinid (golden shiner, creek chub), leuciscid (finescale dace); Perciformes: centrarchid (pumpkinseed), percid (Iowa darter, johnny darter); Siluriformes: ictalurid (black bullhead)	North America
A. cauveriensis	free-swimming	India
A. celioi	Siluriformes: loricariid (cascudo preto velho)	South America
A. cheni	Cypriniformes: cyprinid (grass carp)	China
A. chesapeakensis	Pleuronectiformes: paralichthyid (summer flounder)	North America
A. chicomendesi	Characiformes: prochilodontid (black prochilodus)	South America
A. chilensis	Atheriniformes: atherinopsid (neotropical silverside)	South America
A. chinensis	Ababantiformes: channid (northern snakehead); Cypriniformes: cyprinid (black carp); Siluriformes: bagrid (catfish), ictalurid (yellow-barbeled catfish)	China
A. chiropteroideus	Siluriformes: pimelodid (barred sorubim, spotted soru bim)	South America
A. chromidis	Ovalenteria: pomacentrid (chromis?)(maybe a cichlid)	North America
A. confusus sp. inq.	(probably a male of *Argulus ambloplites*)	Africa
A. coregoni (syn. *A. phoxini*)	Cichliformes: cichlid (red tilapia); Cypriniformes: acheilognathid (tanago), cyprinid (black carp); Osmeriformes: plecoglossid (ayu); Salmoniformes: salmonid (rainbow trout, brook trout, cherry trout, white-spotted char)	Asia
A. cubensis	Cichliformes: cichlid (Cuban cichlid)	Americas
A. cunningtoni	Characiformes: distichodontid (Nile distichodus); Cichliformes: cichlid (yellow-belly bream); Perciformes: latid (Nile perch); Siluriformes: bagrid (bayad), clariid (African sharptooth catfish), claroteid (giraffe catfish), mochokid (wahrindi)	Africa
A. dactylopteri	Dactyloperiformes: dactylopterid (flying gurnard)	Africa
A. dageti	Siluriformes: clariid (mudfish, eel-like fattyfin catfish); Tetraodontiformes: tetraodontid (Fahaka puffer)	Africa
A. dartevellei	Perciformes: polynemid (giant African threadfin), serranid (grouper)	Africa
A. diversicolor	Perciformes: sparid (bream)	Australia
A. diversus	Siluriformes: ictalurid (yellow bullhead); Anura: ranid (river frog)	North America
A. ellipticaudatus	Cypriniformes: cyprinid (Eurasian carp)	China
A. elongatus	Characiformes: serrasalmid (red-bellied piranha, catirina, speckled piranha); Cichliformes: cichlid (tucanare peacock bass)	South America
A. ernsti	Cypriniformes: cyprinid (goldfish)	Eurasia

