Chapter 7
Heterokonts (Xanthophyceae and Chrysophyceae) in Rivers

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Abstract The heterokont classes Xanthophyceae and Chrysophyceae are introduced with its key characteristics and typical benthic river genera. Two relatively widespread genera are the xanthophyte siphonous *Vaucheria* and the filamentous *Tribonema*. The heterokont classs (Chrysophyceae) genus *Hydrurus* is also listed, which consists of a branched colony and can be widespread in cold mountain rivers with turbulent waters.

Keywords Algae • Benthic • Biodiversity • Chrysophyceae • Heterokontophyta • Xanthophyceae • Yellow-green algae

Introduction

The purpose of this chapter is to introduce the algal groups common and occasionally abundant in stream habitats but not diverse enough in terms of representatives to justify a specific chapter. One major group treated here is the class Xanthophyceae (yellow-green algae). The genus *Hydrurus* of the class Chrysophyceae (golden algae) can also be widespread and abundant in some drainage basins and is briefly listed as well.

The Xanthophyceae (=Tribophyceae), or yellow-green algae, do not have fucoxanthin masking the chlorophylls *a* and *c* and so they have a greenish color (Graham et al. 2009). The xanthophytes have the storage polymer chrysolaminarin but also produce cytoplasmic lipid droplets. The cell walls are composed primarily of cellulose, with silica sometimes present. Members of the class occur primarily in freshwater and they reproduce by various means but some produce thick-walled cysts to persist over the non-growing season.

Members of this xanthophytes are generally not as common as the other stream algal groups described in this book but some taxa can be periodically widespread

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and abundant. The coenocytic genus *Vaucheria*, for example, is distributed in rivers and streams from most biomes in North America (Sheath and Cole 1992) and southeastern Brazil (Necchi et al. 2000) and it is composed of many species. Another genus of this class (*Tribonema*) can also be found in streams, but it is not so species rich and widespread as *Vaucheria*.

The Chrysophyceae, or golden algae, have large amounts of the accessory pigment fucoxanthin in their chloroplasts, masking chlorophylls *a*, c_1, and c_2, a storage polymer chrysolaminarin in vacuoles, and a variety of cell coverings (Graham et al. 2009). The majority of these algae occur in freshwater habitats and they employ a silica-walled resting stage, the stomatocyst, to persist through the non-growing season. Benthic, lotic members of the golden algae are not very diverse and widespread as members of other algal groups but one genus (*Hydrurus*) can be quite widespread and it is particularly distributed in cold, mountain streams where the colonial thalli are firmly attached to hard rock or large stones in turbulent water (Wehr and Sheath 2015).

Phylogenetic Relationships of Heterokont Algae

Within the Phylum Heterokontophyta, two classes are treated here: Chrysophyceae and Xanthophyceae (=Tribophyceae). Both were shown to be monophyletic within the phylum by Riisberg et al. (2009). For the Xanthophyceae I followed the taxonomic scheme by Maistro et al. (2009), who recognized the two orders treated here (Tribonematales and Vaucheriales) as monophyletic, whereas for the Chrysophyceae, Kawai and Nakayama (2015) was adopted.

Sample Collection and Preservation

Informative sources describing in details procedures, equipment, and tools for collection and preservation of these algal groups are essentially the same as described for other groups, particularly green and red algae (Chaps. 3 and 4). Thus, no descriptions are presented here and readers should search for more detailed information in those chapters.

Taxonomic Key to the Genera of Xanthophyceae and Chrysophyceae in Rivers

1a	Thalli golden colored (Chrysophyceae)	*Hydrurus*
1b	Thalli yellow-green or green (Xanthophyceae)	2
2a	Thalli coenocytic, consisting of siphons lacking cross walls	*Vaucheria*
2b	Thalli filamentous, consisting of chain of cells	3
3a	Cell walls with one section, not forming H-shaped pieces	*Xanthonema*

3b	Cell walls with two sections, forming H-shaped pieces	4
4a	Filaments short, breaking into fragments, with short cells (length/diameter ratio ≤1.5)	*Bumilleria*
4b	Filaments long, not breaking into fragments, with elongate cells (length/diameter ratio ≥2)	*Tribonema*

Descriptions of Heterokontophyta genera in rivers

Phylum Heterokontophyta

Class Xanthophyceae (= Tribophyceae): Order Tribonematales

Bumilleria Borzi (Figs 7.1a–b)

Filaments unbranched, straight, often constricted at cross walls, short; filaments break apart into fragments in some species. Cells cylindrical to cubic, short (length/diameter ratio ≤1.5), thin-walled, with one to several parietal, disc-shaped chloroplasts; cell walls in two sections, with H-shaped intercalary segments of the cell wall every 2–4 cells, usually evident between cells but sometimes only at broken ends; each cell with one to several discoid parietal chloroplasts with pyrenoids visible only on staining; oil globules often present. Asexual reproduction by biflagellate zoospores released by cell wall disruption.

