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Freshwater Algae in Northwest Washington, Volume II, Chlorophyta and Rhodophyta

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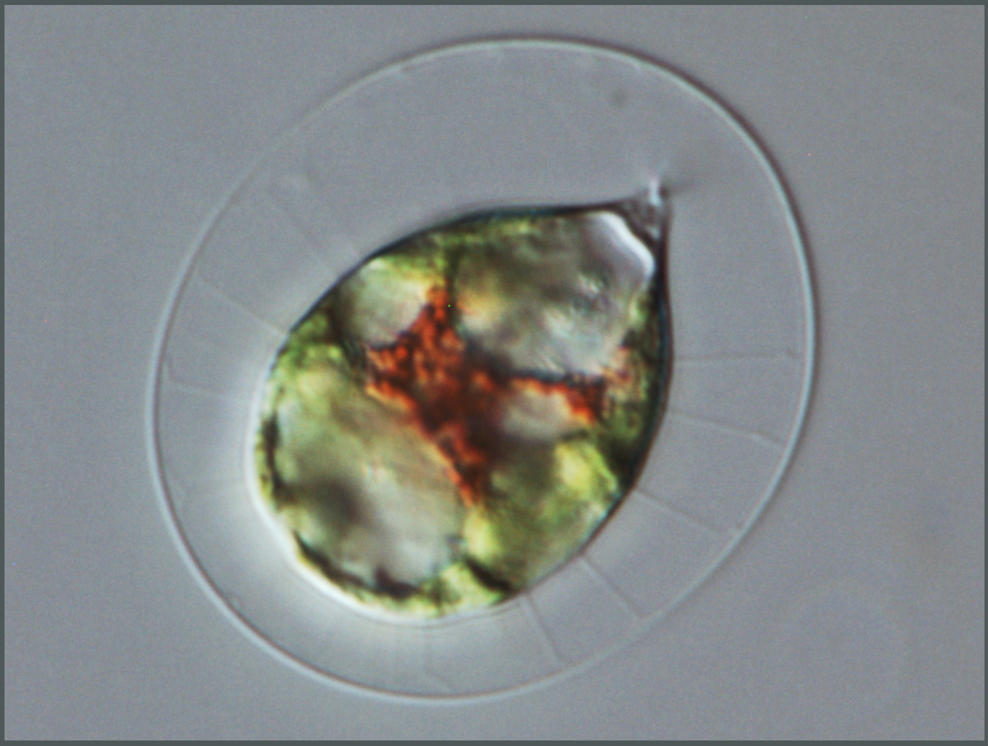
Volume II. Chlorophyta and Rhodophyta

Freshwater Algae in Northwest Washington



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Acknowledgments

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Special thanks go to my daughters Elizabeth, who patiently helped me write a computer program that made the biovolume calculations easier and more accurate, and Guinevere, who shares my love of pond scum. Finally, I want to thank my husband Geoffrey, who has written numerous custom software programs that made this book possible, and is always willing to scrape a rock or wade out to get one more sample that is just beyond my reach!

Chapter 1

Introduction

The idea for this guide began in 2006 when the Institute for Watershed Studies (`www.wwu.edu/iws`) expanded its Northwest Lakes monitoring project to collect water quality samples from more than 70 local lakes. Plankton samples collected from these lakes and other sites formed the basis for the Institute's online digital image library of freshwater algae and provided the material I needed to develop this guide.

The first version of this guide was finished in the spring of 2009 and used as a class reference for ESCI 428, *Freshwater Algal Bioindicators*. After much additional sampling and taxonomic effort, the guide expanded to the point where it was not feasible to print as a single volume. As a result, the current version has been separated into multiple volumes as described in Table 1.1 (page 6). Although the emphasize is on freshwater lakes, samples collected in streams, seeps, waterfalls, and other lotic systems are included, with comments on whether the taxa[1] are likely to be found in plankton samples.

All identifications represent my best effort to provide accurate classifications using major keys (Dillard,1989a, 1989b, 2008; John, et al., 2011; Prescott, 1962; Wehr, et al., 2015); and other taxonomic sources listed in Section 7 (page 787). Uncertain identifications were flagged using a "?" following the species name.[2] Unknown taxa that could be separated using morphological features were given a

[1]The word "taxa" (singular "taxon") is used to distinguish unique groups of organisms.

[2]Taxonomists often use "cf" (Latin: *conferre* or *conformis*) or "aff" (Latin: *affinis*) to indicate taxonomic uncertainty, but these terms have distinctions that are beyond the scope of this guide.

unique code (e.g., *Carteria* sp.1). The terms “sp” and “spp,” were used to indicate when one, or more one species were present, respectively.

Algal nomenclature has changed rapidly over the past few decades, largely due to the use of genetic analysis to separate algal species (see Brodie & Lewis, 2007, for a good discussion of recent changes in algal systematics). It has become increasingly difficult to keep up with changes in algal scientific names. My general approach was to follow the nomenclature in AlgaeBase (`www.algaebase.org`; Guiry & Guiry, 2016). But some genetic revisions separated algal that are so similar in appearance that it is difficult for students who are just beginning their study of algal taxonomy to separate the genera based on conventional light microscopy. If the revision applied to a small number of species, the revised species were kept in the same section with other morphologically similar species, and the revised name was included in the taxa list. For example, For example, *Pediastrum boryanum* (Turpin) Meneghini is currently named *Pseudopediastrum boryanum* (Turpin) E. Hegewald, but this species was included with other species of *Pediastrum* in Section 3.28 (page 424). More extensive revisions were addressed by including several genus names in the section heading. For example, *Scenedesmus* has been split into four morphologically similar genera (*Acutodesmus*, *Desmodesmus*, *Scenedesmus*, and *Tetradesmus*). All four of these genera were combined into a single section in this guide (Section 3.2, page 174). In all cases, remember that scientific names are a moving target, so check an authoritative source like AlgaeBase if you need to cite the correct scientific name.

Unless otherwise noted, all images in this manual were photographed by Dr. Robin Matthews using a Nikon Eclipse 80i with phase contrast and Nomarski (DIC) objectives equipped with either a QImaging or Nikon DS-Fi2 digital camera. The images may be used for noncommercial educational purposes under the Creative Commons license (`www.creativecommons.org`), with appropriate credit given to the author and Western Washington University. Comments and suggestions may be directed to R. Matthews, Western Washington University, 516 High Street, Bellingham, WA, 98225.

1.1 Collecting and Identifying Algae Samples

Guidelines for collecting algae: Collect your sample using a plankton net, by scraping visible algae from rocks or wet surfaces, or by collecting a small sample of shoreline vegetation. Put the sample into a clean, wide-mouth jar or bottle along with a small amount of clear water from the site. Leave 1–2 inches of air space and put it in a cool location away from direct sunlight. If the sample must be held for more than one day, you can preserve the algae using Lugol's iodine solution, but this may make the algae more difficult to identify.

- Algae that sit in a sealed jar may form oxygen bubbles in the chloroplast, especially if the jar sits in direct sunlight. This damages the chloroplast, and makes the specimen hard to identify.
- If the sample is sealed too long or gets too hot (sits in a hot car or in direct sunlight), the algae die and start to decompose. Not only does this smells really bad, the algae are nearly impossible to identify. If you can't examine your sample within an hour, loosen or remove the lid to allow fresh air to reach the water surface.
- Similarly, algae that sit too long (i.e., more than 10–15 minutes) on a hot microscope slide will be hard to identify. The cells may start shedding flagella or excreting mucilage, and will eventually be deformed or crushed by the cover slip as the slide dries.

Guidelines for identifying algae: Start your identification by reviewing Table 1.1 (page 6) to make sure you are using the correct volume of this series. Algae described in this volume will usually stain dark brown or purple in Lugol's iodine solution, most live cells will be bright green, and motile cells will have two or four equal length flagella.

The preliminary key on page 9 separates algae based on motility and whether the cells are solitary or form colonies or filaments. The keys in this guide are not dichotomous.[3] Instead, you are offered several choices among matching numbers or letters. The preliminary key directs you to more advanced keys that will take you to genus.

[3]Dichotomous keys are based on paired choices.

Here are a few guidelines to remember when identifying algae:

- Algae are diverse! You will almost certainly encounter specimens that do not match the figures or are not described in the text. Try to find several examples of the cell, colony, or filament.

- Many types of algae form resting cells or other specialized cells that look different than the vegetative cells. Where possible, I have included figures showing specialized cells that help distinguish different taxa.

- Try to work with *healthy*, live specimens. Preserved samples are fine for someone familiar with algae, but they are difficult to work with if you are a beginner.

- If possible, take photographs of your specimens. If you do not have access to a good camera on your microscope, carefully drawn illustrations can be a good alternative.

- Keep clear records of your observations, photographs, and drawings. Include the sampling location, date, and magnification.

- Take advantage of online image libraries like AlgaeBase (`www.algaebase.org`), PhycoTech (`www.phycotech.com`), PhycoKey (`www.cfb.unh.edu/phycokey/phycokey.htm`), or the Protist Information Server (`http://protist.i.hosei.ac.jp`).

  Nearly all online images are copyright-protected, so don't download and use them without permission.

  ⇒**Warning: not all online images are correctly identified!**

1.2 Recognizing the Algal Divisions

This guide is designed to be used by novices who are beginning their exploration of algal taxonomy. The taxonomic identifications are based on simple morphological features rather than genetic relationships. Photographs, cell dimensions, and biovolume estimates[4] are included for local taxa. Keeping with the goal of introducing new students to algal taxonomy, I have avoided the use of specialized taxonomic terms (jargon) except when necessary for clarity. This guide emphasizes algae collected from lakes and ponds, so it contains fewer taxa than guides that cover all types of freshwater algae in broad geographic regions. If you are working outside this region, I recommend using a simple generic key like **Common Freshwater Algae of the United States** (Dillard, 2008) or **Freshwater Algae: Identification and Use as Bioindicators** (Bellinger and Sigee, 2015), or any of the advanced keys listed in Section 7 (page 787).

The first step in this book requires separating algae into major divisions. Even this broad separation can be difficult. Table 1.1 provides a summary of major distinguishing features for the divisions and indicates which volume describes each type of algae. If you are having difficulty separating by division, try using several keys or looking at photographs that show the different examples.

Motility as a key feature in Chlorophyta: Motile Chlorophyta will have two or four equal length flagella and (often) a red eyespot. The presence of these features usually indicates potential motility, even if the cells in your sample are stationary.

Although motility is a distinctive feature, the lack of motility is not as helpful. Many types of motile Chlorophyta respond to stress by shedding their flagella and becoming nonmotile. Just to keep things interesting, there are also a few common nonmotile Chlorophyta that have residual eyespots or nonfunctional structures that resemble flagella (pseudocilia).

Your sample may contain other types of motile algae that are not Chlorophyta. These algae will probably have either one flagellum or two *dissimilar* flagella, and may not form starch (see Table 1.1). A few of the taxa contain starch, but have other unique features that distinguish them from Chlorophyta.

[4]The term “biovolume” refers to the volume of a cell or colony. It is estimated by measuring the width and length (± depth) of a cell or colony, then using a volume equation for a similar geometric shape (e.g., sphere). Biovolume calculations are discussed in more detail in Chapter 6.

Table 1.1: Summary of the Major Algal Divisions

Volume I	**Cyanobacteria** (blue-green algae): cells lack organelles like chloroplasts; no flagella (may move by gliding); starch absent.
Volume II*	**Chlorophyta** (green algae): chloroplasts often bright green; motile cells have two or four flagella; starch present.† **Rhodophyta** (red algae): chloroplasts red or blue-green; nonmotile; starch present.†
Volume III**	**Charophyta - Desmids:** nonmotile; chloroplasts often bright green; most form mirror image semicells; starch present.†
Volume IV**	**Chrysophyceae** (golden algae) and **Xanthophyceae** (yellow-green algae): chloroplasts golden-brown or yellow-green; motile cells with two unequal flagella; starch absent. **Haptophyta:** solitary cells; chloroplasts golden-brown; all cells motile with what looks like three flagella (two flagella + one haptomere); starch absent.
Volume V**	**Cryptophyta:** solitary cells; chloroplasts greenish, golden-brown, or brown; all cells motile with two nearly equal flagella; oral groove; starch present.† **Dinophyta:** solitary cells; chloroplasts golden-brown or brown; usually motile with visible trailing flagellum; second flagellum encircles cell; cell wall often plate-like; starch present.† **Euglenophyta:** solitary cells; chloroplast usually bright green; single visible flagellum; starch absent.

*Volume II includes non-desmid **Charophyta**; **Volumes currently in preparation.
†Cells with starch will stain dark purple/brown in Lugol's iodine solution.

1.3 Introduction to Chlorophyta and Rhodophyta

Chlorophyta (green algae) are eukaryotes, which means they contain cell organelles like chloroplasts and a nucleus (Figures 1.1–1.3, pages 10–12). Chlorophyta cells contain chlorophyll (like all algae), the green pigment that is used to capture light energy for photosynthesis. Chlorophyta cells create starch inside the chloroplast (Lee, 2008), often using special organelles called pyrenoids (e.g., Figure 1.3). The starch causes the cell to stain dark purple or brown in Lugol's iodine solution. The cell walls typically contain cellulose, similar to terrestrial plants. In addition to chlorophyll, the cells may contain accessory pigments for capturing light energy at different wavelengths, but the accessory pigments usually don't obscure the characteristic green color of this division. There are notable exceptions, including *Chlamydomonas nivalis* (Section 2.3, page 35) and *Haematococcus pluvialis* (Section 2.8, page 104), which contain haematochrome and are bright red.

Unlike Cyanobacteria, Chlorophyta can't use dissolved nitrogen gas (N_2) as a nitrogen source.[5] Instead, Chlorophyta need dissolved inorganic nitrogen (DIN)[6] for growth. Many lakes in northwest Washington have low concentrations of dissolved inorganic nitrogen in the water column by late summer and are dominated by Cyanobacteria from late summer through early fall.

There are many different kinds of freshwater Chlorophyta, and nearly all freshwater sites will contain at least a few members of this division. The Chlorophyta are extraordinarily diverse in form and function. Some taxa have distinctive shapes, but many, including simple spherical or nearly spherical, nonmotile, single-cell taxa, can be surprisingly difficult to identify, even to genus. The Chlorophyta included in this volume are divided into sections based on whether the vegetative cells are motile and whether the cells are normally solitary or in colonies or filaments. It is important to note that even if the vegetative cells are nonmotile, many Chlorophyta reproductive cells are motile and resemble *Chlamydomonas* (Section 2.3, page 35). In addition, colonial taxa can, on occasion, be present as solitary cells; solitary taxa can occasionally clump together to form groups. The best approach is to observe the same species throughout its growing period, watching for changes in morphological features.

[5]See **Freshwater Algae in Northwest Washington, Volume I. Cyanobacteria**.

[6]DIN = ammonium + nitrite + nitrate

Rhodophyta (red algae) are also eukaryotes and therefore contain distinct cell organelles (Figure 1.4, page 13). Almost all taxa are found in marine or estuarine environments. Some of the marine species are commercially harvested as food or are used in food processing, notably as thickening or gelling agents. Although Rhodophyta are rare in freshwater plankton samples, there are a few taxa that are common in streams and along shorelines.

Rhodophyta contain chlorophyll (like all algae) and accessory pigments for capturing light energy at different wavelengths. In particular, Rhodophyta contain phycoerythrin (red pigment), phycocyanin (blue pigment), and allocyanin (blue pigment), which give the cells a distinctive red, blue-green or purple color. Rhodophyta store floridean starch, which is not quite the same as the "true" starch formed by Chlorophyta, but it will stain slightly in Lugols iodine solution. Rhodophyta lack flagella in both vegetative and reproductive life cycle stages. Rhodophyta cell walls contain cellulose similar to Chlorophyta, but may also contain calcium carbonate and commercially important compounds like agar and carrageenans.

Rhodophyta are considered to be one of the oldest forms of eukaryotic algae (Lee, 2008). The chloroplast in the Rhodophyta resembles a Cyanobacteria cell, and it is hypothesized that Rhodophyta originated from heterotrophic cells that acquired Cyanobacteria via endosymbiosis (Graham, et al., 2016).

Table 1.2: Preliminary Key to the Chlorophyta and Rhodophyta

A		Vegetative cells motile, with flagella usually visible; solitary or in colonies; ⇒note that motile cells often lose motility when stressed and may form nonmotile reproductive cells (Figure 1.1, page 10)	Motile Chlorophyta; Table 2.1 (page 16)
B		Vegetative cells nonmotile, lacking flagella; solitary or in colonies; ⇒note that nonmotile cells may form motile reproductive cells (Figure 1.2, page 11)	Solitary/Colonial Chlorophyta; Table 3.1 (page 161)
C		Cells joined end-to-end in filaments or in pseudofilaments (cells not actually joined end-to-end, but filamentous structure is obvious)	
	C.1	Filaments bright green, yellowish or orange, but not red, purple, or blue-green; cells stain dark purple/brown in Lugol's iodine solution (Figure 1.3, page 12)	Filamentous Chlorophyta; Table 4.1 (page 532)
	C.2	Filaments dark blue-green, olive green, purple, or reddish brown; cells stain ⇒faintly in Lugol's iodine solution (Figure 1.4, page 13)	Rhodophyta; Table 5.1 (page 755)

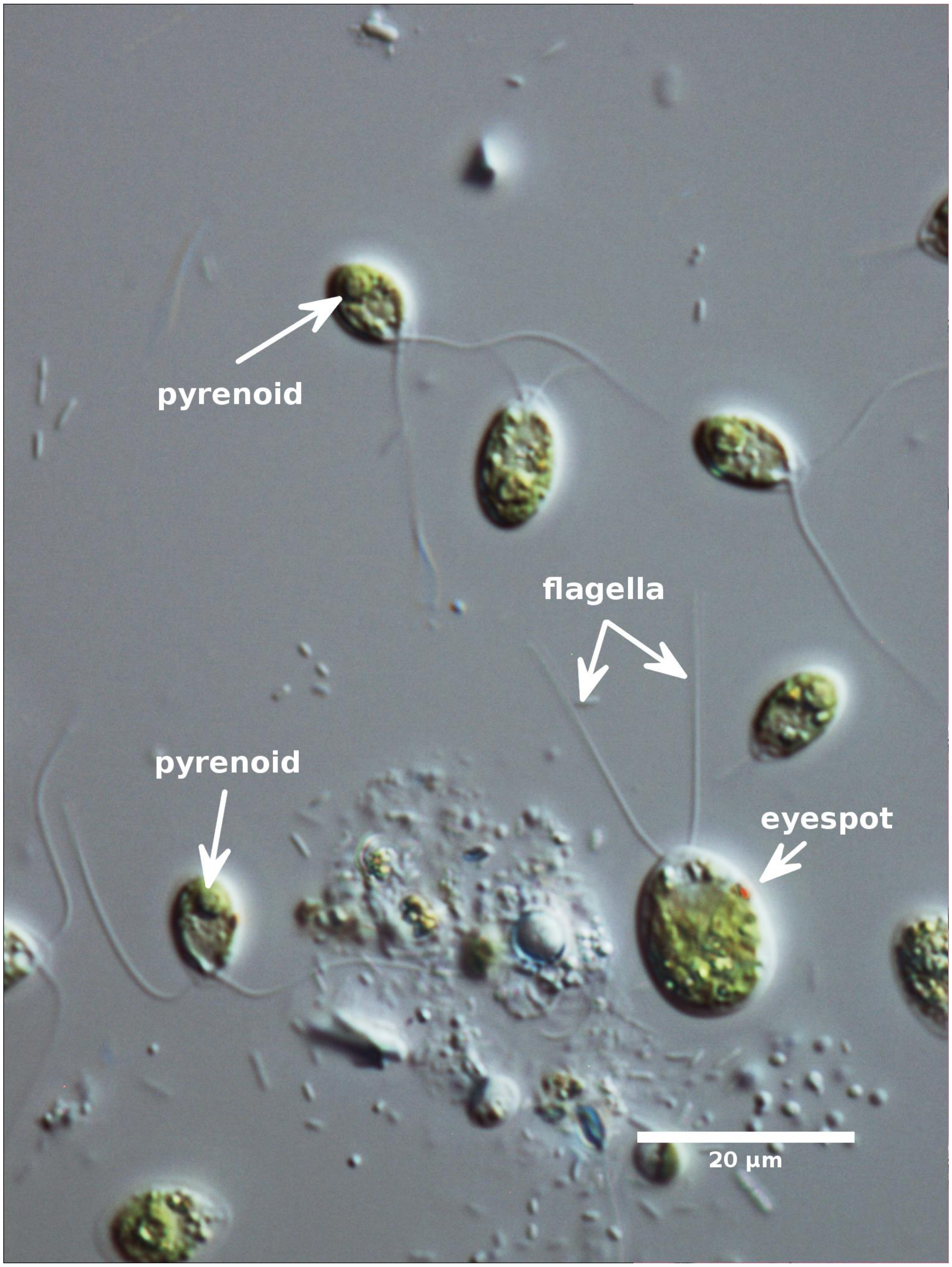


Figure 1.1: Typical motile Chlorophyta (*Chlamydomonas*).