A. exiguus	Cichliformes: cichlid (kalterilevahautoja); Cyprinodontiformes: poecilid (Tanganyika killifish)	Africa
A. flavescens	Acanthuriformes: sciaenid (freshwater drum); Amiiformes: amiid (bowfin); Siluriformes: ictalurid (flathead catfish)	North America
A. floridensis	host unknown (erroneous record in mullet)	North America
A. fluviatilis	free-swimming	India
A. foliaceus (syn. *A. argulus, armiger, charon, delphinus, rothschildi, viridis*)	Anguilliformes: anguillid (European eel); Carangiformes: carangid (Atlantic horse mackerel); Cypriniformes: cyprinid (Eurasian carp, zope, common bleak, tench, silver carp, ide**,** common roach, goldfish, crucian carp, white bream, seven khramulya, longspine scraper, chub, rudd), leuciscid (Danube bleak); Esociformes: esocid (northern pike); Gasterosteiformes: gasterosteid (three-spined stickleback); Gobiiformes: odontobutid (Chinese sleeper); Mugiliformes: mugilid (Abu mullet); Perciformes: centrarchid (pumpkinseed), percid (redfin perch, zander); Salmoniformes: salmonid (rainbow trout, brown trout); Siluriformes: silurid (wels catfish); Synbranchiformes: mastacembelid (Euphrates spiny eel); Urodela: salamandrid (smooth newt)	cosmopolitan
A. fryeri	Cichliformes: cichlid (redbelly tilapia)	Africa
A. funduli (syn. *A. latus*)	Cyprinodontiformes: fundulid (mummichog, striped killifish)	North America
A. fuscus	Carangiformes: carangid (Florida pompano); Perciformes: haemulid (pigfish); Eupercaria: sciaenid (silver perch)	North America
A. giordanii	free-swimming	Europe
A. gracilis	Siluriformes: claroteid (giraffe catfish)	Africa
A. hylae nomen nudum	Anura: hylid (map tree frog)	South America
A. ichesi	Clupeiformes: clupeid (alewife)	South America
A. incisus	Siluriformes: claroteid (giraffe catfish)	Africa
A. indicus	Anabantiformes: channid (giant snakehead, spotted snakehead), osphronemid (snakeskin gourami, Siamese fighting fish); Cypriniformes: cyprinid (Eurasian carp)	Asia
A. ingens	Lepisosteiformes: lepisosteid (Cuban gar)	Americas
A. intectus	Perciformes: sparid (scup)	North America
A. izintwala	Clupeiformes: clupeid (Kelee shad)	Africa
A. japonicus (syn. *A. matritensis, pelucidus*) (Japanese fish louse)	Cichliformes: cichlid (Mozambique tilapia, banded tilapia); Clupeiformes: clupeid (American gizzard shad); Cypriniformes: cyprinid (goldfish, crucian carp, Eurasian carp, common carp, koi carp, Korean carp, grass carp, mrigal carp, Orange River mudfish, Indian carp, Hoven's carp, largescale yellowfish, moggel, smallmouth yellowfish, largemouth yellowfish, papermouth, rohu, fathead minnow, rosy bitterling); Perciformes: percid (yellow perch); Salmoniformes: salmonid (rainbow trout); Siluriformes: clariid (African sharptooth catfish); Siluriformes: ictalurid (channel catfish)	Africa
A. jollymani	Cichliformes: cichlid (fenestratus, haplo)	Africa
A. juparanensis	Characiformes: characid (twospot astyanax); serrasalmid (red-bellied piranha, spotted piranha, speckled piranha); Eupercaria: sciaenid (La Plata croaker, pescada); Siluriformes: pimelodid (barred catfish): Myliobatiformes: potamotrygonid (Thorny river stingray, Ocellate river stingray, Raspy river stingray, smooth back river stingray)	South America
A. kosus (syn. *A. smalei*)	Cichliformes: cichlid (Mozambique tilapia); Elopiformes: elopid (tenpounder); Mugiliformes: mugilid (flathead grey mullet, St Lucia mullet); Perciformes: haemulid (smallspotted grunter, cock grunter), sciaenid (tigertooth croaker), sparid (Cape stumpnose, salema porgy); Tetraodontiformes: monacanthid (unicorn leatherjacket)	Africa
A. kunmingensis	free-swimming	China
A. kusafugu	Tetraodontiformes: tetraodontid (grass puffer)	Japan
A. laticauda	Anguilliformes: anguillid (common eel); Batrachoidiformes: batrachoidid (oyster toadfish); Blenniformes: blennid (blenny); Gadiformes: gadid (Atlantic tomcod); Perciformes: serranid (Atlantic goliath grouper); Pleuronectiformes: paralichthyid (southern flounder, summer flounder), pleuronectid (winter flounder); Scorpaeniformes: cottid (sculpin); Siluriformes: ariid (hardhead catfish); Myliobatiformes: dasyatid (Atlantic stingray); Rajiformes: rajid (little skate)	Americas
A. lepidostei	Lepisosteiformes: lepisosteid (longnose gar, shortnose gar)	North America
A. longicaudatus	Cypriniformes: leuciscid (emerald shiner); Perciformes: centrarchid (bluegill, white crappie)	North America
A. lunatus	Cypriniformes: cyprinid (goldfish)	North America