Remarks: *Bumilleria* is probably a cosmopolitan genus, with only five species known (Guiry and Guiry 2015), which are usually found associated with other filamentous algae in streams, rivers, and ponds, mostly reported in North America and Europe (Johnson 2002; Ott et al. 2015).

Tribonema Derbès et Solier (Figs 7.1c–d)

Filaments unbranched, straight, non-constricted, long. Cells cylindrical or less often barrel-shaped, elongate (length/diameter ratio ≥2.0), usually thin-walled, with one to many parietal, disc-shaped chloroplasts, lacking pyrenoids; cell walls in two sections, with H-shaped pieces usually evident at the end of broken ends. Asexual reproduction by zoospores, aplanospores, and cysts; sexual reproduction isogamous.

Remarks: *Tribonema* is a cosmopolitan and diverse genus with 28 species currently accepted (Guiry and Guiry 2015), which is relatively well represented in streams and rivers. It occurs as free-floating masses or entangled to other filamentous algae, bryophytes, and macrophytes or less frequently it is found attached, especially in young stages. The genus can be misidentified as *Microspora*, which also has H-shaped pieces, but the latter has chloroplasts with starch; a simple test to distinguish these two genera is to apply Lugol's solution, which colours the starch in *Microspora* dark purple.

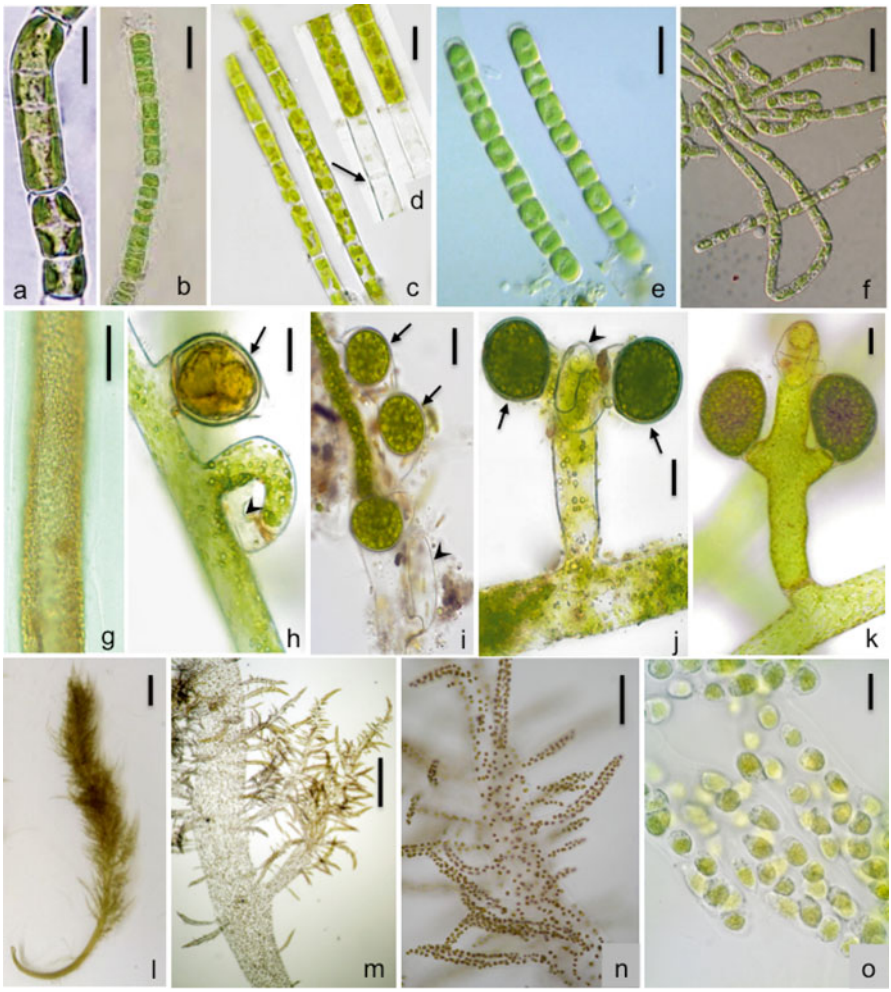

Fig. 7.1 (**a**–**b**) *Bumilleria*. (**c**–**d**) *Tribonema*: (**c**) filaments with vegetative cells; (**d**) empty cell with H-shaped cell wall (*arrow*). (**e**–**f**) *Xanthonema*. (**g**–**k**) *Vaucheria*: (**g**) detail of a siphon; (**h**–**k**) oogonia (*arrows*) and antheridia (*arrowheads*). (**l**–**o**) *Hydrurus*. Scale bars: fig. **l** = 5 mm; fig. **m** = 500 μm; fig. **n** = 250 μm; fig. **k** = 50 μm; figs **f**–**j**, o = 25 μm; figs **a**–**e** = 10 μm. Image authors: (**a**) Coimbra Collection of Algae (ACOI); (**b**) Photobucket; (**c**–**d**, **h**–**k**, **o**) C. Carter; (**e**) Y. Tsukii; (**f**) Culture Collection of Autotrophic Organisms (CCALA; (**l**–**n**) I. Bárbara

Xanthonema P.C. Silva (= *Heterothrix* Pascher) (Figs 7.1e–f)

Filaments unbranched, straight, slightly curved or undulated, often constricted at cross walls, short; filaments fragile and breaking apart into fragments or single cells in some species. Cells cylindrical, with one or two parietal, disc-shaped chloroplasts without pyrenoids. Asexual reproduction by zoospores and aplanospores. Akinetes also reported.

Remarks: *Xanthonema* is a cosmopolitan genus, with 14 species presently recognized (Guiry and Guiry 2015), which occurs in a variety of aquatic habitats and also as subaerial; few species are found in stream habitats, mostly in distrophic or oligotrophic water bodies.

Class Xanthophyceae (= Tribophyceae): Order Vaucheriales