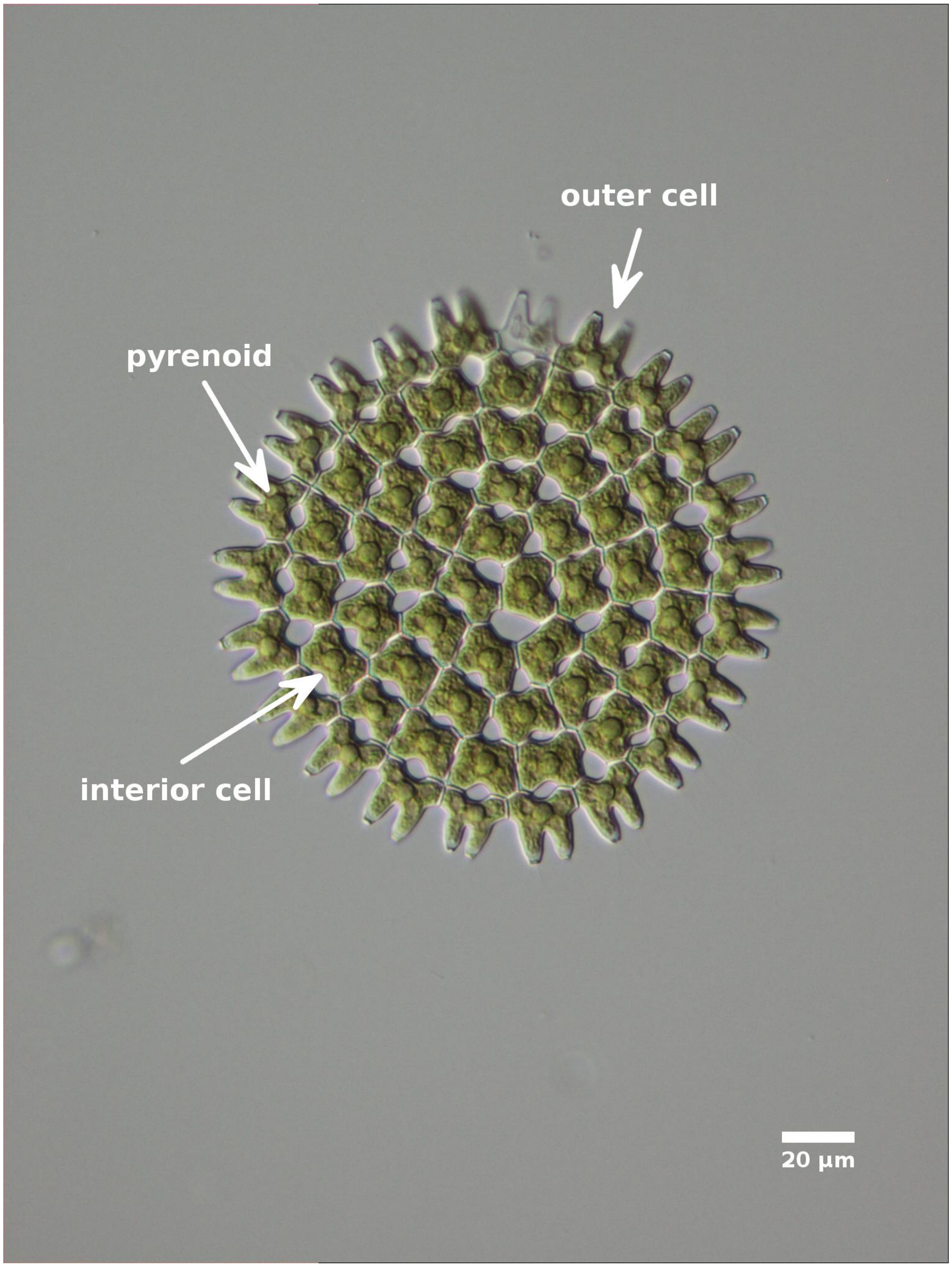


Figure 1.2: Typical nonmotile colonial Chlorophyta (*Pediastrum*).

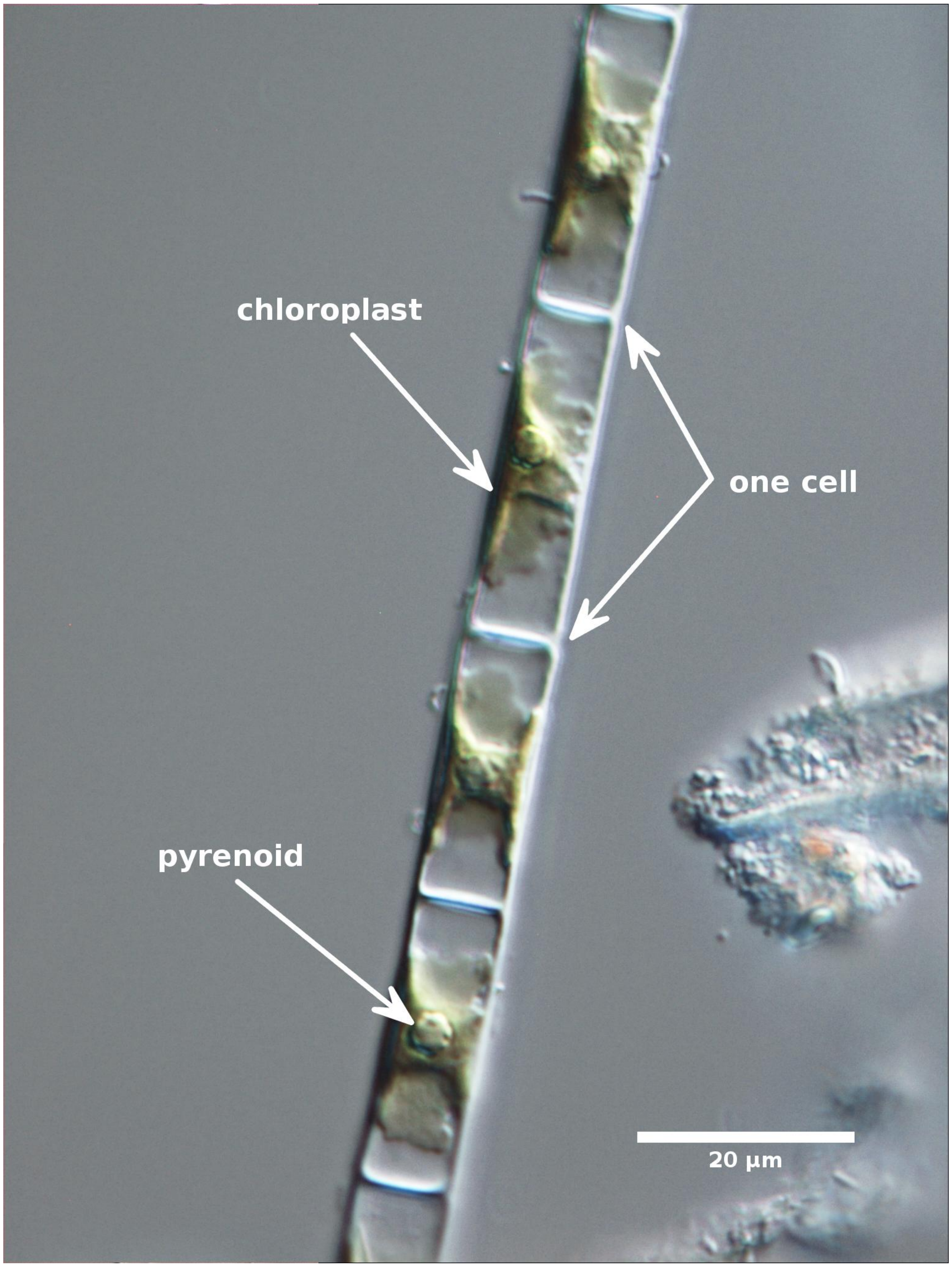


Figure 1.3: Typical filamentous Chlorophyta (*Ulothrix*).

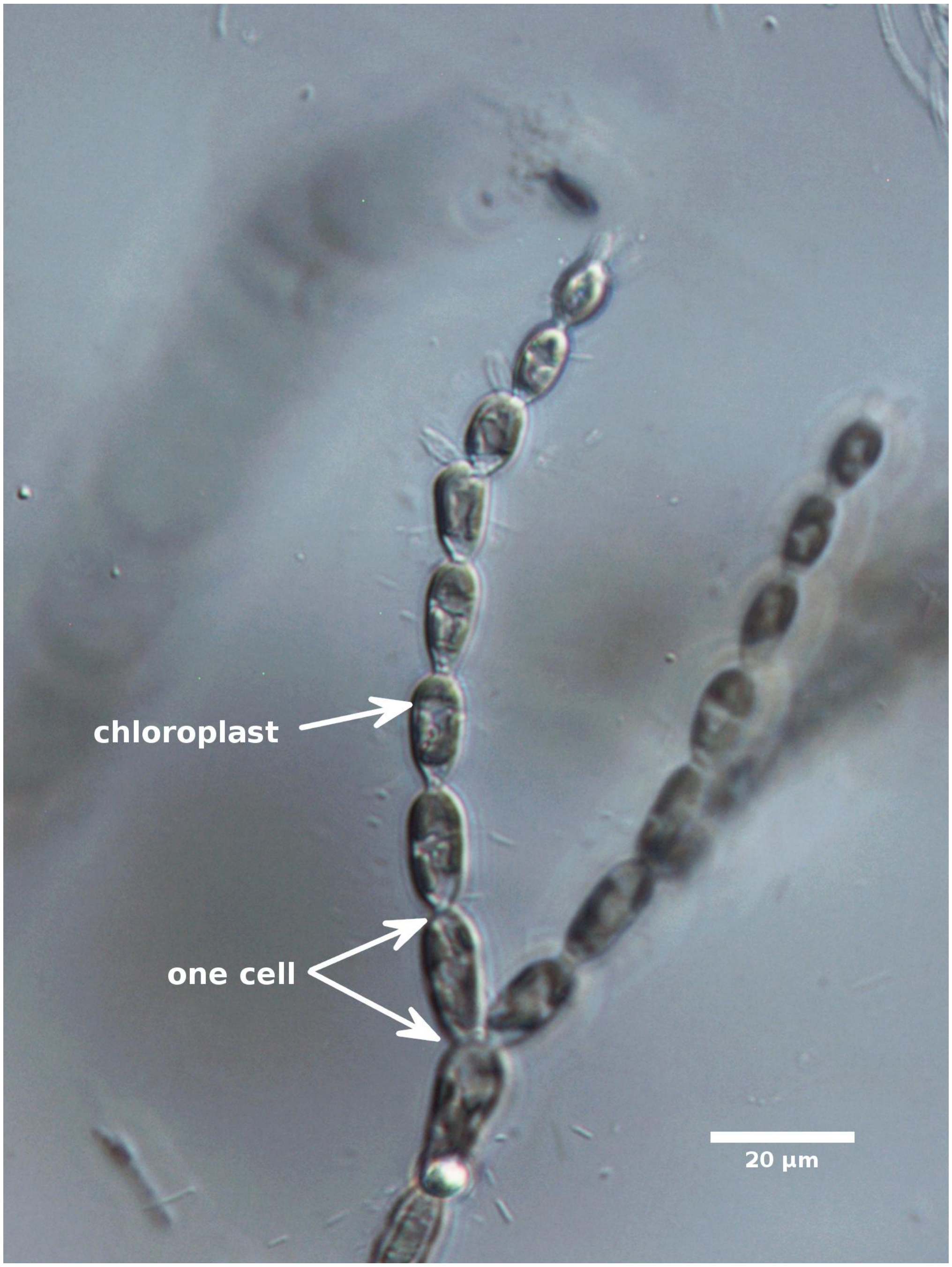


Figure 1.4: Typical filamentous Rhodophyta (*Batrachospermum*).

Chapter 2

Motile Chlorophyta

The key on page 16 will help identify motile Chlorophyta. For nonmotile, solitary and colonial Chlorophyta, go to page 161; for filamentous[7] Chlorophyta, go to page 532; and for filamentous Rhodophyta, go to page 755.

Motile Chlorophyta include solitary and colonial species. Many of the species have individual cells that resemble *Chlamydomonas* (Section 2.3, page 35), with a cup-shaped or H-shaped chloroplast, a single red or orange eyespot, and either two or four equal length flagella located near the top of the cell (anterior).

While motility is a useful taxonomic feature, it can be deceptive. The presence of motility is unambiguous if the cell or colony moves across the slide. But the absence of motility can indicate that the cell or colony is always nonmotile, or is temporarily inactive due to stress, chemical inactivation, or other factors. *Chlamydomonas*, for example, often enters a nonmotile *palmelloid* state in response to stress or other environmental conditions. In the palmelloid state, *Chlamydomonas* is virtually indistinguishable from *Chlorella* except for the presence of an eyespot. Some taxa like *Chlorogonium* (Section 2.4, page 65), are rarely seen moving, despite having visible flagella and an eyespot, and some taxa like *Asterococcus* (Section 3.6, page 245) have eyespots, but are nevertheless nonmotile. As a final challenge, many nonmotile Chlorophyta form motile reproductive cells that are nearly indistinguishable from motile taxa.

[7] The filamentous Chlorophyta key includes pseudofilaments (cells not actually joined end-to-end) as long as the filamentous structure is obvious.

Table 2.1: Key to the Motile Chlorophyta

A	Nonmotile cysts of snow algae; cysts bright red, orange, or yellow-green; motile cells rare	
	A.1 Cysts spherical, bright red; may have ornate corona (compare *Haematococcus*, page 104)	*Chlamydomonas nivalis* (page 35)
	A.2 Cysts oval, bright red, covered with blunt, conical spines	*Chlainomonas rubra* (page 30)
	A.3 Cysts elliptical or fusiform, yellow-green or orange; with longitudinal ridges or short spines	*Chloromonas* (page 74)
B	Solitary cells with 4 equal length flagella	
	B.1 Cells heart-shaped and slightly flattened	*Tetraselmis* (page 127)
	B.2 Cells spherical, oval, teardrop-shaped, or broadly elliptical; ±circular in cross-section	*Carteria* (page 19)
C	Solitary cells with 2 equal length flagella	Go to page 17
D	Motile colonies, usually with a fixed number of cells (coenobium)	Go to page 17
E	Cells not motile, but often have gelatinous, thread-like pseudocilia that resemble flagella; may have eyespot (±pseudocilia); cells solitary or in 4-cell subgroups (**Tetrasporales**)	*Asterococcus*, *Tetraspora*, and similar; see key on page 161

continued on next page

Table 2.1: Key to the Motile Chlorophyta, continued

C Solitary cells with 2 equal length flagella	
C.1 Protoplast enclosed in a rigid, oval lorica with net-like ornamentation and an equatorial groove (see **Volumes IV–V** for other taxa with loricas)	*Hemitoma* (page 111) (rare!)
C.2 Protoplast completely separated from expanded, mucilaginous cell wall	
C.2a Protoplast green, not bright red	*Vitreochlamys* (page 35)
C.2b Protoplast contains bright red pigment; nonmotile red cysts usually present	*Haematococcus* (page 104)
C.3 Protoplast not completely separated from cell wall; cell wall not expanded and mucilaginous	
C.3a Cells spherical, oval, teardrop-shaped, or broadly elliptical; cells usually actively motile	*Chlamydomonas* (page 35)
C.3b Cells fusiform or narrowly elliptical; flagella recurved; cells often stationary	*Chlorogonium* (page 65)
D Motile colonies, usually with a fixed number of cells (coenobium)	
D.1 Spherical or elliptical colonies containing >128 cells; vegetative cells spherical, oval, or stellate; daughter colonies or zygotes often contained inside mother colony	*Volvox* (page 134)

continued on next page

Table 2.1: Key to the Motile Chlorophyta, continued

D.2	Spherical or elliptical colonies containing 4–128 cells	
	D.2a Cells closely spaced; compressed, wedge-shaped; colonies with 4–32 cells	*Pandorina* (page 115)
	D.2b Cells separated, spherical or oval, not compressed; all cells similar in size; colonies with 8–64 cells	*Eudorina* (page 84)
	D.2c Large and small spherical cells partitioned into upper/lower hemispheres; Colonies with 64–128 cells	*Pleodorina* (page 121)
D.3	Flat colonies of 4 or 16 cells	*Gonium* and *Tetrabaena* (page 95)

2.1 *Carteria* Diesing

Local taxa
Carteria globosa Korshikov (=*Carteria pseudoglobosa* Ettl);
Carteria spp.

Abundance
Infrequently collected; occasionally forms blooms.

Local measurements		Width	Length	Biovolume†
Carteria globosa	min	11.9 μm	–	882 μm^3
cells (sphere)	med	15.9 μm	–	2,080 μm^3
	max	22.0 μm	–	5,580 μm^3
Carteria sp.1	min	5.5 μm	6.9 μm	111 μm^3
cells (spheroid)	med	6.1 μm	8.1 μm	157 μm^3
	max	6.8 μm	8.9 μm	216 μm^3
Carteria sp.2‡	min	–	–	–
cells (spheroid)	med	12.0 μm	18.3 μm	1,380 μm^3
	max	–	–	–
Carteria sp.3	min	5.3 μm	–	78 μm^3
cells (sphere)	med	6.4 μm	–	137 μm^3
	max	7.2 μm	–	195 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume estimate based on <5 cells.

Description
Carteria cells are solitary, spherical, oval, elliptical, or teardrop-shaped, with four equal length apical flagella (Figures 2.1–2.9). Each cell has a cup-shaped or H-shaped chloroplast with a single red eyespot and, often, a distinct pyrenoid. Species identification is based on the shape and location of the pyrenoid, shape of the chloroplast, and presence or absence of an apical knob called a papilla.

Like *Chlamydomonas* (Section 2.3, page 35), *Carteria* cells often shed their flagella and become stationary (palmelloid state). In addition, the cells may undergo asexual reproduction, forming groups of 4–8 *temporarily* nonmotile cells enclosed in a mucilaginous envelope. These reproductive cells resemble nonmotile colonial Chlorophyta, but close observation may reveal eyespots or flagella, and the cells may move inside the mucilage envelope.

Carteria globosa cells are spherical and lack an apical papilla (Figures 2.2–2.4). The chloroplast is cup-shaped, with one large basal pyrenoid; the eyespot is small and located in the anterior portion of the cell.[8] This species seems to be the most common type of *Carteria* found in local lakes.

Carteria sp.1 has tiny, tear-drop shaped cells and an apical papilla (Figures 2.5–2.6). This species has only been collected from Lake Geneva, a small, eutrophic soft-water lake in the Stimpson Family Nature Reserve (adjacent to Lake Whatcom).

Carteria sp.2 was collected in Lake Whatcom, and is characterized by large, elliptical cells with a distinct apical papilla and central pyrenoid (Figure 2.7–2.8). Despite the close proximity between the Stimpson Reserve and Lake Whatcom, these two species of *Carteria* are distinctly different in both shape and size.

Carteria sp.3 resembles *Carteria globosa*, with spherical cells and a cup-shaped chloroplast (Figure 2.9), but the cells are much smaller and the pyrenoid is centrally located, not basal. This species is common in stagnant water, plant saucers, ditches, etc., and may occasionally forms blooms with *Chlamydomonas* (Section 2.3, page 35).

[8] Dillard (1989a) describes the eyespot as "near-median."

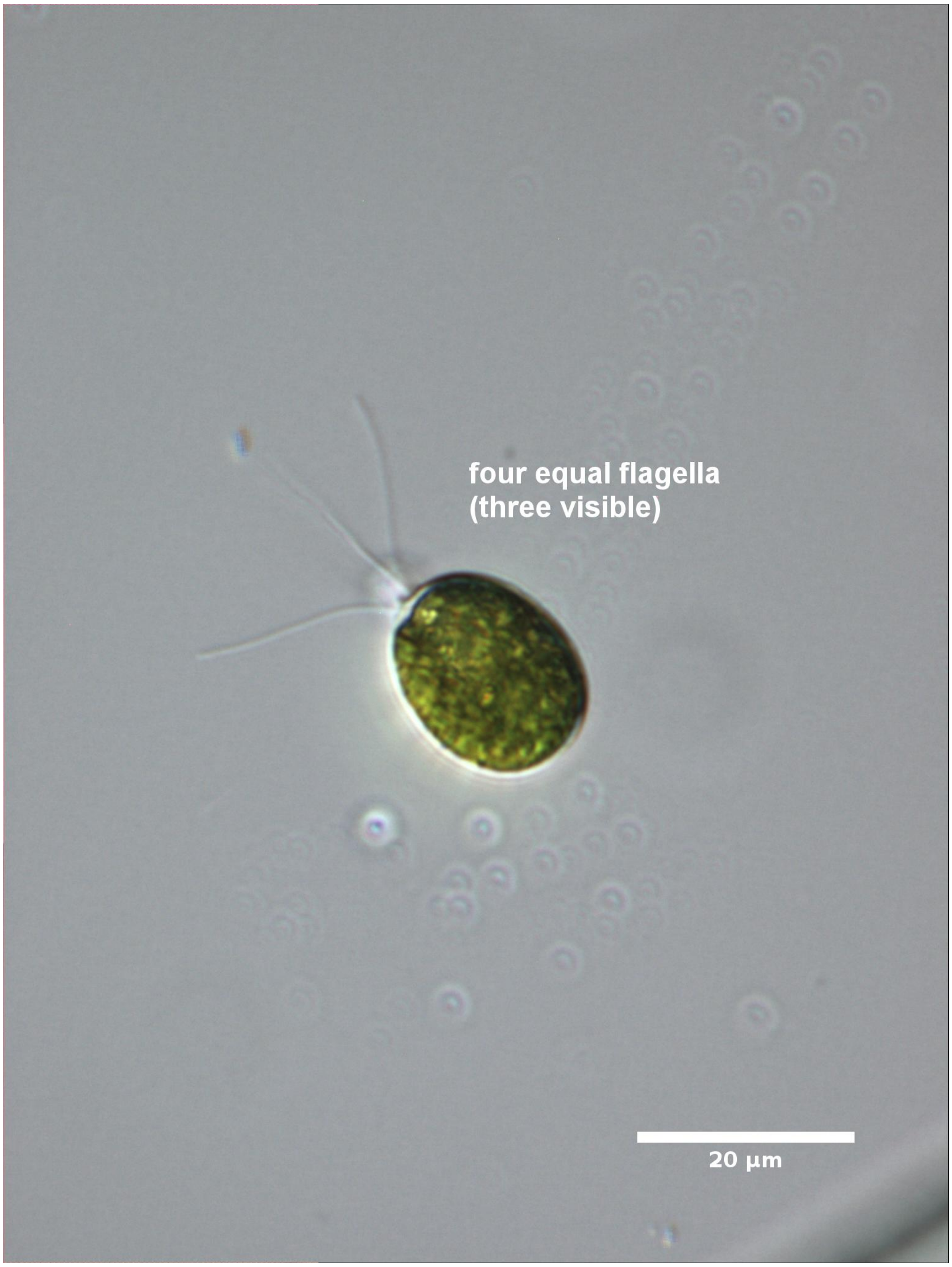


Figure 2.1: *Carteria* (600x DIC), Wards Biological Supply Co., May 29, 2009.

Figure 2.2: *Carteria globosa* (400x DIC), Lake Erie, IWS water quality sampling site, Skagit County, July 7, 2010.