A. macropterus	Mugiliformes: mugilid (mullet)	Australia
A. maculosus	Esociformes: esocid (muskellunge); Perciformes: centrarchid (rock bass); Siluriformes: ictalurid (brown bullhead, yellow bullhead)	North America
A. maharashtrians	free-swimming	India
A. major	Cypriniformes: cyprinid (Eurasian carp)	China
A. mangalorensis	free-swimming	India
A. matuii	Eupercaria: haemulid (three-lined grunt)	China
A. meehani	Lepisosteiformes: lepisosteid (gar)	North America
A. megalops	Batrachoidiformes: batrachoidid (oyster toadfish); Cyprinodontiformes: fundulid (killifish); Gadiformes: gadid (Atlantic tomcod), Lophiiformes: lophiid (European angler); Pleuronectiformes: paralichthyid (summer flounder, spotted sand flounder), pleuronectid (winter flounder, American smooth flounder, American plaice): Rajiformes: rajid (common skate); Scorpaeniformes: cottid (longhorn sculpin), triglid (northern sea robin)	Europe, Americas
A. melanostictus	plankton sample	Asia
A. melita	unidentified shark species	Africa
A. mexicanus	Cichliformes: cichlid (Mayan cichlid)	Americas
A. mississippiensis	Lepisosteiformes*:* lepisosteid (shortnose gar)	North America
A. mongolianus	not known	Manchuria
A. monodi	Characiformes: alestid (African tigerfish); Cichliformes: cichlid (redbelly tilapia)	Africa
A. moratoi	Osteoglossiformes: osteoglossid (pirarucu)	South America
A. mugili	Mugiliformes: mugilid (mullet)	?
A. multicolor	Characiformes: anostomid (black-banded leporinus, threespot leporinus, piau coco), cynodontid (payara, biara), erythrinid (wolf fish), prochilodontid (black prochilodus), serrasalmid (red-bellied piranha, spotted piranha, speckled piranha, tambaqui), triportheid (asandiki); Cichliformes: cichlid (Nile tilapia, oscar, demon eartheater, speckled peacock bass, butterfly peacock bass, Rio Jari peacock bass); Eupercaria: sciaenid (corvina); Siluriformes: auchenipterid (manduba), pimelodid (redtail catfish, spotted tiger shovelnose catfish, tiger sorubim)	South America
A. multipocula	Mugiliformes: mugilid (South African mullet)	Africa
A. nativus	Perciformes: serranid (giant grouper)	Sri Lanka
A. nattereri (syn. *A. silvestrii*)	Characiformes: characid (golden dorado), serrasalmid (big-belly spine); Siluriformes: pimelodid (spotted sorubim, tiger sorubim, sailfin pim, redtail catfish, barred catfish, moncholo)	South America
A. nobilis	Lepisosteiformes: lepisosteid (Cuban gar)	Americas
A. onodai	Tetraodontiformes: tetraodontid (Hong Kong pufferfish)	Japan
A. papuensis	Gobiiformes: eleotrid (snakehead gudgeon)	Papua New Guinea
A. paranensis	Characiformes: characid (golden dorado)	South America
A. patagonicus	Perciformes: percichthyid (Creole perch)	South America
A. personatus	Cichliformes: cichlid (raitapetoahven, pikkupetoahven)	Africa
A. peruvianus	Gadiformes: merlucciid (Peruvian hake)	South America
A. pestifer	Characiformes: characid (golden dorado), erythrinid (gold wolf fish); Siluriformes: pimelodid (barred catfish, spotted sorubim, tiger sorubim, zebra shovelnose)	South America
A. piperatus	free-living	North America
A. plecoglossi	Osmeriformes: plecoglossid (ayu)	Japan
A. pugettensis (syn. *A. niger*)	Ovalentaria: embiotocid (shiner perch, walleye surfperch, striped surfperch); Salmoniformes: salmonid (rainbow trout)	Pacific
A. puthenveliensis	Anabantiformes: osphronemid (spiketail paradisefish); Cypriniformes: cyprinid (Indian flying barb, greenstripe barb); Cyprinodontiformes: aplocheilid (green panchax)	India
A. quadristriatus	Carangiformes: latid (Waigieu seaperch), rachycentrid (cobia)	India
A. reticulatus	Characiformes: alestid (goliath tigerfish)	Africa
A. rhamdiae	Siluriformes: heptapterid (pale catfish)	Americas
A. rhipidiophorus	Characiformes: alestid (elongate tigerfish, African tigerfish, pebbly fish); Cichliformes: cichlid (blue-spotted tilapia, Nile tilapia, entonga); Cypriniformes: cypriniod (barbel, labeo); Perciformes: latid (Nile perch); Siluriformes: bagrid (bayad), clariid (African sharptooth catfish), mochokid (wahrindi)	Africa
A. rijckmansii	host not recorded	Africa
A. rothschildi	Cypriniformes: cyprinid (common bream)	Europe
A. rotundus	host unknown	
A. rubescens	Siluriformes: claroteid (kibonde)	Africa
A. rubropunctatus	Perciformes: latid (Tanganyika lates, forktail lates)	Africa