Vaucheria De Candolle (Figs 7.1g–k)

Thalli coenocytic, multinucleate, cylindrical, branched, consisting of interwoven, grass- to dark-green, sparingly branched siphons, forming macroscopic felt-like or cushion-like patches; siphons attached by colorless rhizoids; chloroplasts numerous, parietal, disc-shaped to ellipsoidal; with or without pyrenoids; usual storage products oil or fat. Asexual reproduction by zoospores, aplanospores or akinetes. Sexual reproduction oogamous, female gametangia (oogonia) bearing single large eggs and male gametangia (antheridia) producing several heterokont sperms. Gametangia isolated by septa, arranged in either regular bisexual groups or loose arrangements of one or more oogonia and/or antheridia on monoecious or dioecious plants. Antheridia usually tubular, curved or straight, sessile or stalked. Oogonia spherical, ovoid or kidney-shaped, sessile or stalked; mature oogonia have distinctive beak with a pore; fertilization usually through pore in oogonial wall. Sexual reproductive structures is required to identify species of this genus.

Remarks: *Vaucheria* is a cosmopolitan and the most species-rich genus among the Xanthophyceae with 79 species currently accepted (Guiry and Guiry 2015). The genus is very well represented in stream habitats. Some species occurs in marine coastal habitats, particularly in salt marshes. The most important taxonomic characters to distinguish species in the genus are the size of siphons, as well as arrangement, shape, and size of gametangia (Johnson 2002; Ott et al. 2015).

Class Xanthophyceae: Other Potential River Inhabitants

A number of microscopic forms could be overlooked in environmental samples due to their small size and presence in low quantities. Thus, more xanthophytes could be potentially found in streams and general identification keys for Xanthophyceae should be applied (e.g., Ott et al. 2015). The branched filamentous genus *Heterococcus* can be found epillithic in streams (Rybalka et al. 2013) or as a lichen photobiont of the aquatic members of the fungal family Verrucariaceae (Thüs et al. 2011).

Class Chrysophyceae: Order Hydrurales

Hydrurus C. Agardh (Figs 7.1l–o)

Thalli macroscopic, consisting of branched mucilaginous colonies up to 30 cm in length. Cells distributed in the colonial matrix, oval with a two-lobed chloroplast containing a pyrenoid.

Zoospores tetrahedral, with one long and one short flagellum. Stomatocysts lenticular, with an equatorial wing.

Remarks: *Hydrurus* is common in cold, clear, fast-flowing mountain streams attached to firm substrata (Guiry and Guiry 2015). It has a peculiar and unpleasant smell described as foetid. During warm weather, the macroscopic form degrades and cysts are formed.

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