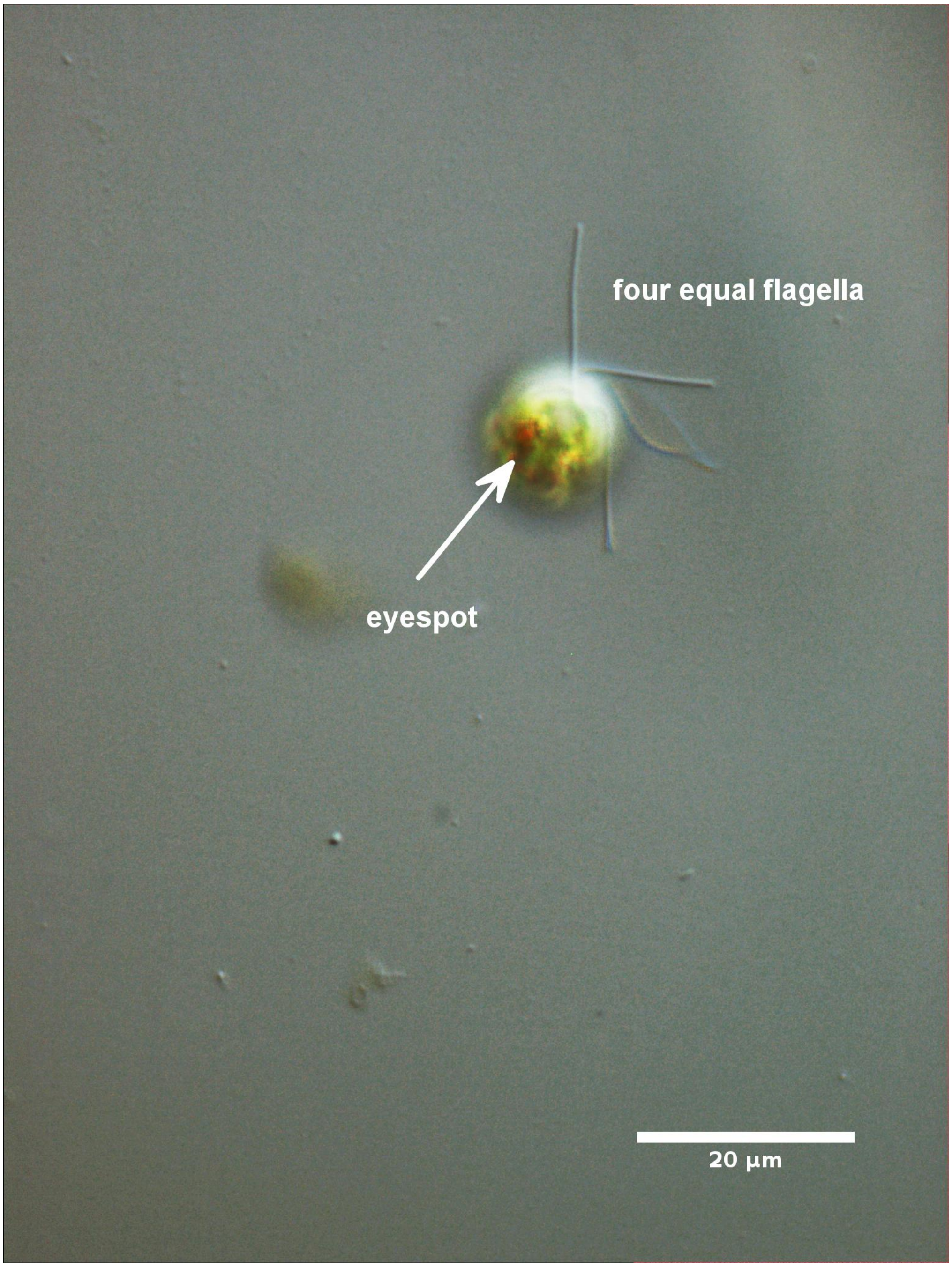


Figure 2.3: *Carteria globosa* (600x DIC), Bug Lake, IWS water quality sampling site, Whatcom County, August 20, 2008.

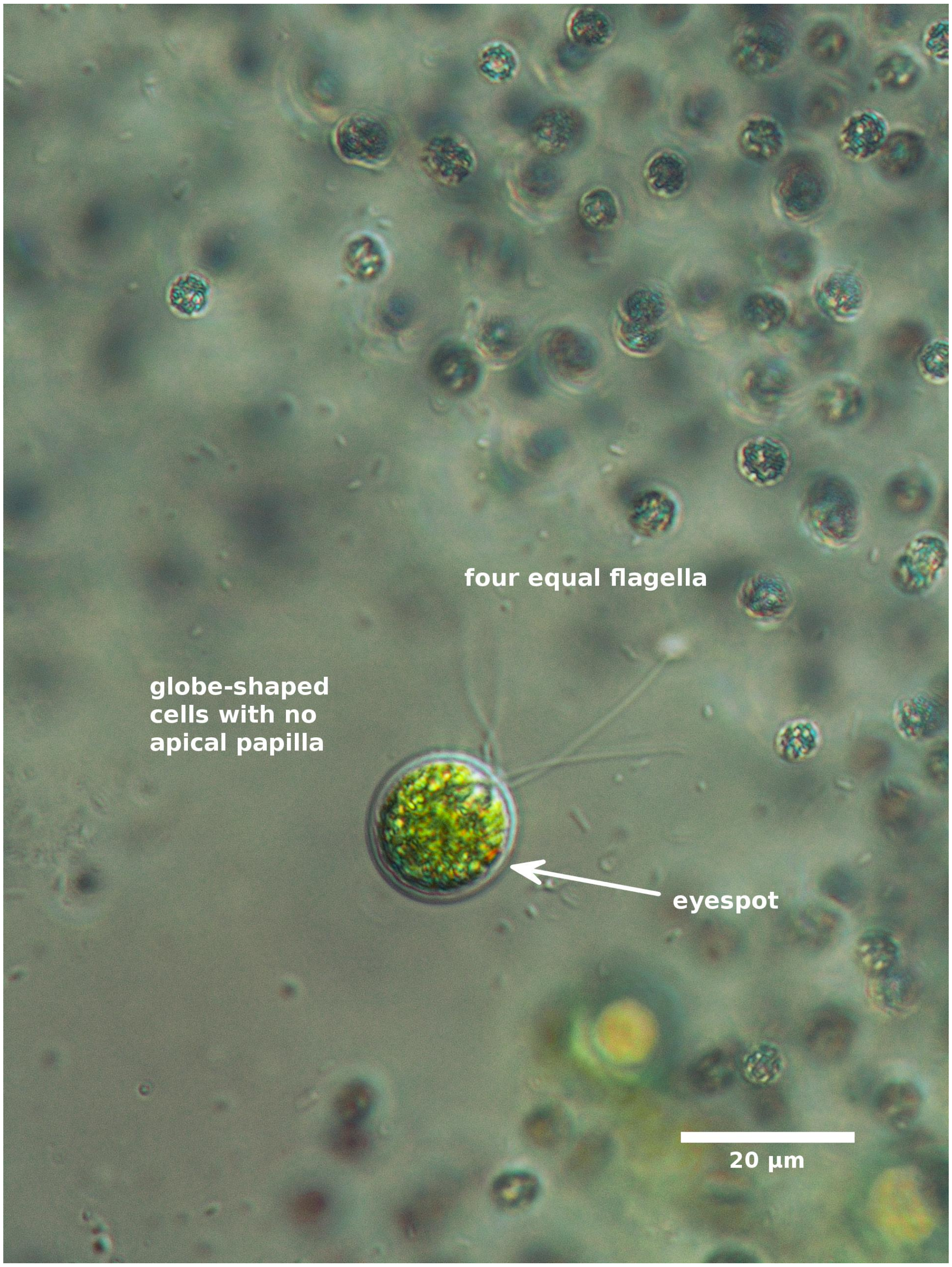


Figure 2.4: *Carteria globosa* (600x DIC), Lake Armstrong, IWS water quality sampling site, Snohomish County, July 28, 2014.

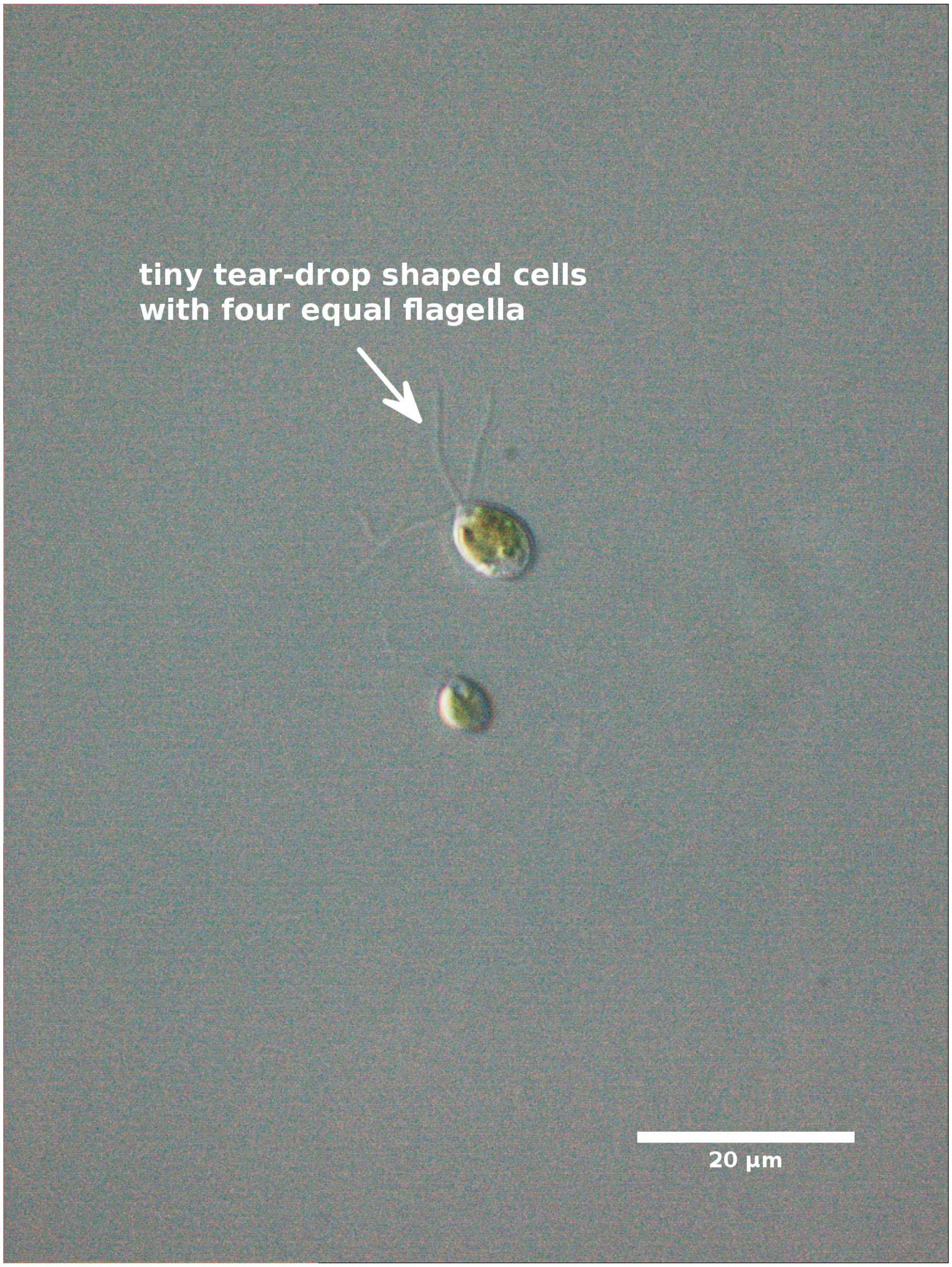


Figure 2.5: *Carteria* sp.1 (600x DIC), Lake Geneva, IWS water quality sampling site, Whatcom County, April 4, 2011.

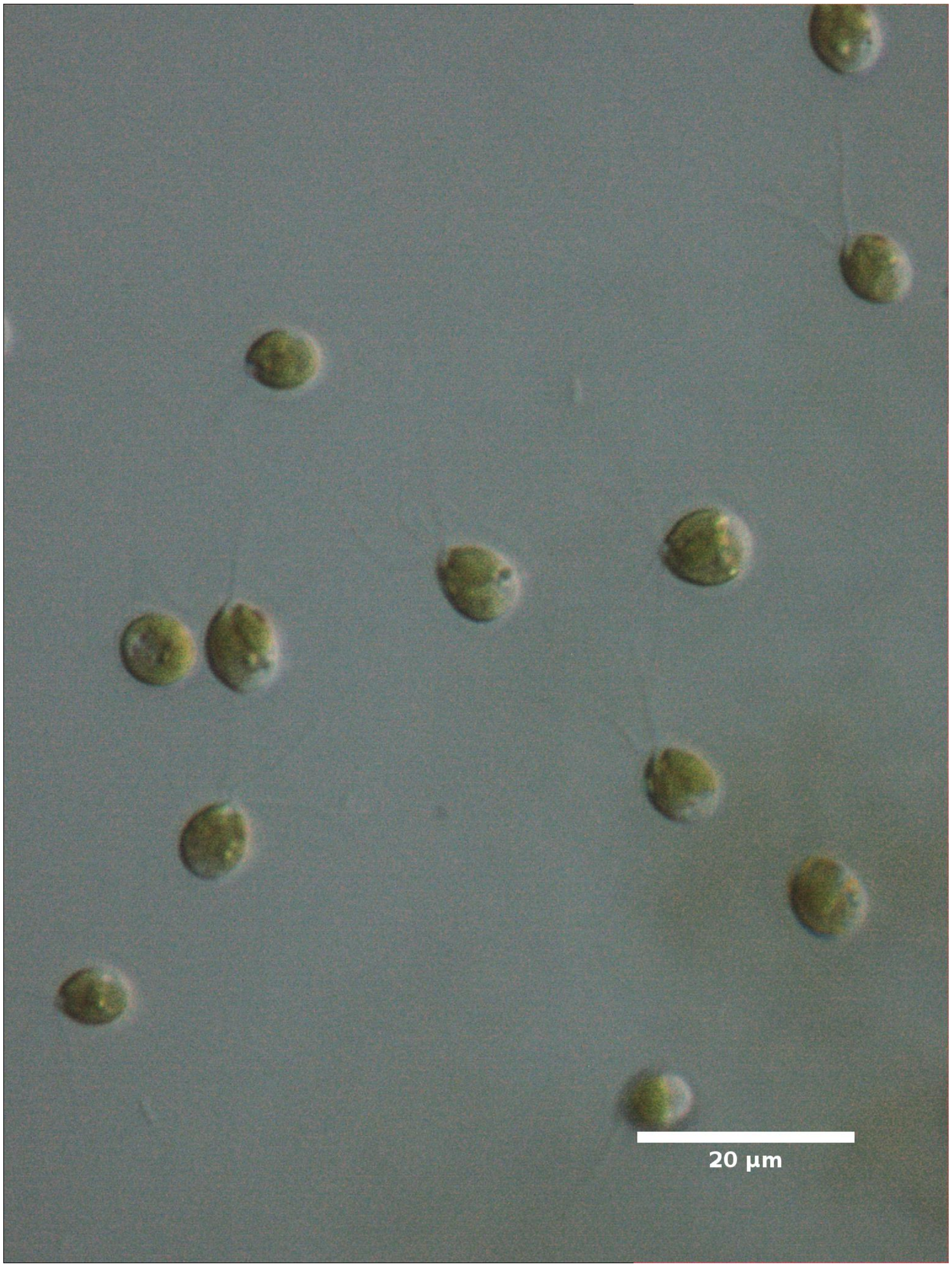


Figure 2.6: *Carteria* sp.1 (600x DIC), Lake Geneva, IWS water quality sampling site, Whatcom County, April 2, 2011.

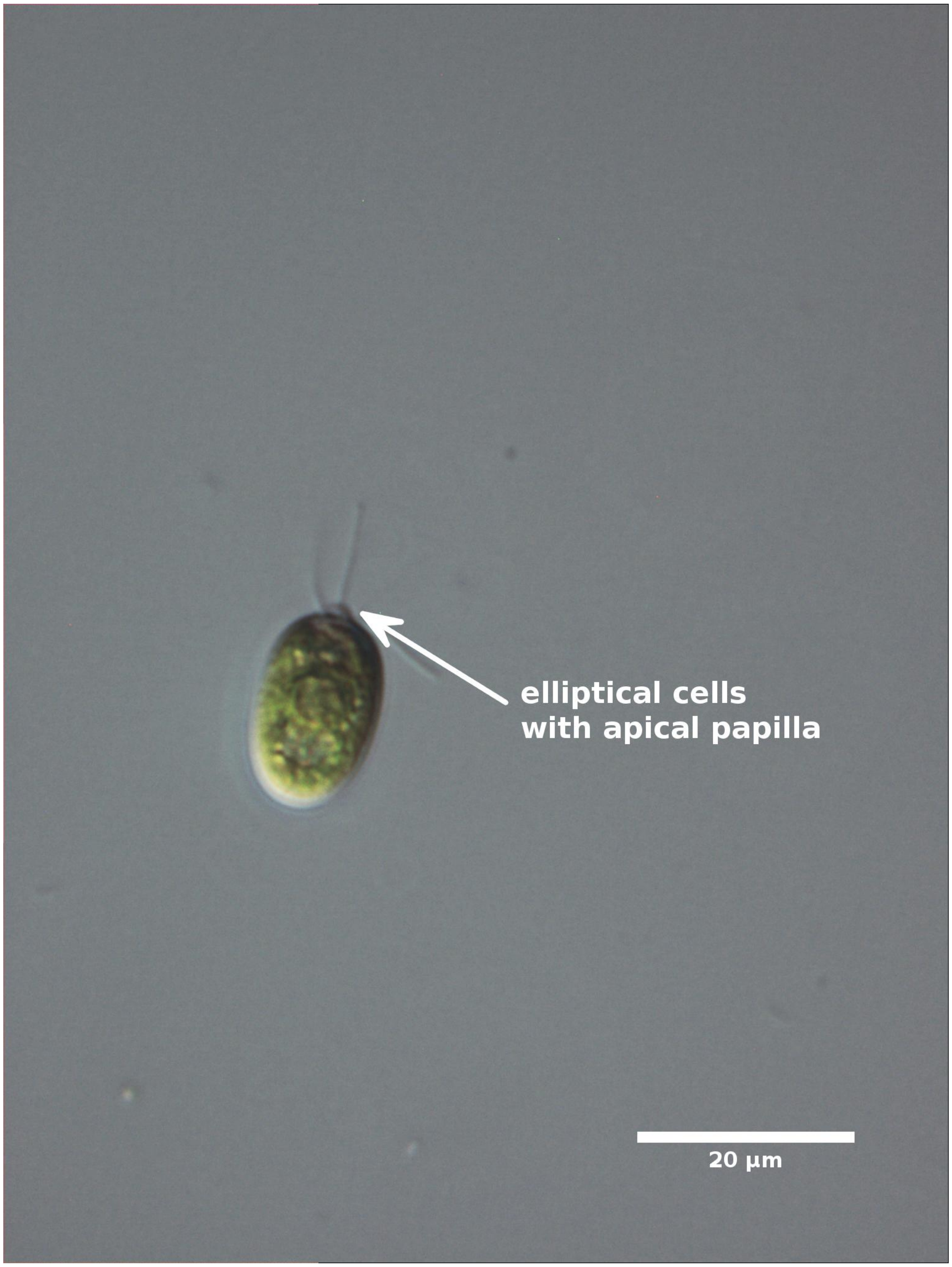


Figure 2.7: *Carteria* sp.2 (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, September 10, 2010.

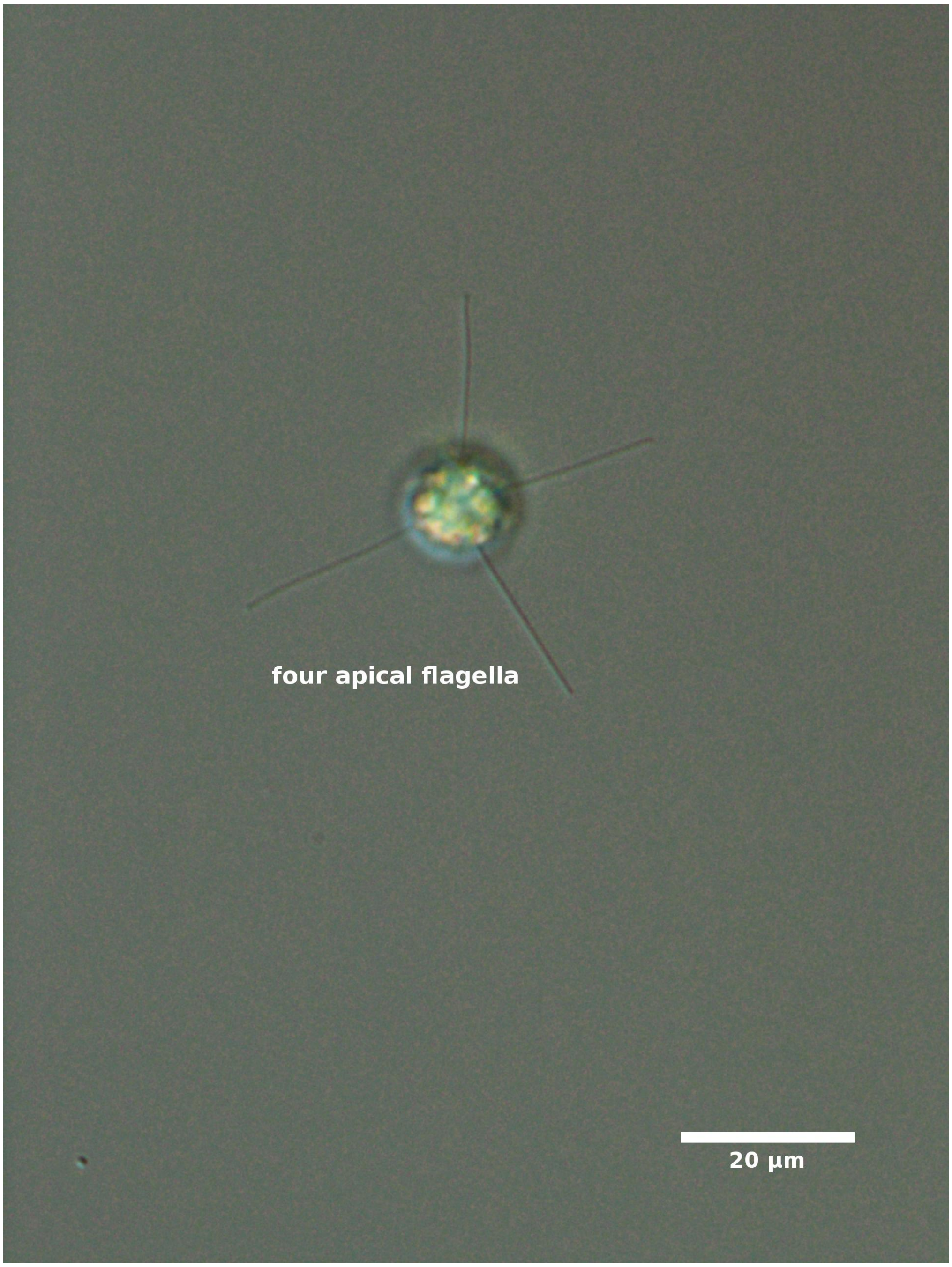


Figure 2.8: *Carteria* sp.2 (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, September 22, 2014.