A. salminei (syn. *A. paulensis*)	Characiformes: characid (dorado)	South America
A. schoutedeni	Characiformes: citharinid (imbaza), distichodontid (sharktail distichodus)	Africa
A. scutiformis	Abantiformes: channid (striped snakehead, spotted snakehead); Cypriniformes: cyprinid (rohu); Tetraodontiformes: molid (ocean sunfish), tetraodontid (pufferfish)	Asia, India
A. siamensis	Anabantiformes: osphronemid (gourami); Cypriniformes: cyprinid (carp, mrigal carp); Perciformes: ambassid (Indian glassy fish)	India
A. sindhensis	Cypriniformes: cyprinid (rohu)	India
A. spinulosus	Characiformes: cynodontid (payara), erythrinid (wolf fish); Cichliformes: cichlid (Nile tilapia)	Americas
A. stizostethii (syn. *A. canadensis)*	Acipenseriformes: acipenserid (lake sturgeon); Clupeiformes: clupeid (American shad, American gizzard shad); Cypriniformes: catostomid (white sucker), leuciscid (spottail shiner); Esociformes: esocid (northern pike, muskellunge); Gasterosteiformes: gasterosteid (three-spined stickleback, ninespine stickleback, blackspotted stickleback); Perciformes: percid (yellow perch, walleye, sauger), moronid (white bass); Salmoniformes: salmonid (A*tlantic salmon,* cisco, lake whitefish, brook trout)	North America
A. striatus	Cichliformes: cichlid (Tanganyika tilapia); Siluriformes: clariid (African sharptooth catfish, dinopterus, African catfish), claroteid (giraffe catfish, kibonde)	Africa
A. taliensis	free-swimming	China
A. tientsinensis	Siluriformes: bagrid (yellowhead catfish)	China
A. trachynoti	Carangiformes: carangid (snubnose dart)	Africa
A. trilineatus	Cypriniformes: cyprinid (goldfish)	North America
A. tristramellae	Cichliformes: cichlid (shortjaw tristramella)	Middle-East
A. varians	Carangiformes: echeneid (live sharksucker); Lophiiformes: ogcocephalid (shortnose batfish); Perciformes: sparid (pinfish); Tetraodontiformes: diodontid (striped burrfish, baiacu)	Americas
A. ventanensis	Anura: hylid (Montevideo tree frog, tadpoles)	South America
A. versicolor	Esociformes: esocid (chain pickerel); Perciformes: centrarchid (rock bass), percid (yellow perch, walleye), percopsid (trout perch)	North America
A. vierai	Cyprinodontiformes: poecilid (ten-spotted livebearer)	South America
A. violaceus	Atheriniformes: atherinopsid (pejerrey); Characiformes: erythrinid (wolf fish); Siluriformes: heptaptetrid (South American catfish), loricariid (cascudo), pimelodid (mandi-branco)	South America
A. vittatus (syn. *A. giganteus, purpureus*)	Perciformes: sparid (bogue, common pandora, red porgy, gilt-head bream); Tetraodontiformes: tetraodontid (lunartail puffer, oblong blowfish)	Africa, India
A. wilsoni	Characiformes: alestid (goliath tigerfish)	Africa
A. ybatecobe	Characiformes: curimatid (mocinha)	South America
A. yucatanus	Cichliformes: cichlid (Mayan cichlid)	North America
A. yuii	Cypriniformes: cyprinid (Eurasian carp, black carp)	China
A. yunnanensis	free-swimming	China