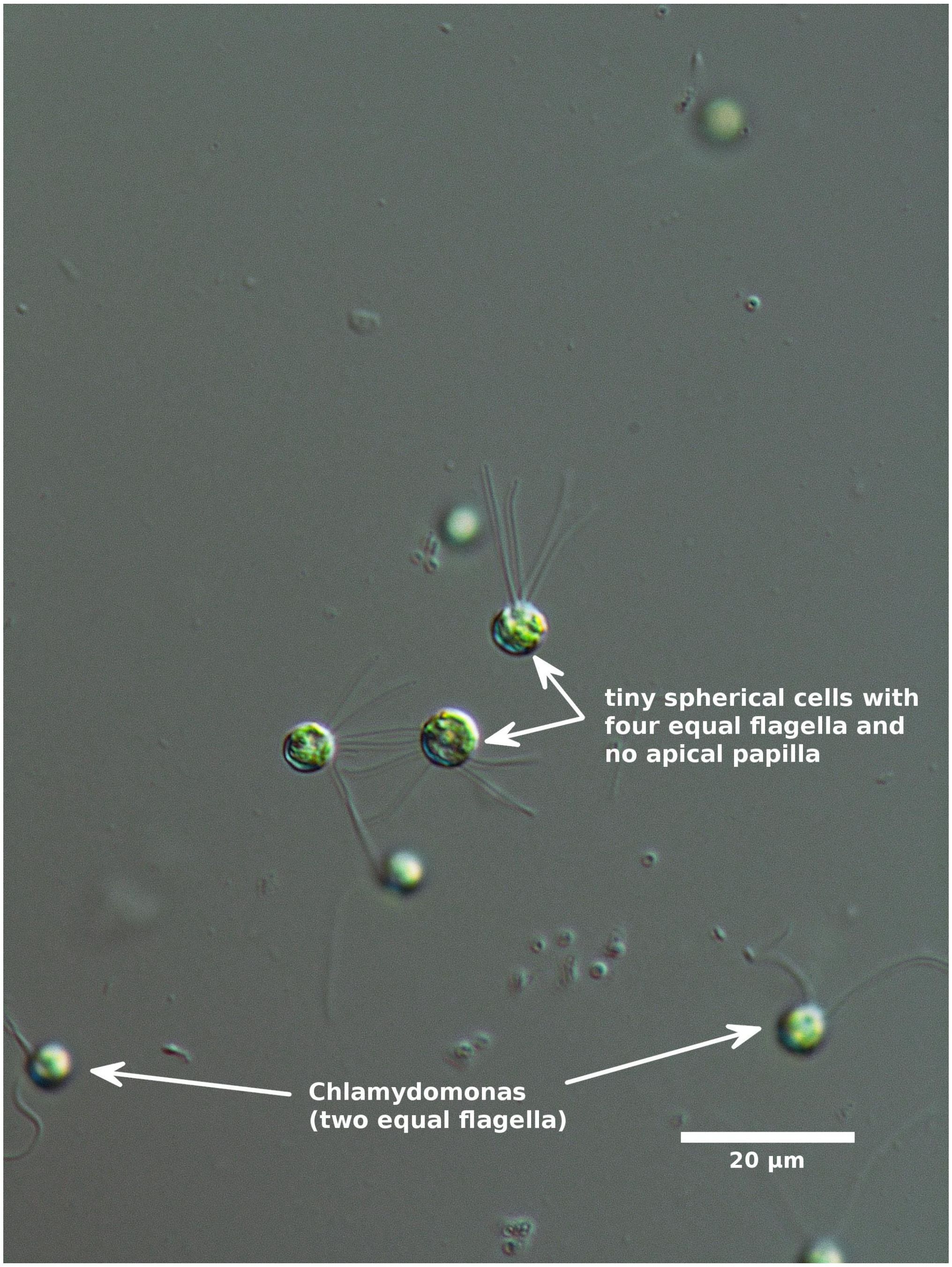


Figure 2.9: *Carteria* sp.3 (600x DIC), standing water, Whatcom County, May 21, 2014.

2.2 *Chlainomonas* H. R. Christen

Local taxon
Chlainomonas rubra (Stein & Brooke) Hoham

Abundance
Infrequently collected; common in snow samples.

Local measurements		Width	Length	Biovolume†
Chlainomonas rubra	min	19.5 μm	27.2 μm	5,420 μm^3
cysts without spines	med	36.0 μm	51.2 μm	33,800 μm^3
(spheroid)	max	44.3 μm	64.4 μm	66,200 μm^3

†Calculated using original measurements, not summary values.

Description
Chlainomonas rubra is a type of "snow algae" that forms bright red, oval cysts near the surface in snow packs (Figures 2.10–2.12). The cysts are usually covered with short, blunt spines, and may be surrounded by mucilage, but smooth-walled, oval cysts may also be present. The cysts are common in snow samples in the Pacific Northwest (Hoham, 1974), often staining the snow pink or red.

The large oval *Chlainomonas* cysts are easily distinguished from smaller, spherical, red cysts formed by another common type of snow algae, *Chlamydomonas nivalis* (see comparison in Figure 2.12). And the bright red cysts of *Chlainomonas rubra* and *Chlamydomonas nivalis* are easily distinguished from the yellow-green and orange snow algae cysts formed by *Chloromonas brevispina* and *Chloromonas nivalis* (Section 2.5, page 74).

When present, the motile vegetative cells of *Chlainomonas rubra* should have four equal length apical flagella and a cup-shaped chloroplast that is usually obscured by the red pigments. The protoplast of the motile cell is usually bright red and surrounded by clear mucilage (Figure 2.13).

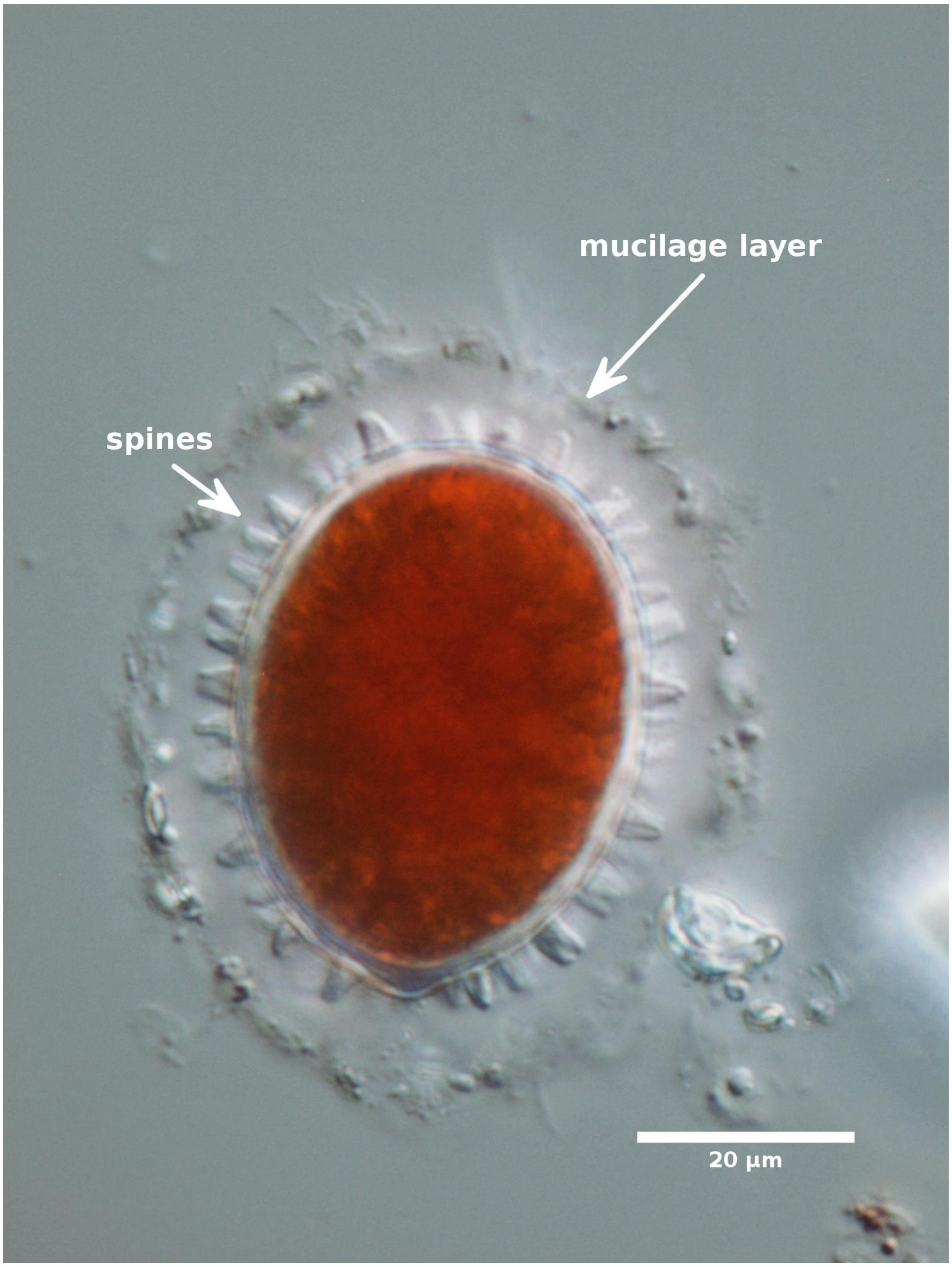


Figure 2.10: *Chlainomonas rubra* (600x DIC), snow sample on Lake Dorothy trail, Alpine Lakes Wilderness Area, July 11, 2013.

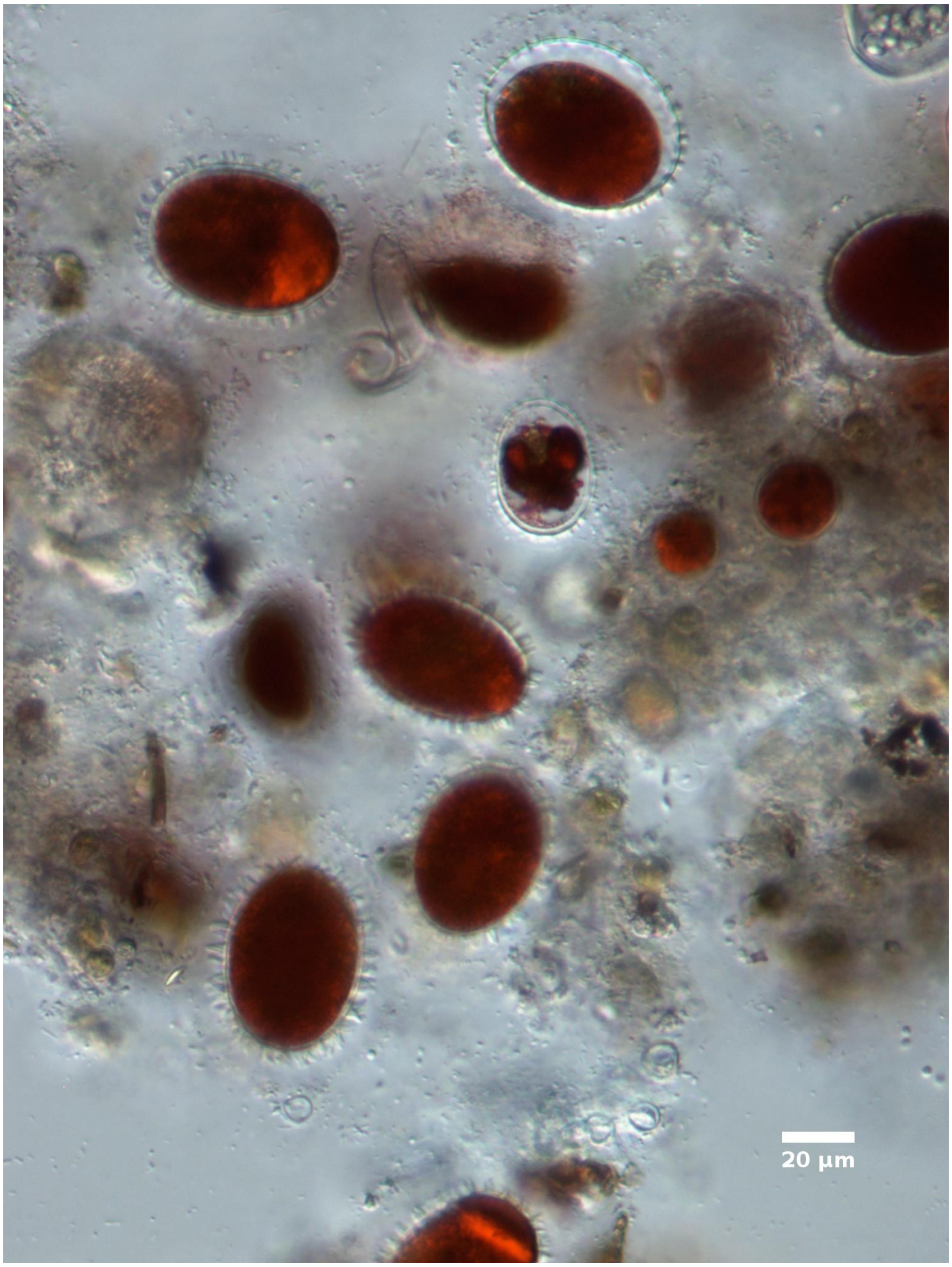


Figure 2.11: *Chlainomonas rubra* (200x DIC), snow sample on Lake Dorothy trail, Alpine Lakes Wilderness Area, July 22, 2013.

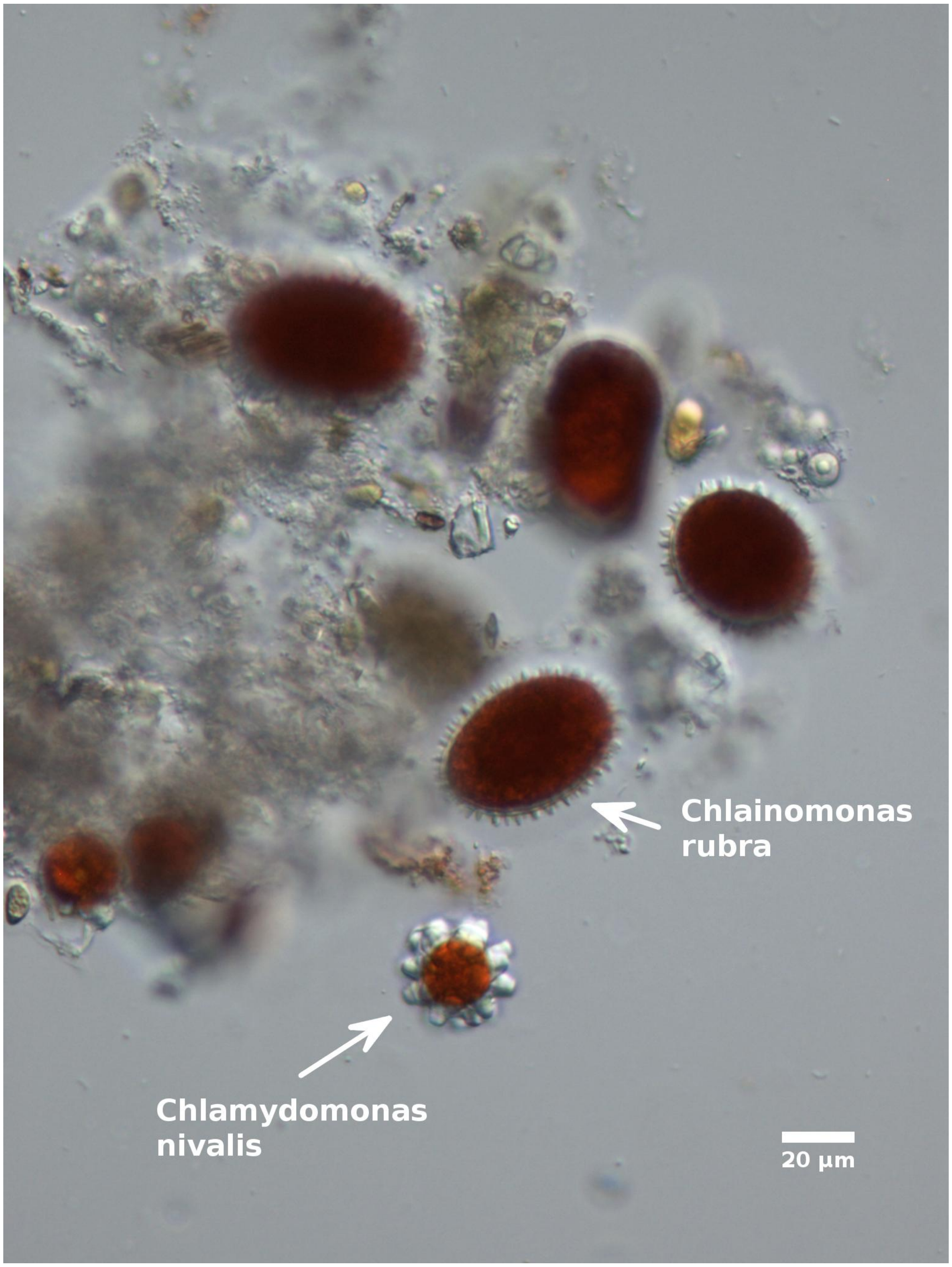


Figure 2.12: *Chlainomonas rubra* and *Chlamydomonas nivalis* (200x DIC), snow sample on Lake Dorothy trail, Alpine Lakes Wilderness Area, July 12, 2013.

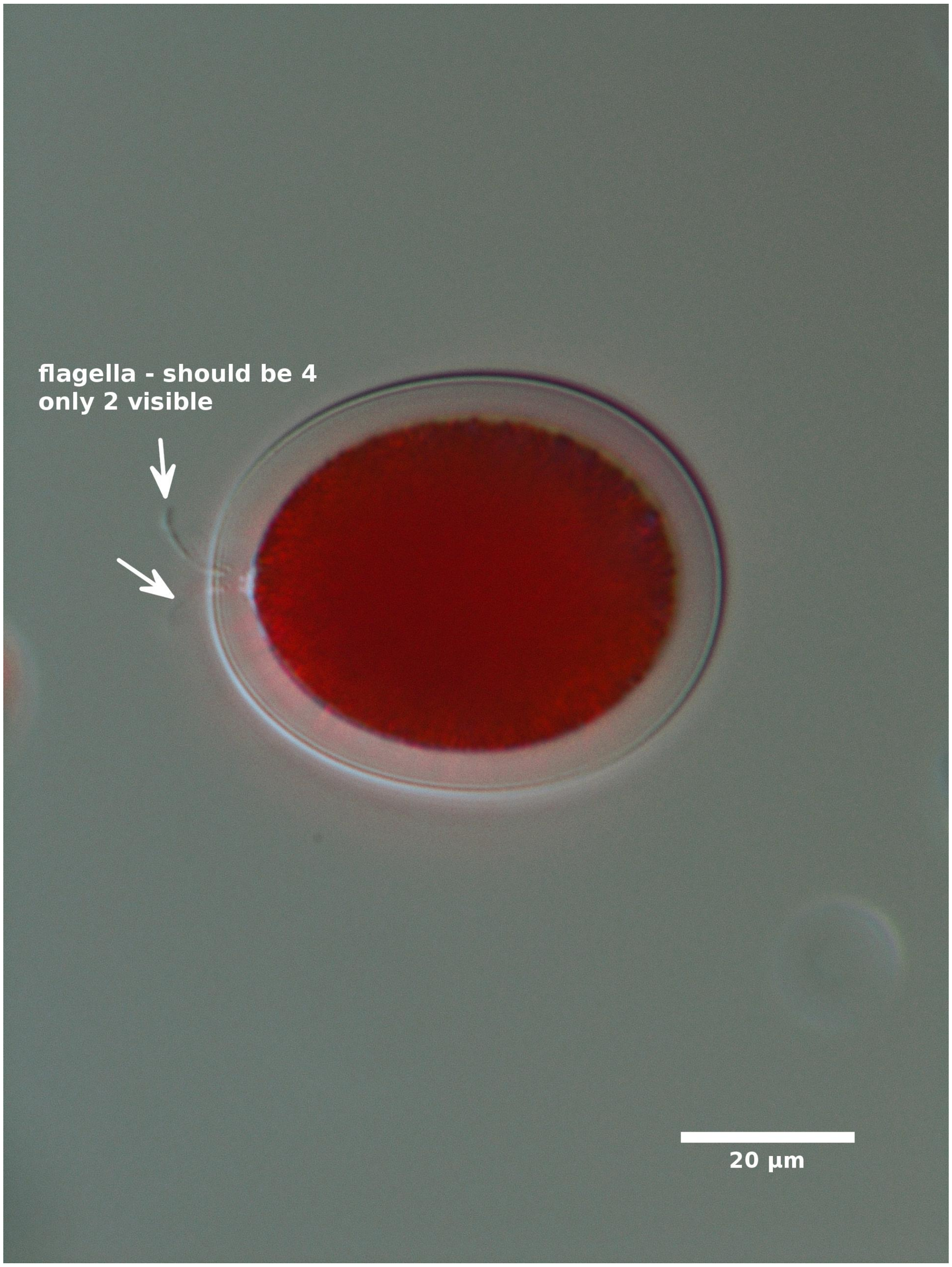


Figure 2.13: *Chlainomonas rubra* motile cell (600x DIC) snow sample at Rainy Pass, North Cascades along Hwy 20, June 18, 2014.

2.3 *Chlamydomonas* Ehrenberg and *Vitreochlamys* Batko

Local taxa
Chlamydomonas nivalis (Bauer) Wille;
Chlamydomonas spp.;
Vitreochlamys spp.

Abundance
Chlamydomonas is moderately common and may be present in large numbers but rarely forms blooms; *Chlamydomonas nivalis* is common in snow samples; *Vitreochlamys* is infrequently collected.

Local measurements		Width	Length	Biovolume†
Chlamydomonas type A	min	5.5 μm	7.2 μm	119 μm^3
cells (spheroid)	med	11.0 μm	15.3 μm	1,050 μm^3
	max	22.6 μm	23.9 μm	4,870 μm^3
Chlamydomonas type B	min	11.7 μm	–	839 μm^3
cells (sphere)	med	16.5 μm	–	2,370 μm^3
	max	20.2 μm	–	4,320 μm^3
Chlamydomonas type C.1	min	6.2 μm	12.5 μm	270 μm^3
cells (spheroid)	med	8.2 μm	15.8 μm	570 μm^3
	max	14.2 μm	22.9 μm	2,420 μm^3
Chlamydomonas type C.2	min	12.0 μm	30.0 μm	1,660 μm^3
cells	med	12.2 μm	33.2 μm	2,120 μm^3
(cyl + two $\frac{1}{2}$ spheres)	max	12.8 μm	38.6 μm	2,520 μm^3
Chlamydomonas type D‡	min	7.7 μm	10.6 μm	335 μm^3
cells (spheroid)	med	8.2 μm	11.1 μm	393 μm^3
	max	9.1 μm	11.4 μm	494 μm^3

continued on next page

Local measurements		Width	Length	Biovolume[†]
Chlamydomonas type E[‡]	min	15.6 μm	22.8 μm	3,020 μm^3
cells (spheroid)	med	15.8 μm	23.5 μm	3,040 μm^3
	max	15.9 μm	24.1 μm	3,070 μm^3
Chlamydomonas nivalis	min	15.9 μm	–	2,100 μm^3
cysts without corona	med	21.6 μm	–	5,280 μm^3
(sphere)	max	26.2 μm	–	9,420 μm^3
Vitreochlamys sp.1,	min	9.7 μm	13.7 μm	810 μm^3
cells not including	med	10.8 μm	15.6 μm	920 μm^3
mucilage (spheroid)	max	12.3 μm	16.9 μm	1,320 μm^3
Vitreochlamys sp.1,	min	12.9 μm	17.8 μm	1,550 μm^3
cells including mucilage	med	13.3 μm	19.4 μm	1,780 μm^3
(spheroid)	max	14.5 μm	20.8 μm	2,280 μm^3
Vitreochlamys sp.2	min	6.1 μm	8.9 μm	179 μm^3
cells not including	med	8.1 μm	9.9 μm	344 μm^3
mucilage (spheroid)	max	8.6 μm	11.7 μm	418 μm^3
Vitreochlamys sp.2	min	15.2 μm	18.5 μm	2,240 μm^3
cells including mucilage	med	18.7 μm	20.8 μm	3,840 μm^3
(spheroid)	max	20.5 μm	23.5 μm	5,060 μm^3
Vitreochlamys sp.3[‡]	min	13.8 μm	16.3 μm	1,630 μm^3
cells not including	med	16.1 μm	18.8 μm	2,550 μm^3
mucilage (spheroid)	max	17.4 μm	20.1 μm	3,190 μm^3
Vitreochlamys sp.3[‡]	min	21.0 μm	23.3 μm	5,380 μm^3
cells including mucilage	med	24.8 μm	27.1 μm	8,760 μm^3
(spheroid)	max	25.7 μm	27.2 μm	9,370 μm^3
Vitreochlamys?	min	10.9 μm	12.9 μm	802 μm^3
cells not including	med	13.0 μm	14.0 μm	1,240 μm^3
mucilage (spheroid)	max	16.0 μm	17.0 μm	2,280 μm^3

continued on next page

Local measurements		Width	Length	Biovolume†
Vitreochlamys?	min	16.6 μm	17.7 μm	2,550 μm^3
cells including mucilage	med	19.7 μm	20.7 μm	4,250 μm^3
(spheroid)	max	24.9 μm	23.0 μm	7,470 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume estimate based on <5 cells.

Description

Chlamydomonas and *Vitreochlamys* are very similar, and many *Vitreochlamys* species have synonyms listed under *Chlamydomonas*. The genus *Sphaerellopsis* is another synonym for *Vitreochlamys*. The genus revision from *Sphaerellopsis* to *Vitreochlamys* was proposed by Batko (1970) to resolve confusion because *Sphaerellopsis* is also a genus name for a type of fungus. Many taxonomic keys, however, continue to list species under the genus *Sphaerellopsis*. All of the species except *Chlamydomonas nivalis* (see next page) are difficult to identify correctly, so the taxa have only be identified as morphological types.

Chlamydomonas and *Vitreochlamys* cells are solitary, spherical, oval, elliptical, teardrop-shaped, or pear-shaped, with two equal length apical flagella (Figures 2.14–2.34). The cell has a cup-shaped or H-shaped chloroplast with a red eyespot and one or more pyrenoids. *Chlamydomonas* protoplasts may be slightly separated from the cell wall, but if the protoplast is completely separated or surrounded by mucilage it is more likely to be *Vitreochlamys* or *Haematococcus* (Section 2.8, page 104). *Chlamydomonas* and *Vitreochlamys* reproduce by forming groups of 4–8 cells enclosed in a mucilaginous envelope (e.g., Figure 2.15). These reproductive cells may resemble nonmotile colonial Chlorophyta, but close observation will reveal eyespots or flagella, and the cells may move inside the mucilage envelope.

Chlamydomonas and *Vitreochlamys* often shed their flagella and become stationary in response to stress, which makes the cells difficult to distinguish from *Chlorella* (Section 3.9, page 282) and other types of nonmotile Chlorophyta. Another example of loss of motility can be seen in Figures 2.33–2.34. The *Chlamydomonas* cells in these figures have flagella, but were immobilized by toxins from *Microcystis*, a type of Cyanobacteria.[9] Kearns and Hunter (2001) reported similar inactivation of *Chlamydomonas* from *Anabaena* toxins.

[9]See **Freshwater Algae in Northwest Washington, Volume I. Cyanobacteria**.

Chlamydomonas type A has small oval cells with very long flagella (Figures 2.14–2.16). This taxon is extremely common in nutrient rich temporary ponds and stagnant water, occasionally forming blooms. *Chlamydomonas* type B is common in moderately productive low elevation lakes and is characterized by large, spherical cells with a prominent eyespot (Figures 2.17–2.18). *Chlamydomonas* type C has long, elliptical or cylindrical cells, and was subdivided based on size, habitat, and pyrenoid features: Type C.1 cells are smaller, with a prominent central pyrenoid, and were collected in low elevation lakes (Figures 2.19–2.20); Type C.2 cells are larger and more cylindrical, with multiple pyrenoids, and were collected in boggy, high elevation lakes (Figures 2.21–2.22). *Chlamydomonas* type D, which was collected at a single location (small boggy lake), is characterized by small, pear-shaped cells with a rectangular apical papilla (Figure 2.23). Another uncommon taxon, *Chlamydomonas* type E, has bluntly pointed cells that are slightly separated from the cell wall (Figure 2.24).

Both *Vitreochlamys* sp.1 and sp.2 have oval or tear-drop shaped protoplasts that contain massive chloroplasts that fill most of the cell (Figures 2.25–2.27). The primary distinction between these two taxa is the protoplast size and the shape of the mucilage surrounding the protoplast. The *Vitreochlamys* sp.1 protoplast is larger, and the mucilage surrounding the protoplast is more narrow and elliptical, relative to *Vitreochlamys* sp.2. *Vitreochlamys* sp.2 protoplasts are considerably smaller, but are surrounded by a wide, oval mucilage layer. *Vitreochlamys* sp.3 protoplasts are relatively large and nearly spherical, with a bluntly pointed apex, and massive chloroplast. The protoplasts are surrounded by a spherical mucilage layer (Figures 2.28–2.29). The specimens in Figures 2.30–2.32 are tentatively identified as a species of *Vitreochlamys*. The protoplasts are oval or tear-drop shaped, and are surrounded by a nearly spherical, slightly irregular mucilage layer. But the small, anterior chloroplast does not resemble any of the other local *Vitreochlamys* species.

Chlamydomonas nivalis is a type of *snow algae* that forms bright red, spherical cysts in snow packs (Figures 2.35–2.39). *Chlamydomonas nivalis* cysts are quite variable in size and shape (Figure 2.36), with some of the cysts surrounded by ornate cell wall extensions (Figure 2.37). Motile cells are rare, but will be teardrop-shaped, with two equal flagella and no apical papilla. *Chlamydomonas nivalis* cysts resemble the spiny, oval cysts of *Chlainomonas* (see comparison in Figure 2.12, page 33), but are easily distinguished from yellow-green and orange *Chloromonas* cysts (Figure 2.39; Section 2.5, page 74).

Figure 2.14: *Chlamydomonas* type A (600x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, June 30, 2011.

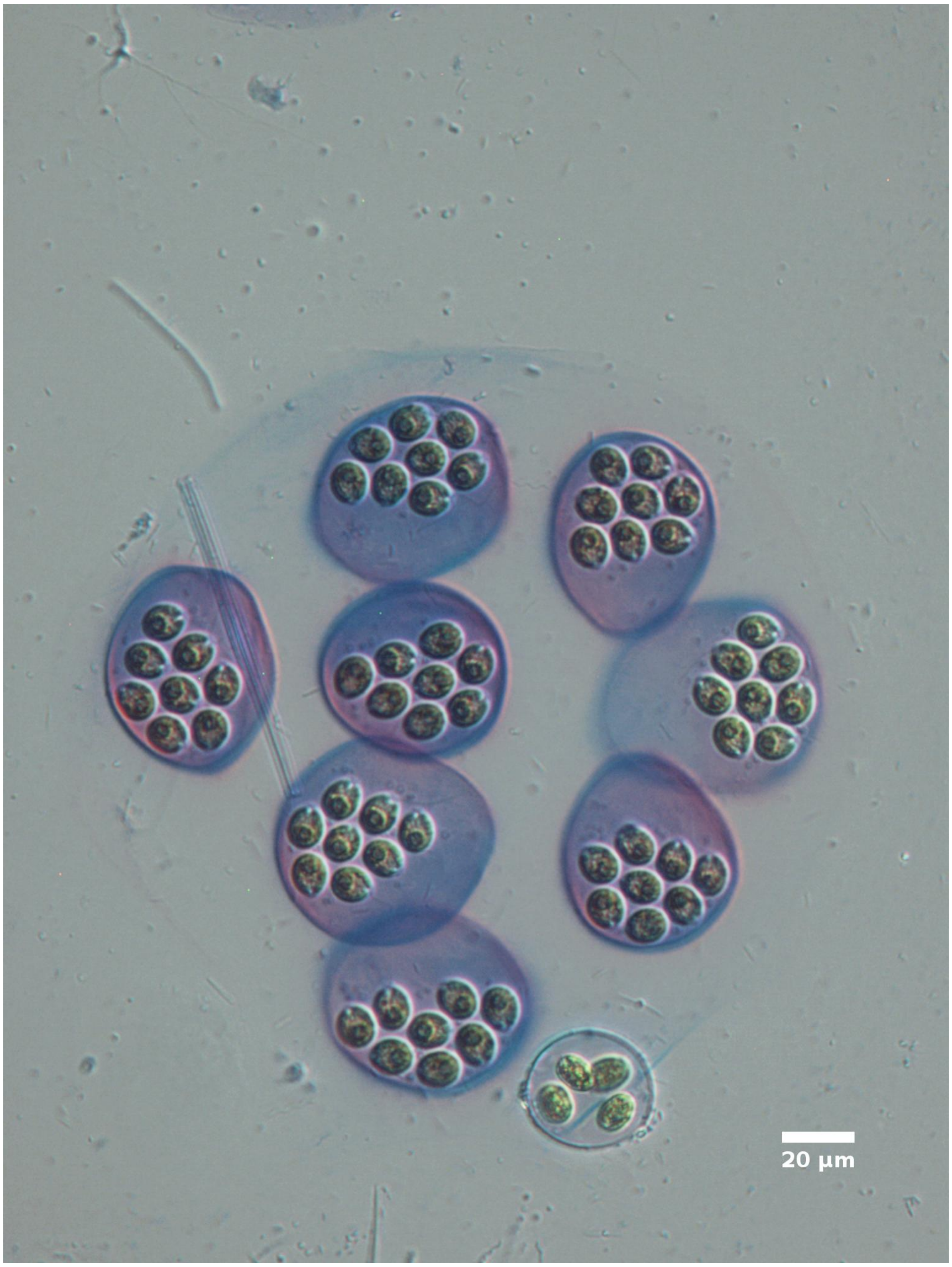


Figure 2.15: *Chlamydomonas* type A cells stained with methylene blue (200x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, September 5, 2013.

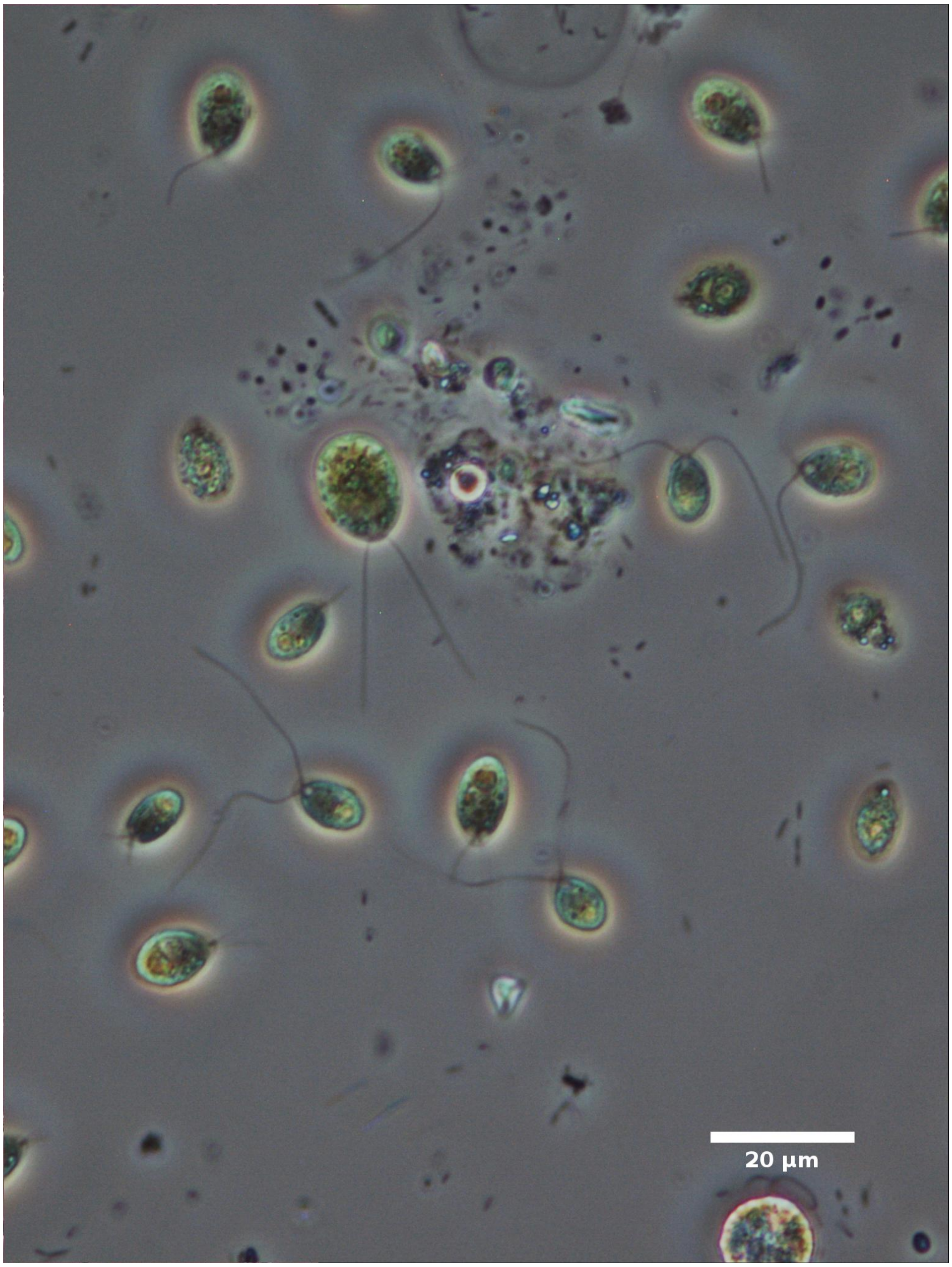


Figure 2.16: *Chlamydomonas* type A (400x phase contrast), stagnant water in plant saucer, May 20, 2011.

Figure 2.17: *Chlamydomonas* type B (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 5, 2011.

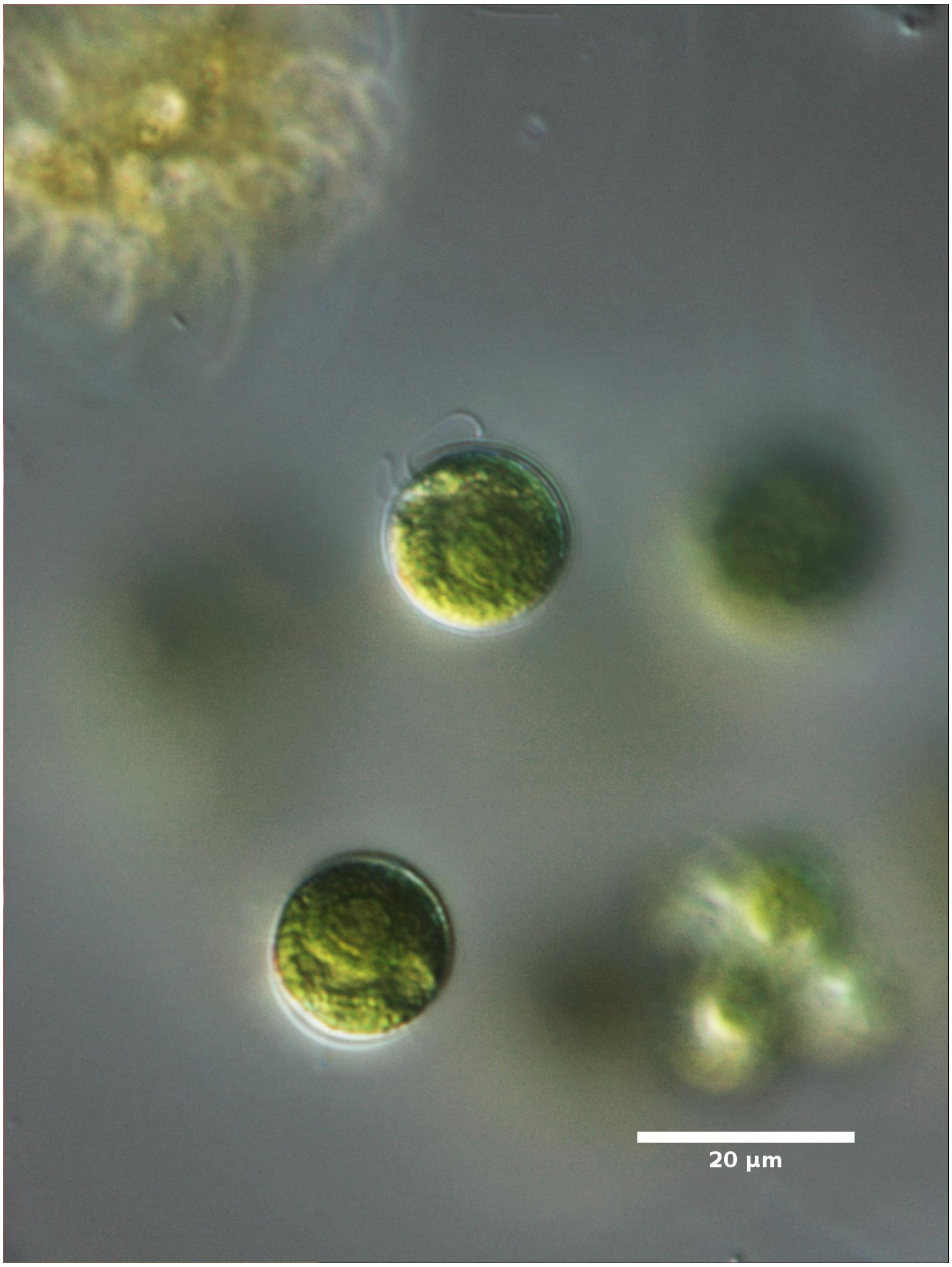


Figure 2.18: *Chlamydomonas* type B (600x DIC), Lake Padden, IWS water quality sampling site, Whatcom County, June 12, 2008.

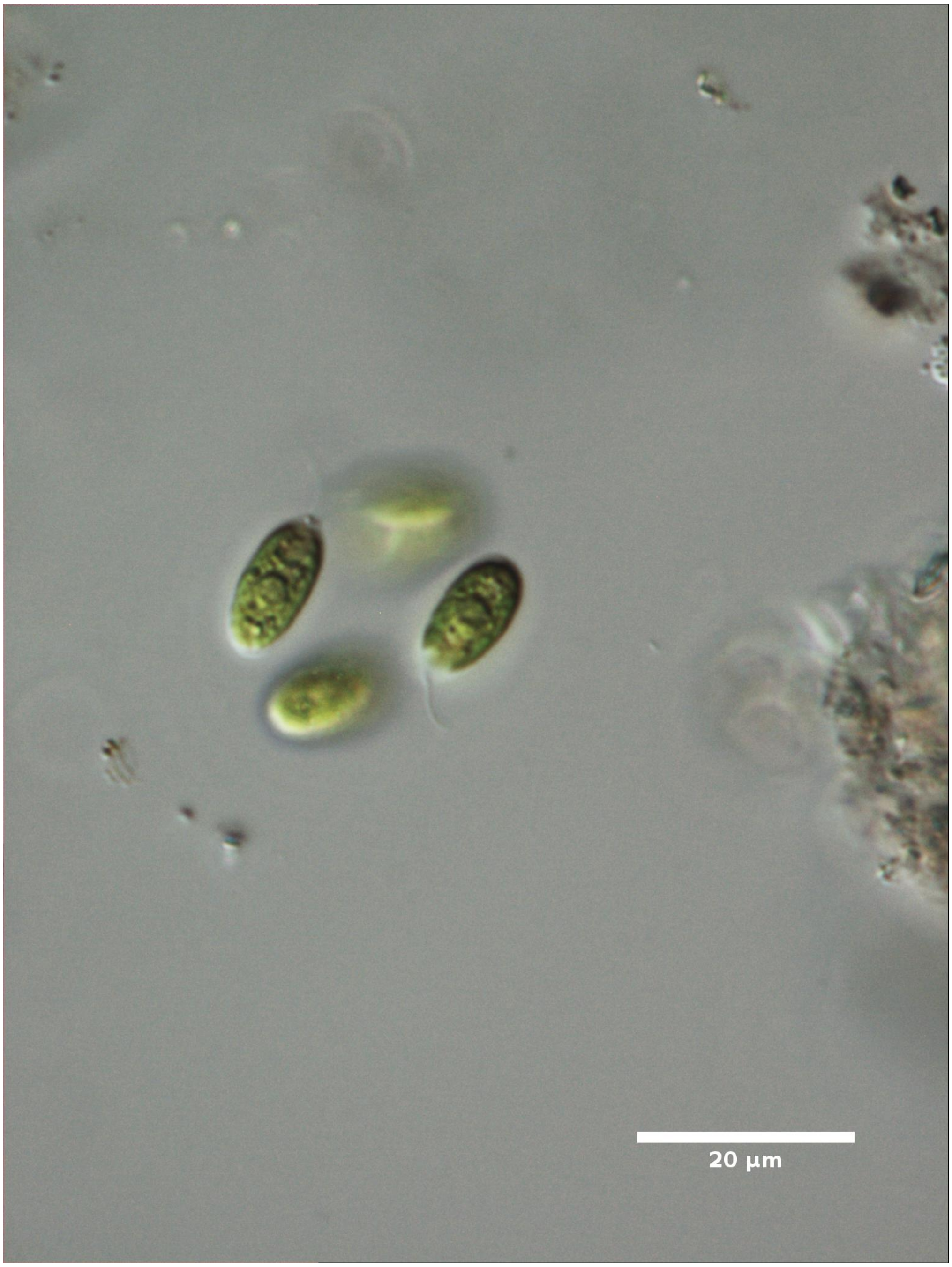


Figure 2.19: *Chlamydomonas* type C.1 (600x DIC), Lake McMurray, IWS water quality sampling site, Skagit County, August 21, 2008.