Parasite morphology: *Argulus* spp. are commonly known as fish lice but they are brachiuran parasites that form 4 different types of developmental stages: namely, eggs; metanaupliar larvae; juveniles (5-11 instars); and adults (males and females). The eggs are brown ovoid-ellipsoid stages measuring 0.2-0.3 mm long (a few species produce larger eggs up to 0.7 mm long). They are bound by thick waxy shells and contain numerous yolk globules. They hatch to release the first larval stage commonly called a metanauplius (or postnauplius) which is discoidal in shape measuring 0.7-1.0 mm in diameter. Metanauplii possess up to 9 pairs of ventral appendages; namely (in order posteriad), antennules, setose antennae, mandibular palps, rudimentary maxillules and maxillae, and swimming legs (first pair well developed, next 3 pairs rudimentary). They attach to fish hosts using their anterior appendages and feed using mouthparts containing the mandibles. They then moult and transform into juvenile stages which subsequently undergo another 5-11 moults, depending on the species. Juveniles grow from 1-10 mm in length (some species up to 30 mm) and they exhibit various morphological changes: with strong claws replacing setae on the antennae, the loss of setose palps on the mandibles, the development of 4 pairs of thoracic swimming legs, the appearance of reproductive organs, and the most pronounced change occurs in the last juvenile stage when the maxillules transform from long claws into powerful circular sucker. These suckers are retained when the juveniles moult to form adult males and females. Adults range in size from 5-20 mm in length, although some species grow up to 34 mm long. They are covered by a semitransparent carapace, usually milky white with pale yellow, green or brown cryptic colourations. The body is disc-shaped being broadly ovoid, dorso-ventrally flattened and dorsally convex. The body plan comprises a large discoid head and a slender tapering trunk (thorax plus abdomen). The head has well-developed carapace lobes formed as posterior extensions of the dorsal head shield, and they typically cover the thorax, and sometimes the abdomen. The carapace also has 2 special ventrolateral areas initially described as respiratory alae (but now thought to be involved in