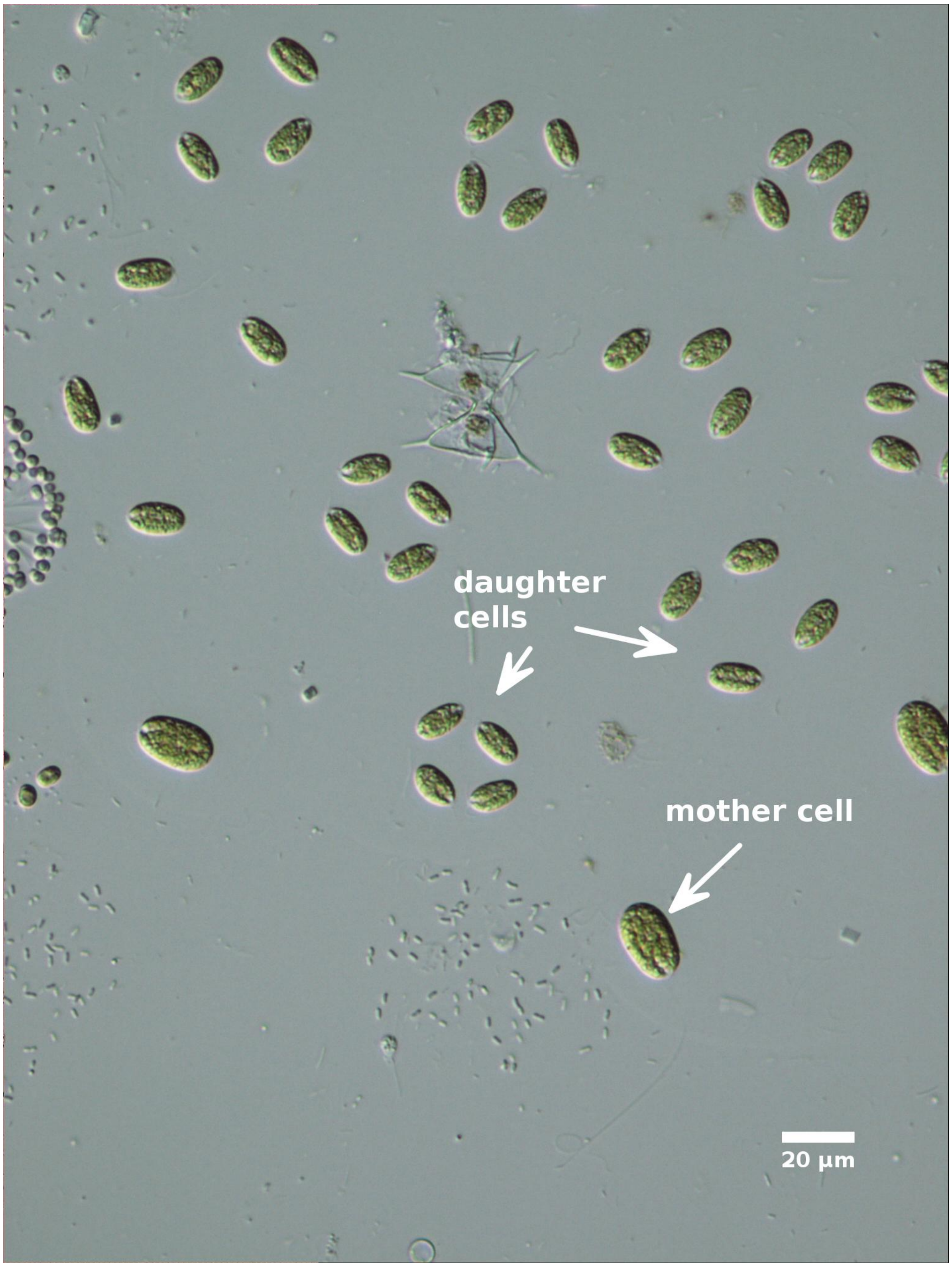


Figure 2.20: *Chlamydomonas* type C.1 (200x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 12, 2010.

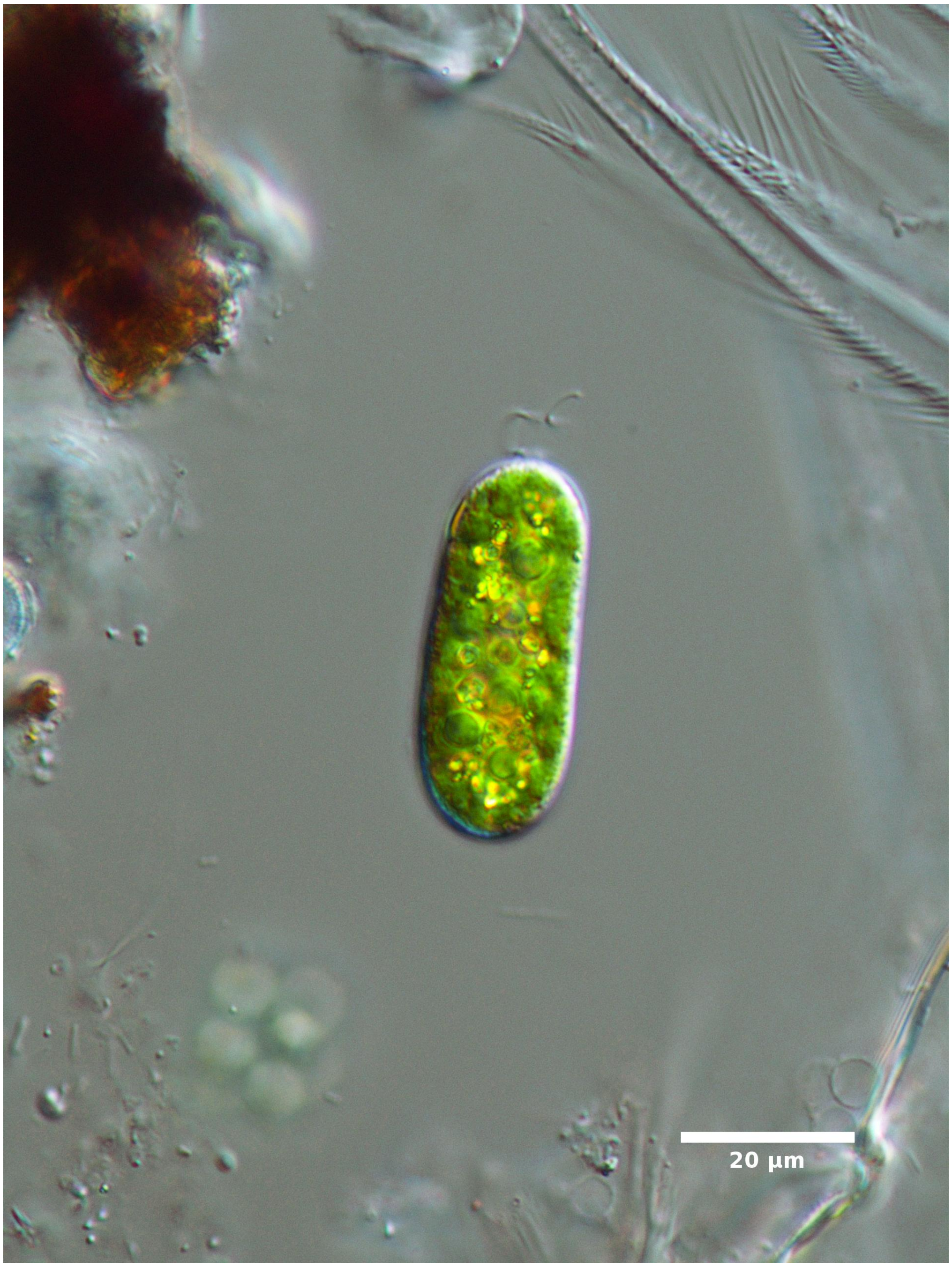


Figure 2.21: *Chlamydomonas* type C.2 (600x DIC), Lake Evan, IWS water quality sampling site, Snohomish County, July 23, 2015.

Figure 2.22: *Chlamydomonas* type C.2 (600x DIC), Lake Evan, IWS water quality sampling site, Snohomish County, July 23, 2015.

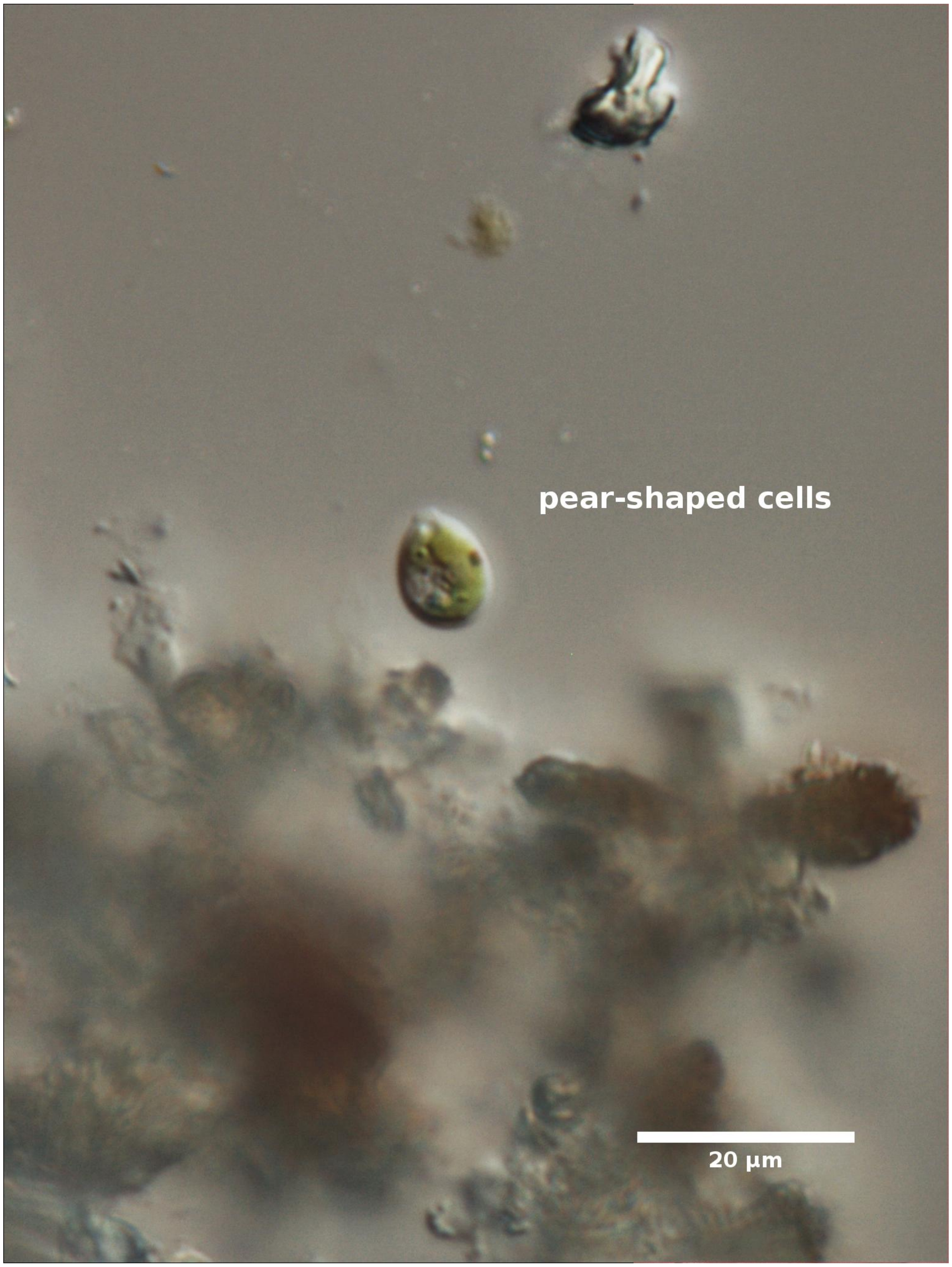


Figure 2.23: *Chlamydomonas* type D (600x DIC), Canyon Lake, IWS water quality sampling site, Whatcom County, August 28, 2008.

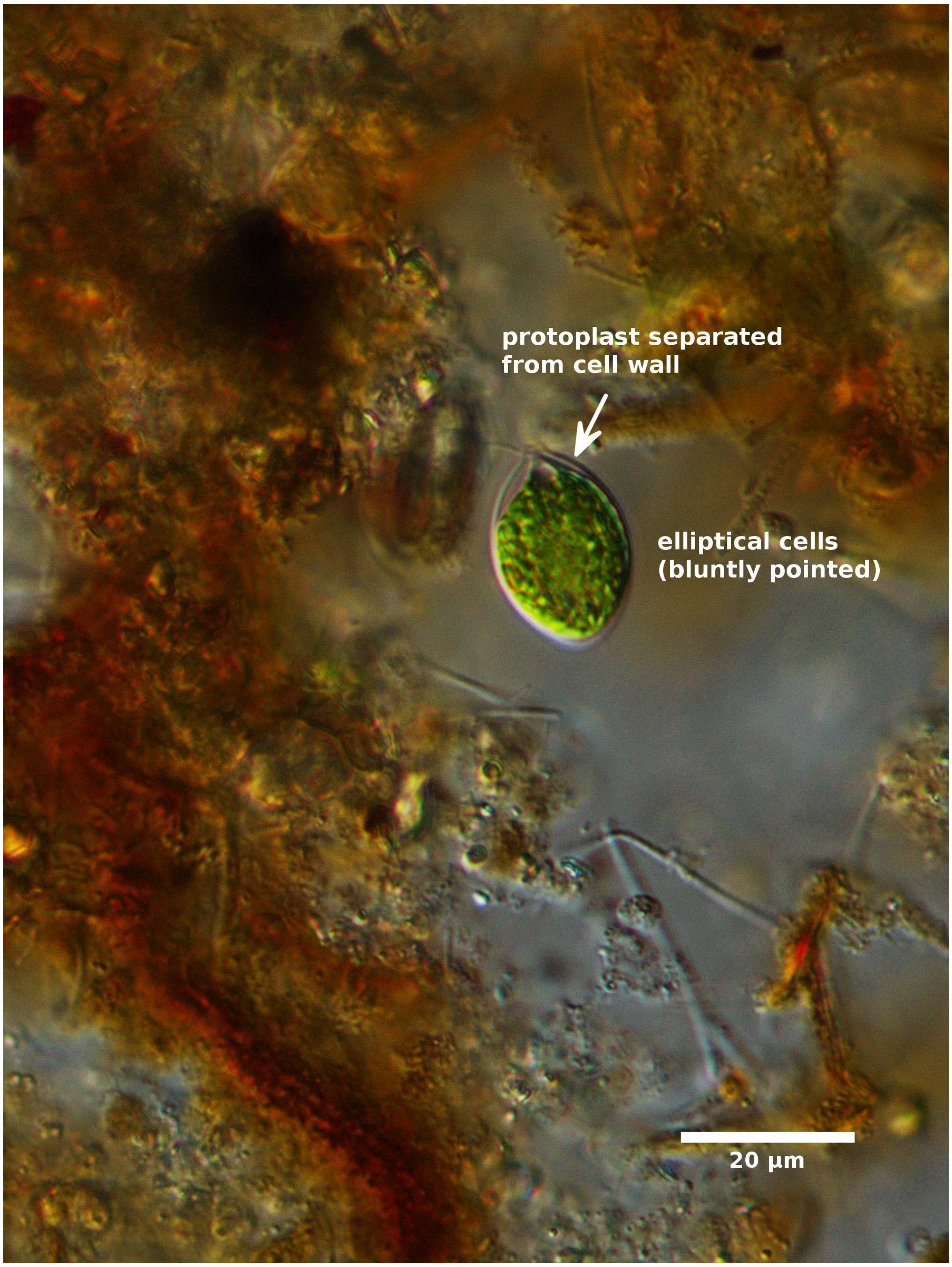


Figure 2.24: *Chlamydomonas* type E (600x DIC), Terrell Creek, Whatcom County, April 11, 2014.

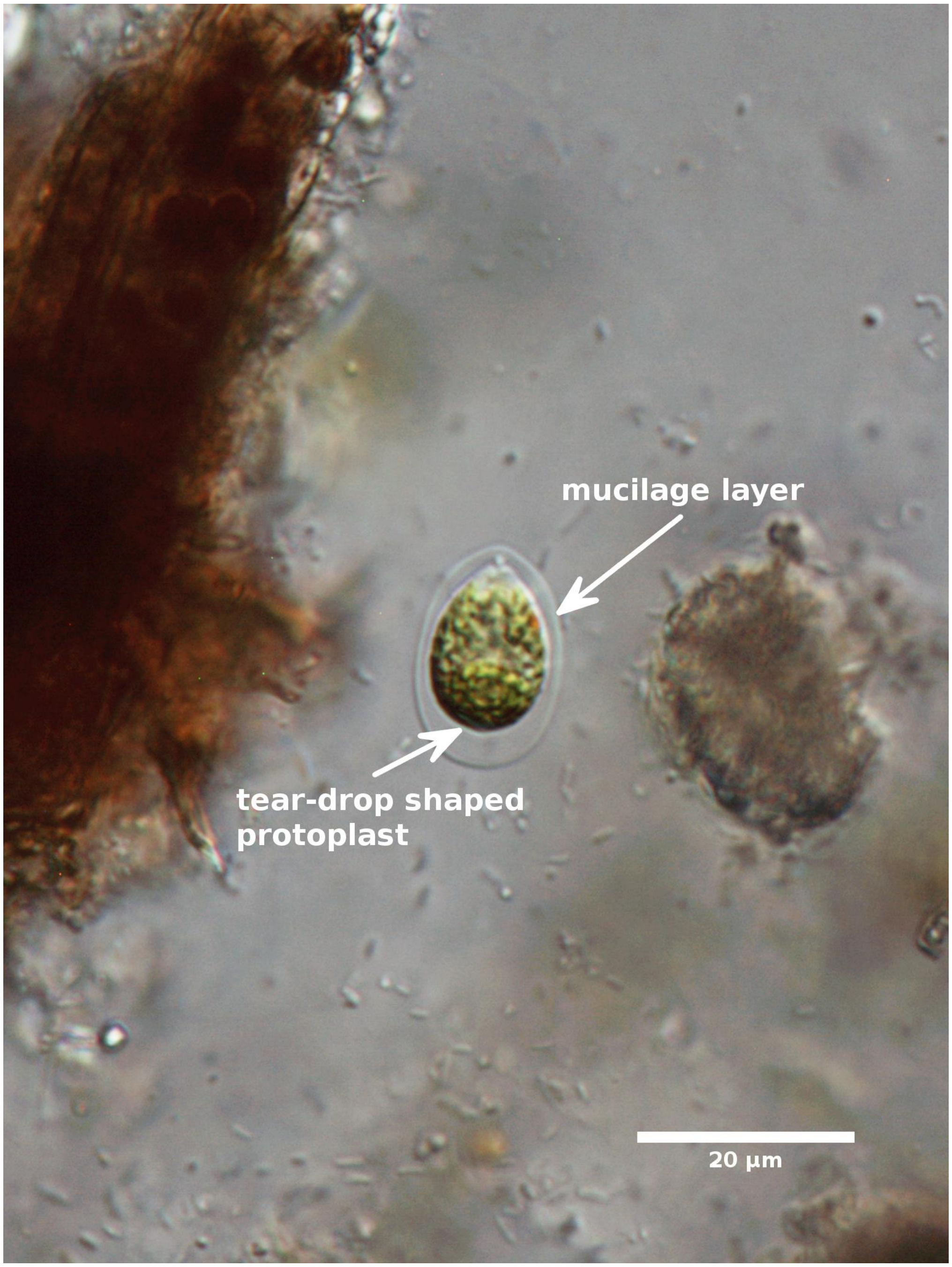


Figure 2.25: *Vitreochlamys* sp.1 (600x DIC), Crabapple Lake, IWS water quality sampling site, Snohomish County, July 11, 2013.

Figure 2.26: *Vitreochlamys* sp.1 (600x DIC), Crabapple Lake, IWS water quality sampling site, Snohomish County, July 11, 2013.