osmoregulation). Ventrally, the head bears 5 pairs of appendages (antennules, antennae, mandibles, maxillules and maxillae), and a pair of prominent compound eyes. The thorax bears 4 pairs of swimming legs and the abdomen has a pair of caudal rami. [This body plan differs from that of copepods as argasilids have a carapace, compound eyes, conspicuous ventral sucking discs, no thoracic segments are completely fused with the head, and the abdomen is unsegmented behind the genital apertures.] In brachiurans, the antennules are short, clawed and setate, while the antennae have characteristic hooks with 2 small distal segments. The tubular sucking mouthparts form a suctorial proboscis (mouth tube) with rasping dentate hooked mandibles at the tip. They also possess a preoral piercing stylet (sting) located just anterior to the mouth. The maxillules (some texts refer to them as first maxillae) are modified into large powerful muscular suckers (cup-shaped discs) used for attachment. Females generally have more support rods (with more sclerites) in their suckers than males. The maxillae are large, stout and dentate and are apparently used to both maintain position and to clean other appendages. The thorax has 4 segments, each with a lateral pair of biramous swimming legs. The first 2 pairs of legs bear recurved processes known as flabella (singular, flabellum) while the last 3 pairs of legs on males have sclerotized segments as sexual modifications that are absent on females. The short unsegmented abdomen contains most of the sexual reproductive organs. Males have a pair of elongate testes with vas deferens leading to a seminal vesicle and a tubular ejaculatory duct. Females have a pair of ovaries (lacking ovisacs) connected by oviducts to a large uterus with lateral spermathecae (for sperm storage), The uterus becomes so distended by developing eggs that they may be seen not only in the abdomen but also in the thorax and sometimes in the lobes of the carapace. Eggs are deposited by female in clutches on hard substrates in the water.

Site of infection: These fish lice are ectoparasitic crustaceans which attach to the skin of the body, gill chambers and mouths of fishes. All motile stages are parasitic and may move about on their hosts; if disturbed, they may detach and swim freely in the water column. The genus *Argulus* has a worldwide distribution (except Antarctica) and most species infest freshwater fish (in running or static waters), although some are found on fishes from estuarine and coastal waters (but not open oceanic waters). They are particularly common on pond-raised freshwater fish and some ornamental species, and are occasionally found on tadpoles of frogs and toads.

Pathogenesis: The larval and adult stages of fish lice attach to the skin and gills of fishes using a variety of claws, hooks, spines and suckers (the latter only in the last stage larvae and adults). All species feed on mucus, epidermal tissues and extracellular material (including sloughed-off scales), and adults may also feed on internal fluids including plasma and blood. Adults also insert their preoral stylets (stings) into host tissues and inject substances (enzymes and anticoagulants) to better facilitate feeding. After engorging themselves, the parasites may wait 2-3 weeks before feeding again. All stages are able to move about on their hosts detaching then reattaching to new sites. Light infestations may not produce any clinical signs, but heavier infestations may cause skin lesions and loss of condition. Hosts often show localized inflammation at attachment and feeding sites due to the mechanical damage caused by holdfast structures as well as reactions to injected enzymes. Fish develop focal skin lesions with petechial (pinpoint or spot) haemorrhages, fin and scale loss, increased mucus production, anaemia with low erythrocyte and haemoglobin levels, decreased osmoregulatory function (unable to balance internal fluids and salt levels), reduced feeding and general loss of body condition. Infested fish may develop a variety of behavioural changes ranging from lethargy, avoiding swimming or erratic swimming, congregating at the water surface or near flowing water inlets, and flashing or rubbing against substrates to relieve irritation and remove parasites. Clinical outbreaks may cause serious problems for aquaculture, with high densities developing particularly in closed culture systems, aquaria, ornamental fishponds and even reservoirs. The open wounds left by parasites are also susceptible to secondary infection by fungi (e.g. *Saprolegnia*) and bacteria (e.g. *Pseudomonas, Aeromonas*). Recent studies indicate that argulids may also transmit the viral agent of spring viremia of carp as well as carp pox, and that they may act as intermediate hosts for various nematodes, including skrjabillanid worms infesting marine fishes, and dracunculid worms parasitizing cichlid and poecilid fishes.