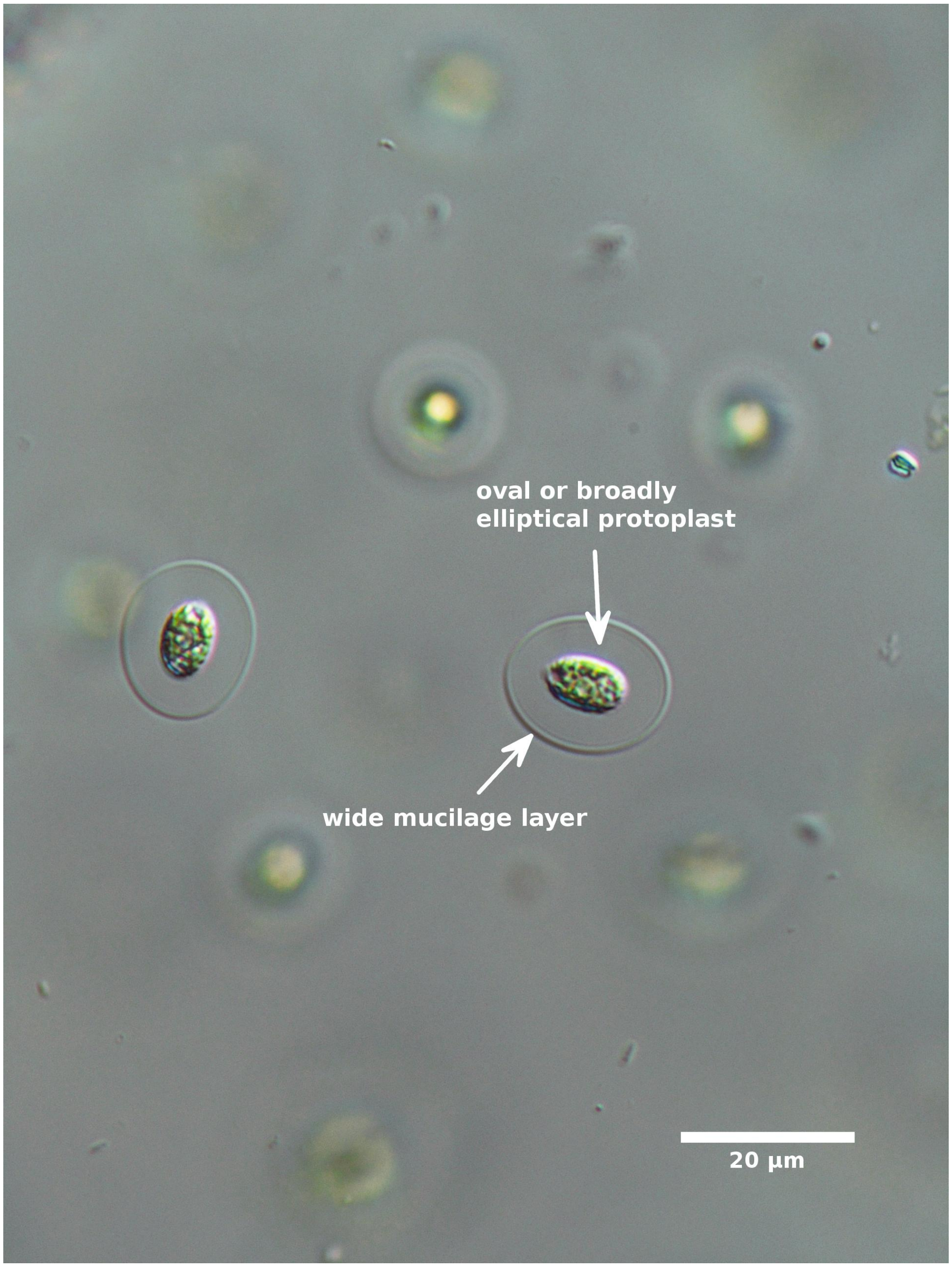


Figure 2.27: *Vitreochlamys* sp.2 (600x DIC), Canyon Lake, IWS water quality sampling site, Whatcom County, August 26, 2014.

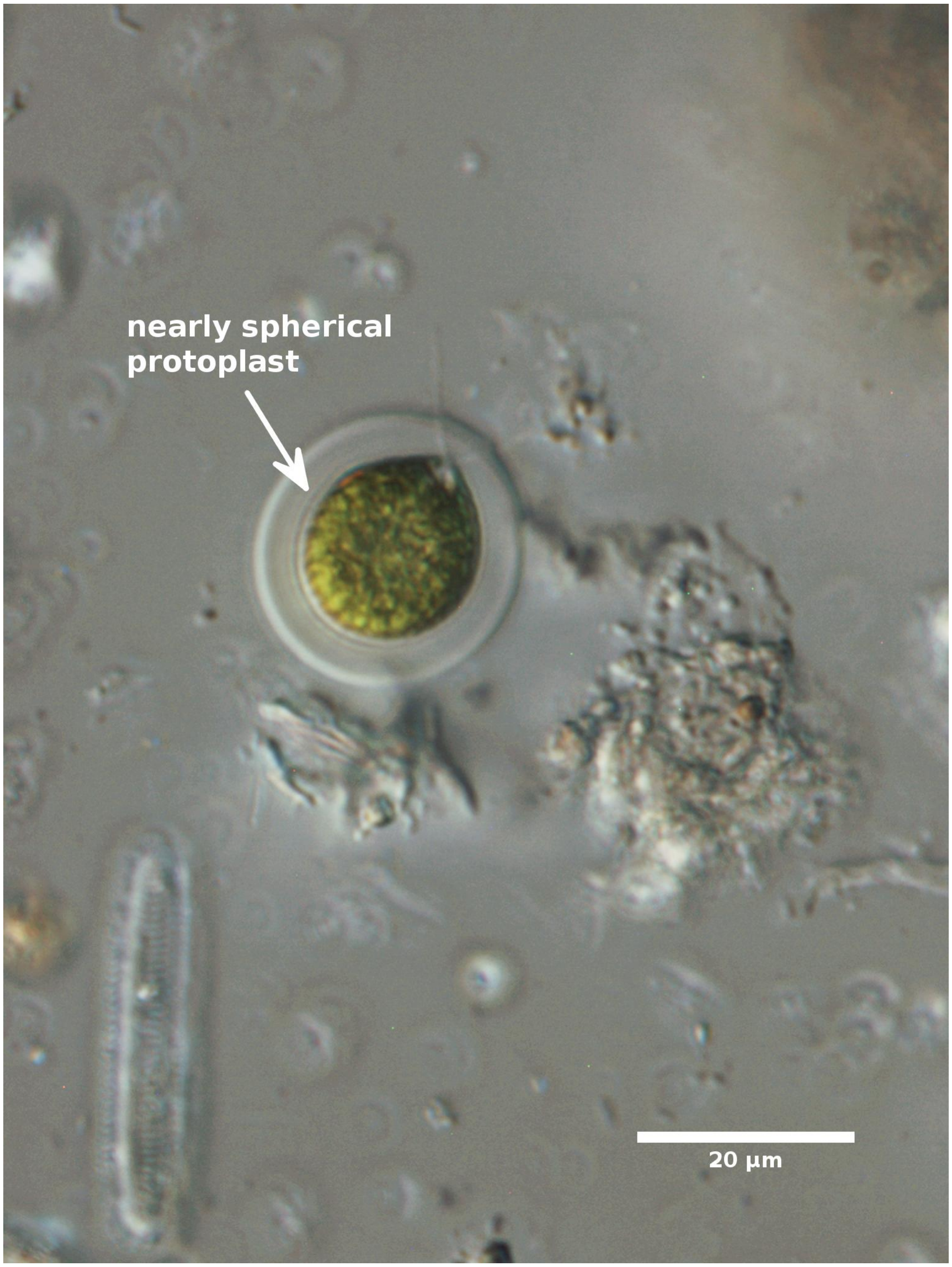


Figure 2.28: *Vitreochlamys* sp.3 (600x DIC), small pond on trail to Lake Anderson, North Cascades along Hwy 20, August 23, 2013.

Figure 2.29: *Vitreochlamys* sp.3 (600x DIC), small lake near Yellow Aster Butte, North Cascades near Mt. Baker, September 3, 2013.

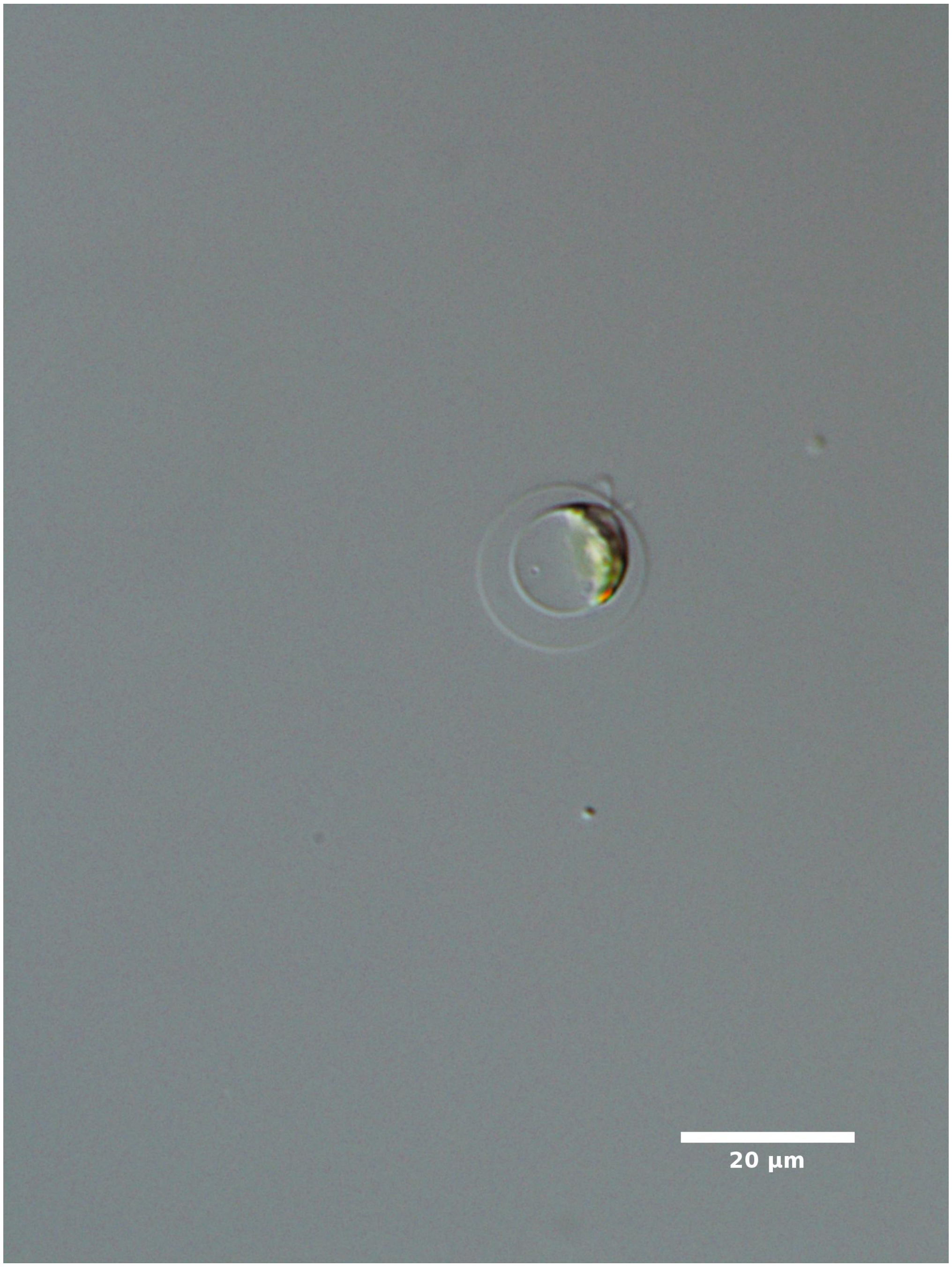


Figure 2.30: *Vitreochlamys*? (600x DIC), small pond near Artist Point Ridge trail, Mt. Baker area, June 29, 2015.

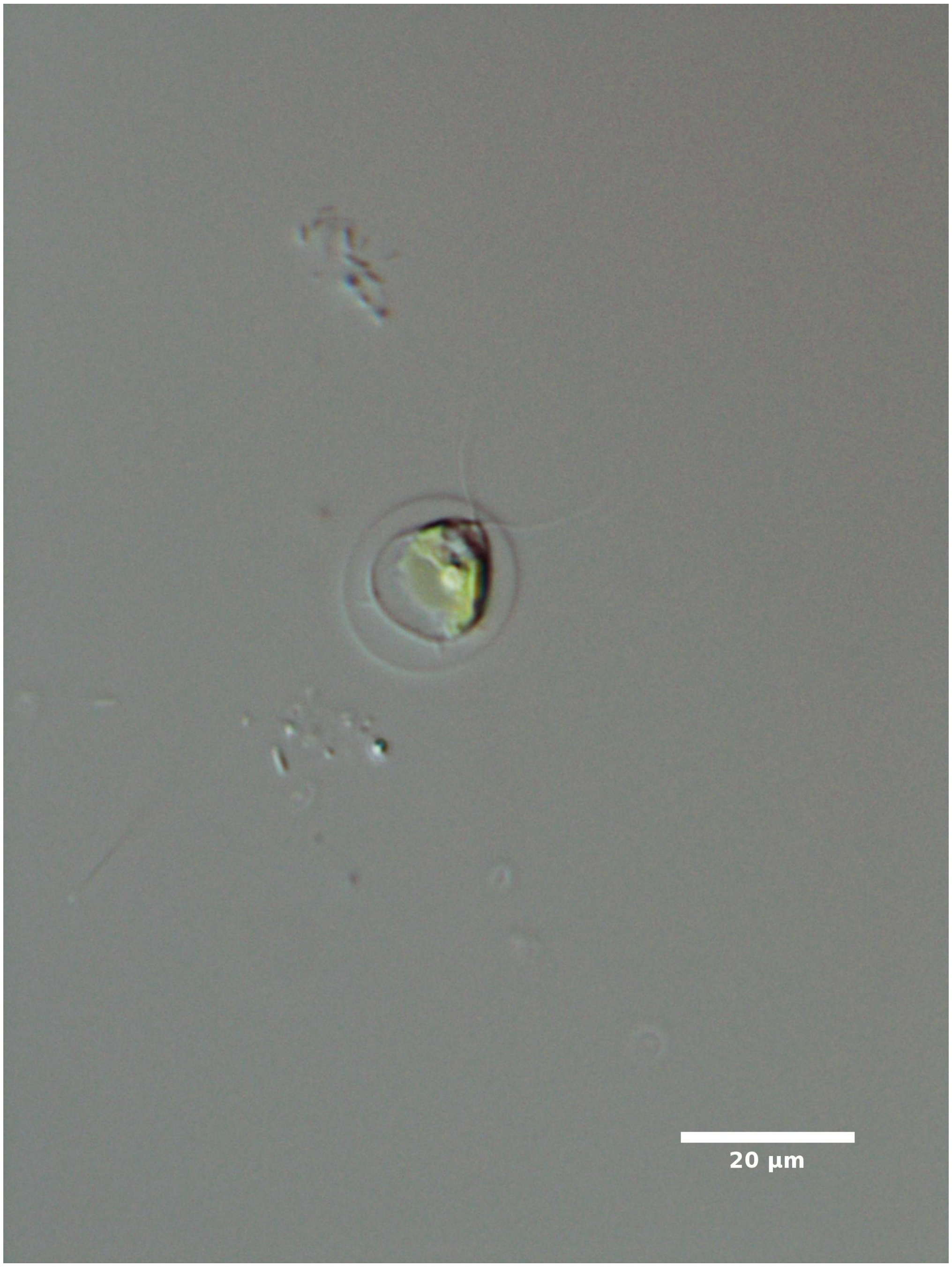


Figure 2.31: *Vitreochlamys*? (600x DIC), small pond near Artist Point ridge trail, Mt. Baker area, June 29, 2015.

Figure 2.32: *Vitreochlamys*? (600x DIC), small pond near Artist Point Ridge trail, Mt. Baker area, June 29, 2015.

Figure 2.33: Inactivated *Chlamydomonas* around *Microcystis* colony (200x DIC), Lone Lake, IWS water quality sampling site, Island County, July 18, 2011.

Figure 2.34: Inactivated *Chlamydomonas* around *Microcystis* colony (600x DIC), Lone Lake, IWS water quality sampling site, Island County, July 18, 2011.

Figure 2.35: *Chlamydomonas nivalis* (200x DIC), snow sample near Triplet Lakes, Chelan County, July 29, 2011.

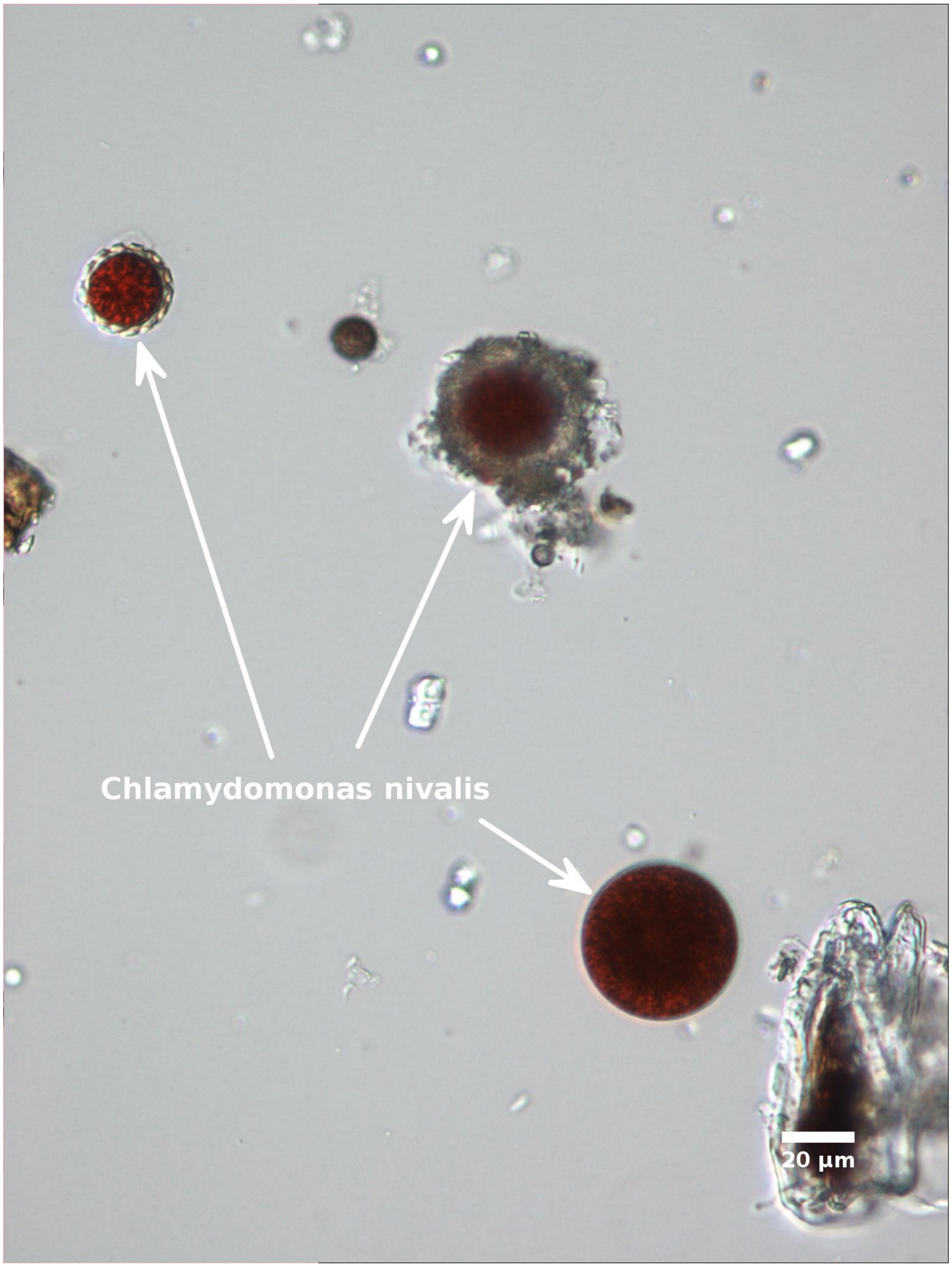


Figure 2.36: *Chlamydomonas nivalis* (200x DIC), Big Four Ice Caves snow sample, Mt. Loop Hwy, July 18, 2011.

Figure 2.37: *Chlamydomonas nivalis* (400x DIC), Big Four Ice Caves snow sample, Mt. Loop Hwy, July 18, 2011.

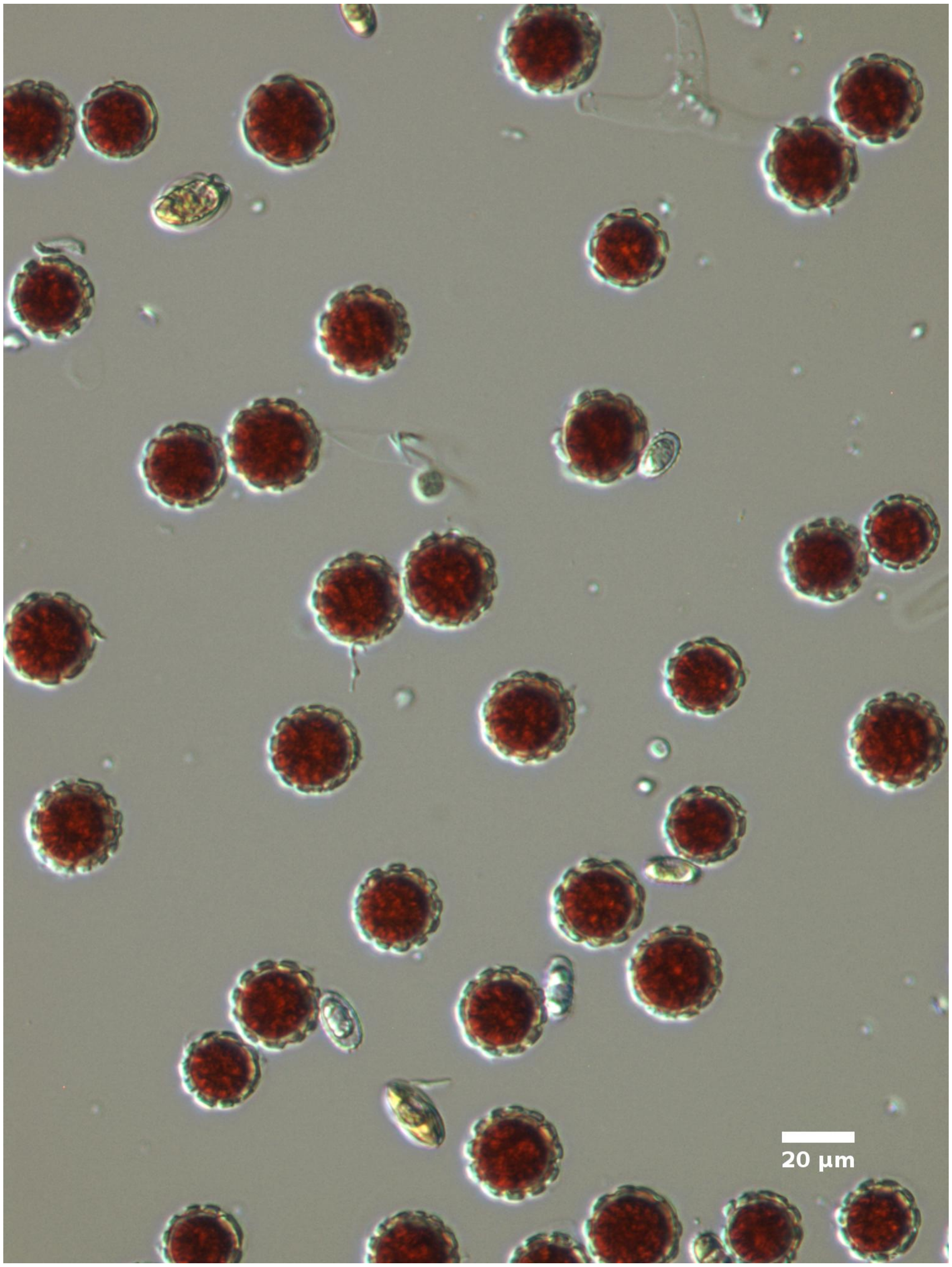


Figure 2.38: *Chlamydomonas nivalis* (200x DIC), snow sample near Foggy Lake (Gothic Basin), Mt. Loop Hwy, August 26, 2013.