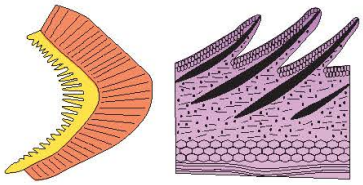
Developmental cycle and mode of transmission: Argulids undergo gradual (incomplete) metamorphosis whereby larval stages gradually transform into adult stages. Gravid females leave their fish hosts and swim to submerged objects with hard surfaces (rocks, sticks, plants) to lay rows of up to 200-400 eggs attached with adhesive secretions. Egg production generally only occurs when water temperatures are above 16°C. The eggs hatch asynchronously after 10-80 days, the duration depending on the species and water temperature (faster in warmer water). In some species, eggs laid in autumn have been found to survive over the winter period to hatch in spring. Hatching releases the first larval stages which are dispersal stages often called metanauplius (their swimming apparatus is too well developed for them to be considered a nauplius). These free-swimming larvae opportunistically find fish and attach with their hooked antennae within 2-4 days.
After 5-7 days, they moult to second stage larvae (called juveniles) which feed, grow and develop through a series of moults at regular intervals over 28-40 days. The number of juvenile moults varies according to the parasite species, ranging from 5-11 moults (representing 6-12 stages). The juveniles all have clawed maxillules for attachment, except for the last juvenile stages which develop prominent suckers which are retained over the next moult to adults. Juveniles, and sometimes adults, may overwinter on hosts surrounded by mucus. Adults that are disturbed or dislodged from hosts can survive free-swimming in the water column for several days (in some instances, up to 3 weeks). Mating occurs on fish hosts when males clasp females using their modified legs. The spermathecal spine of the female is inserted into the genital atrium of the male and pierces the wall of the ejaculatory duct. Sperm are then pumped from the ejaculatory duct into the female spermathecae for storage. The sperm are filiform and motile and have been found to have a fine structure similar to that of pentastomes. There have been several reports of females developing eggs

parthenogenetically in the absence of males for mating. Developing eggs are held in the uterus until ready for oviposition. Females detach and leave their fish hosts to lay eggs on hard submerged substrates. The whole life-cycle may be completed in 30-60 days, but longer in colder regions where eggs over-winter in water or juveniles over-winter on hosts. Most infestations peak in summer and autumn. Transmission between fish hosts is direct, via the contamination of water with eggs releasing free-swimming metanauplii which actively seek hosts. Juveniles and adults on hosts may also transfer to other hosts if they become dislodged or when females return from spawning.

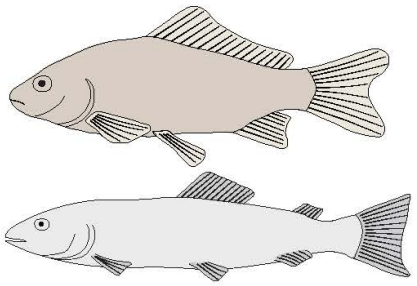
Differential diagnosis: Infestations may be suspected on clinical grounds when fish exhibit aberrant behaviours, skin lesions, and loss of condition. Diagnoses are conventionally made by the direct observation of fish lice attached to host skin or moving around in protected areas such as behind the fins or near the eyes or gills. Juvenile and adult stages are usually evident as small round green discs which are also able to swim free in the water, particularly if disturbed. These stages are best identified under magnification in wet mounts taken from fish, but samples should be collected quickly from captured fish as the parasites rapidly leave hosts removed from water. Free-swimming stages may also be captured using fine mesh plankton nets for examination. All stages are readily identified on the basis of their unique carapace and body plan, with species differentiated by variations in morphometrics and appendage anatomy. Molecular biological techniques have been used to characterize *Argulus* species and indicate phylogenetic relationships following polymerase chain reaction (PCR) amplification of random amplified polymorphic DNA (RAPD), nuclear (18S ribosomal RNA) or mitochondrial (cytochrome c oxidase subunit 1, NADH dehydrogenase subunits 1 and 4) gene sequences.

Treatment and control: While individual fish lice can be removed from fish using tweezers and the wounds cleansed with antiseptics (such as hydrogen peroxide), such intervention is impractical in systems larger than small aquaria. Removing lice has also been shown to be relatively ineffective due to rapid re-infestation of fish by free-swimming stages. Recourse is therefore made to chemical treatments which ideally target all life stages on hosts or in the water. In culture systems, fish are usually bathed in separate treatment tanks while their usual holding facilities are cleansed of eggs by disinfection or drying. Some facilities also introduce wooden slats or boards into tanks and ponds on which females may preferentially deposit their eggs, the hard substrates are then regularly removed and disinfected. Fish lice infestations in freshwater fish are conventionally treated by bathing fish in potassium permanganate or salt solutions (formalin baths are not very effective). Good success has also been reported using baths containing insecticidal organophosphates (trichlorfon) to kill parasites by neuro-interference, and some insect growth regulators which inhibit moulting (diflubenzuron, lufenuron). More recently, the use of macrocyclic lactones (emamectin) given as feed additives has shown promise for managing infestation in both freshwater and marine fishes. Several studies have also indicated that ponds treated with tobacco leaf dust (containing nicotine) seemed to reduce infestations in freshwater fishes. A range of management procedures may be adopted in aquaculture enterprises not only to help fish survive infestations but also to suppress parasite populations. Depending on facilities, such procedures usually involve imposing strict biosecurity (health surveillance, quarantine, cull sick fish), sensible stock management (ovoid overcrowding, esp. juvenile fish as they are more susceptible than adults) and maintaining good water quality (check source water, implement water filtration and/or disinfection practices, maintain good oxygen levels, and where possible, reduce water temperatures).

Argulus



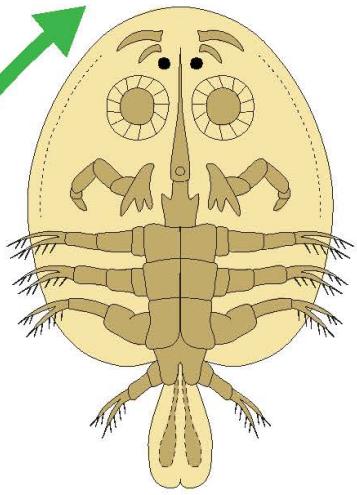
gills, skin
(lesions, haemorrhages, lethargy,
erratic aversion behaviours)



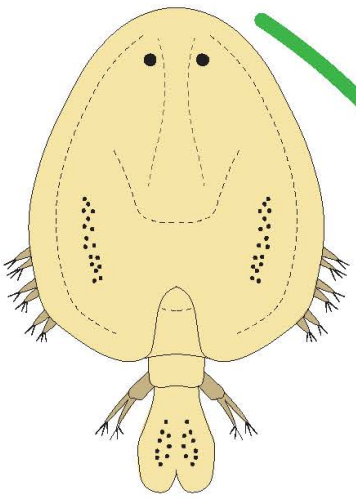
Definitive Hosts
(freshwater and
marine fish)

adult (~ 10 mm)

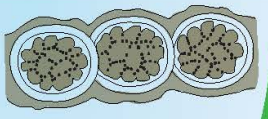
(ventral)



(dorsal)

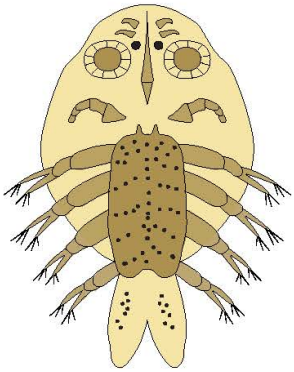


eggs
laid on
substrates

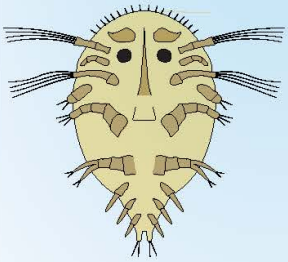


eggs
(~ 50 µm)

hatch



juvenile (ventral)
(~ 5 mm)
[5-11 moults]



metanauplius
(ventral)
(~ 0.8 mm)

juveniles and adults ectoparasitic
(attach using claws/suckers)
(feed on blood)

free-swimming
dispersal stage

	
Argulus adult	*Argulus* adult