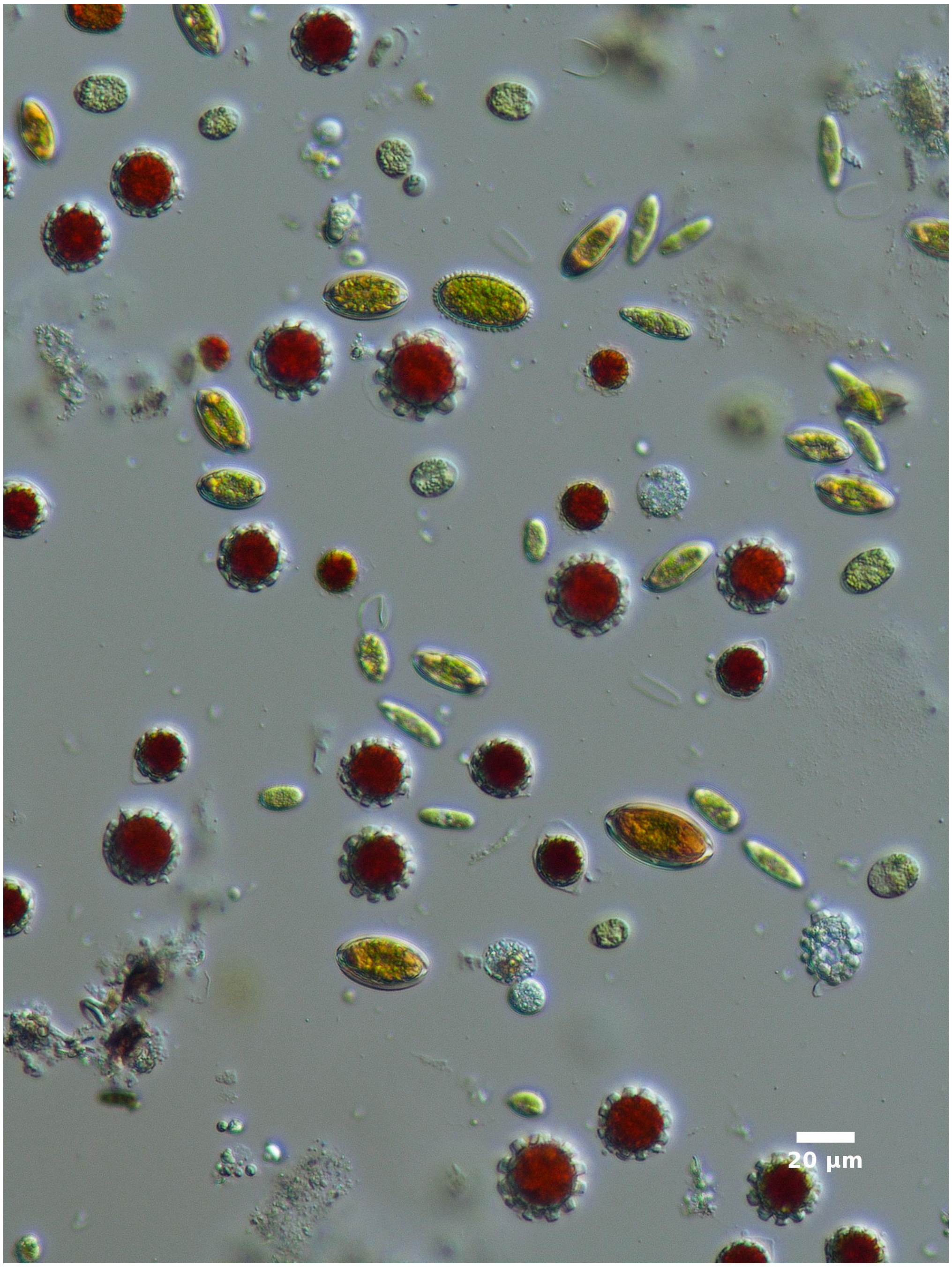


Figure 2.39: *Chlamydomonas nivalis* with other snow algae (200x DIC), snow sample near Cutthroat Lake, North Cascades along Hwy 20, June 18, 2014.

2.4 *Chlorogonium* Ehrenberg

Local taxa
Chlorogonium spp.

Abundance
Moderately common, but easily overlooked.

Local measurements		Width	Length	Biovolume†
Chlorogonium sp.1	min	1.9 μm	7.7 μm	14.7 μm^3
cells (spheroid)	med	3.2 μm	9.0 μm	50.0 μm^3
	max	3.8 μm	9.8 μm	72.6 μm^3
Chlorogonium sp.2	min	3.5 μm	7.0 μm	58.4 μm^3
cells (spheroid)	med	4.4 μm	8.6 μm	85.0 μm^3
	max	5.3 μm	11.4 μm	157 μm^3

†Calculated using original measurements, not summary values.

Description
Chlorogonium cells are solitary and oval, elliptical, or fusiform. The cells have two equal length apical flagella and a prominent eyespot (Figures 2.40–2.47). Although *Chlorogonium* cells have two flagella and an eyespot, the cells are usually stationary and often embedded in the mucilage of other algae. Olrik (1998) reports that *Chlorogonium* can be mixotrophic, and Dillard (pers. comm., 2010) confirmed that *Chlorogonium* is often associated with desmid mucilage.

There appear to be at least two distinctive local species that are common in plankton samples. *Chlorogonium* sp.1 has tiny, inconspicuous, elliptical cells, with strongly recurved flagella (Figures 2.40–2.43). The cells are almost always stationary, usually associated with the mucilage layer surrounding desmids and other algae. *Chlorogonium* sp.2 cells are oval or broadly elliptical, with slightly recurved flagella (Figures 2.44–2.47). The cells are occasionally solitary and planktonic, but are more likely to be associated with the mucilage layer of other algae like *Synura* or *Mallomonas*.[10]

[10]See **Freshwater Algae in Northwest Washington, Volume IV. Chrysophyceae, Xanthophyceae, and Haptophyta**.

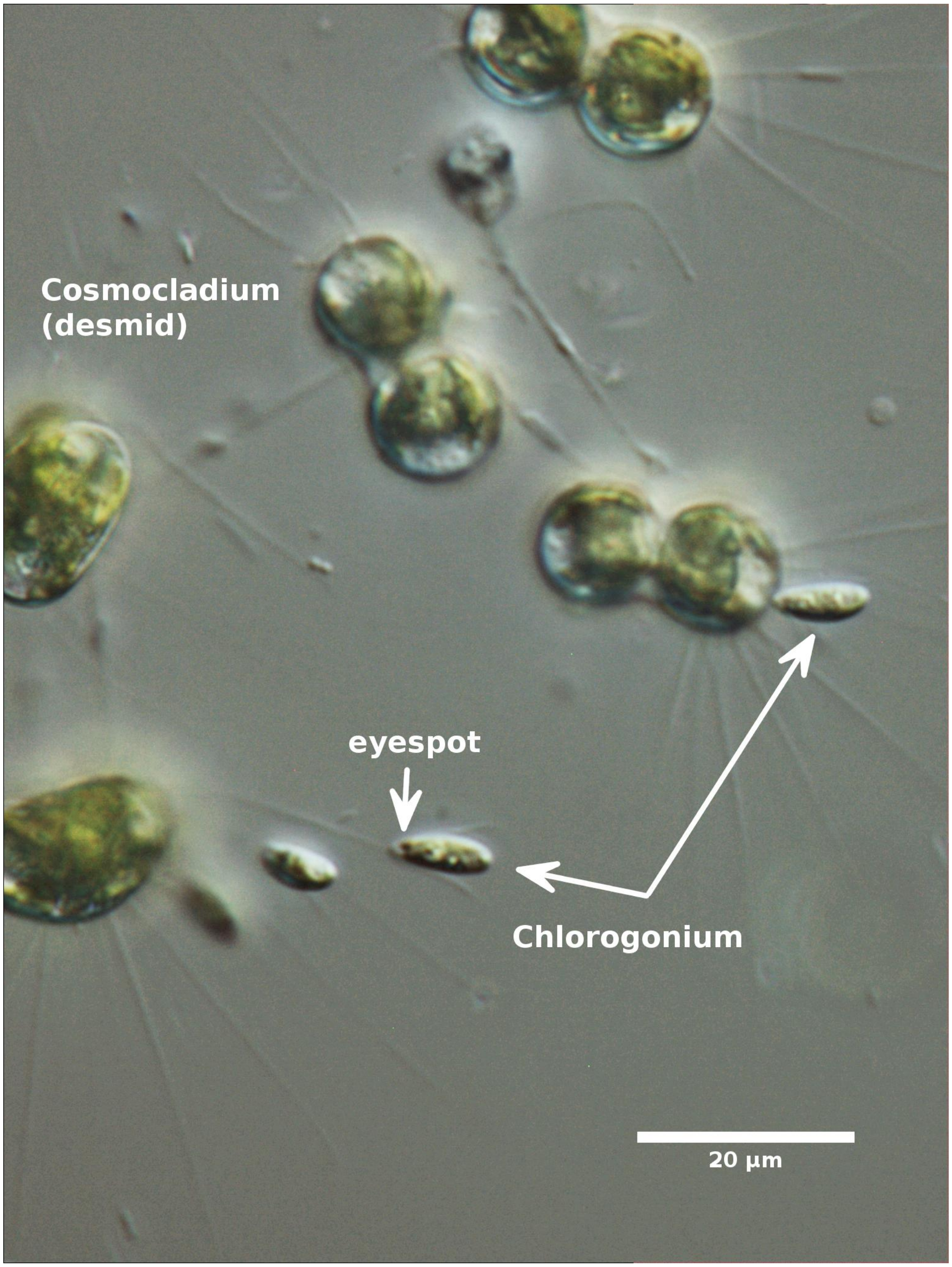


Figure 2.40: *Chlorogonium* sp.1 associated with *Cosmocladium* (600x DIC), Goss Lake, IWS water quality sampling site, Island County, October 6, 2009.

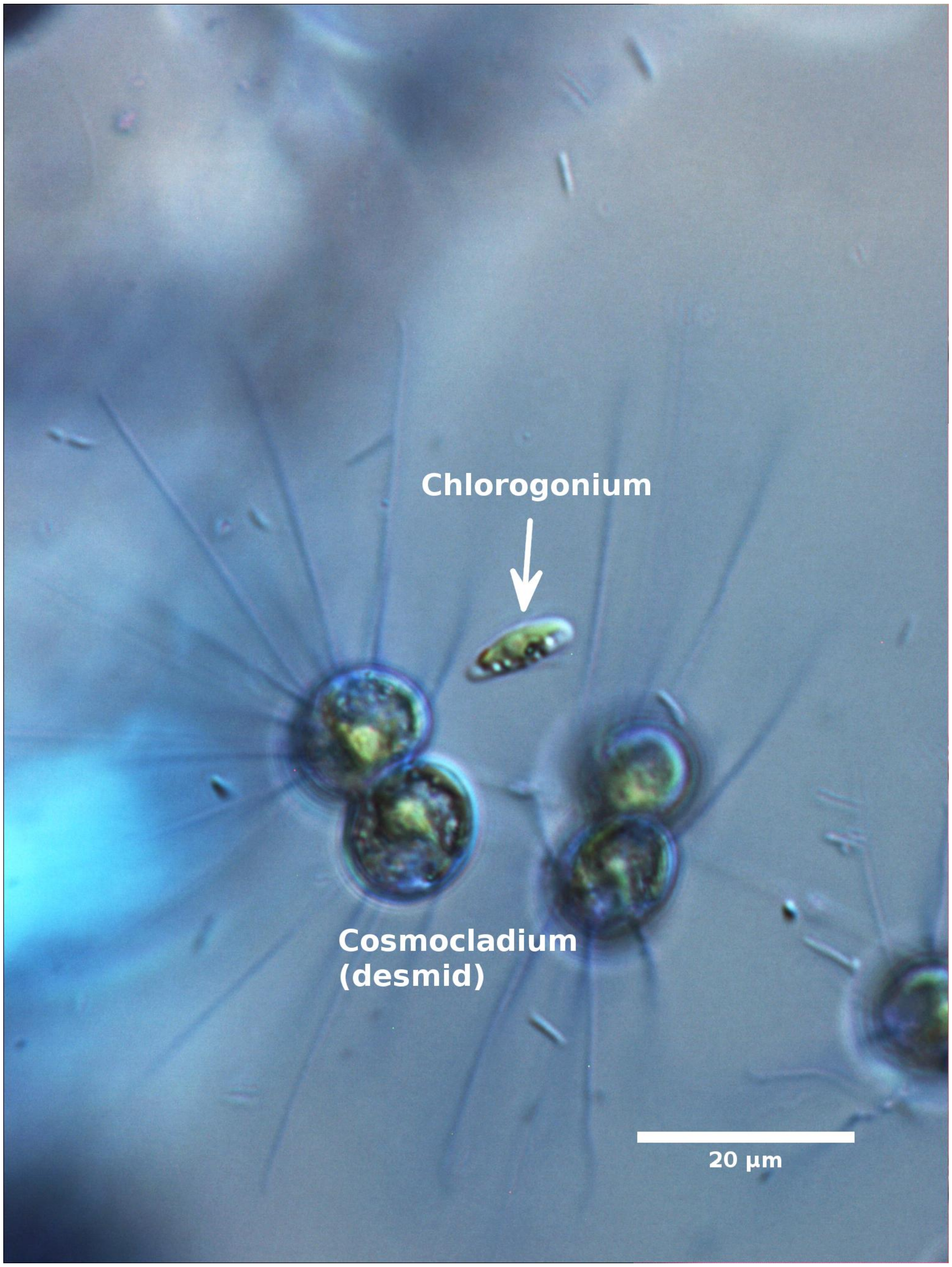


Figure 2.41: *Chlorogonium* sp.1 in *Cosmocladium* mucilage stained with methylene blue (600x DIC), Lake Martha, IWS water quality sampling site, Snohomish County, June 22, 2010.

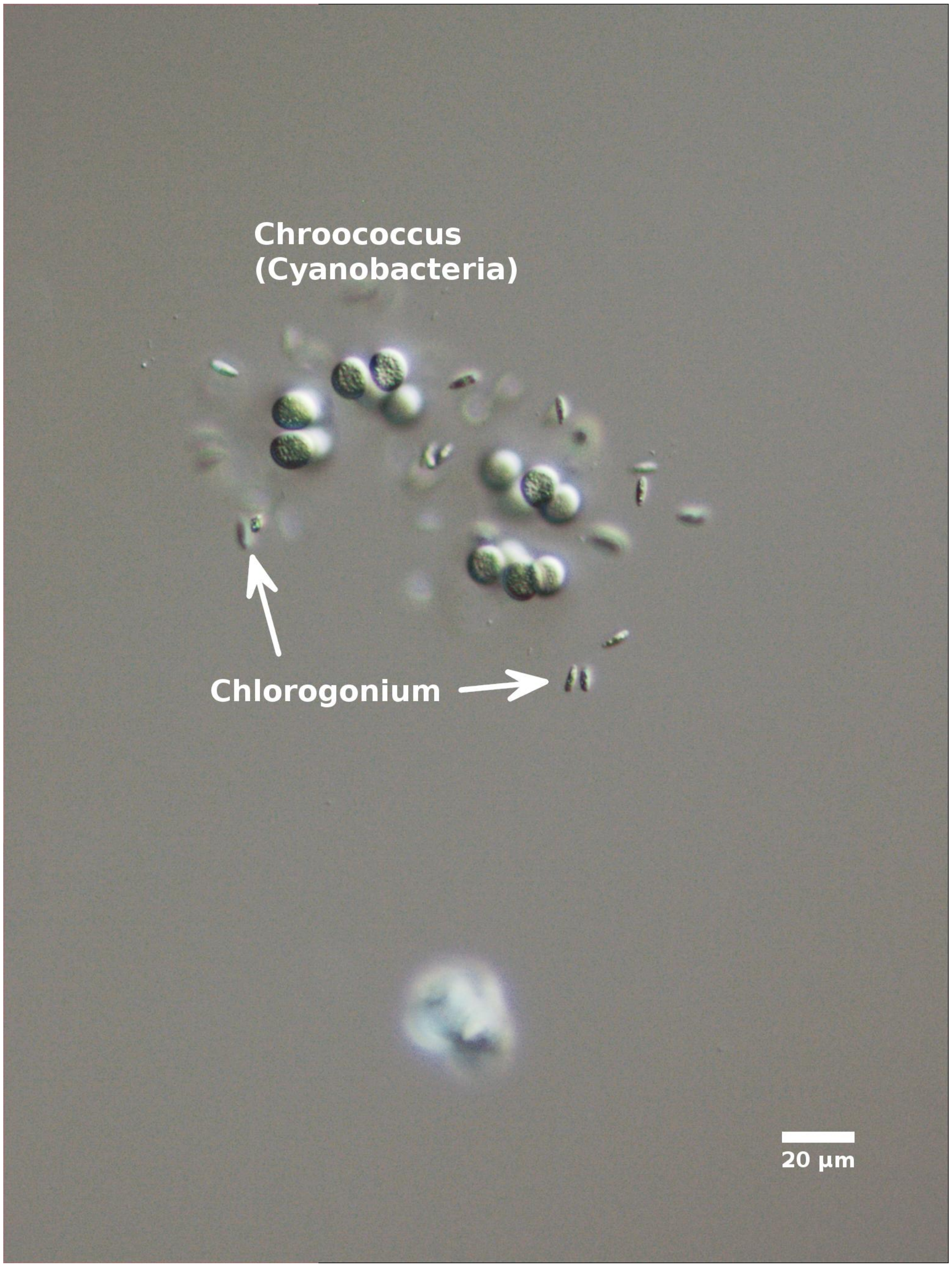


Figure 2.42: *Chlorogonium* sp.1 associated with *Chroococcus* (200x DIC), Lake Martha, IWS water quality sampling site, Snohomish County, June 21, 2010.

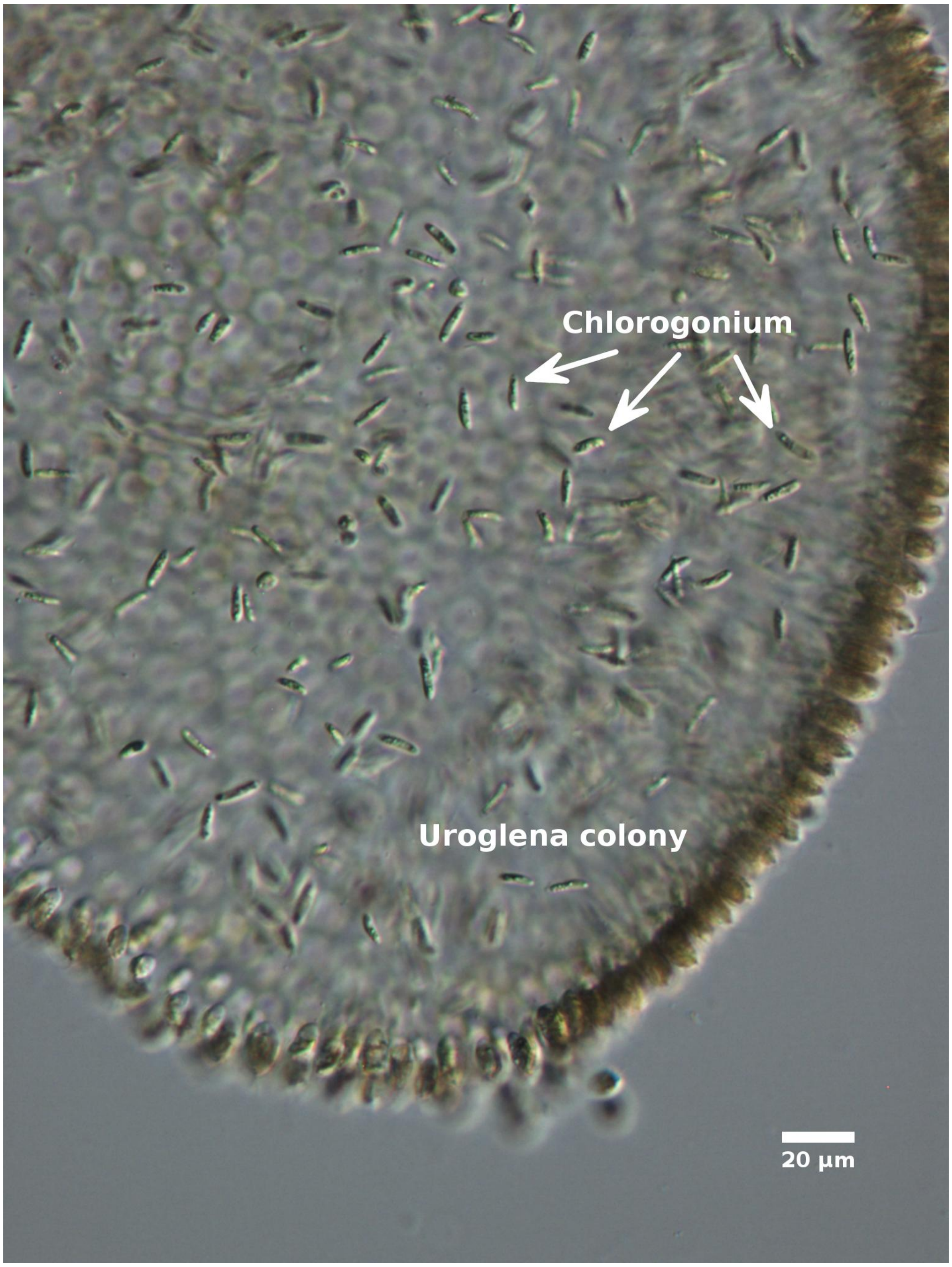


Figure 2.43: *Chlorogonium* sp.1 associated with *Uroglena* (200x DIC), Tennant Lake, IWS water quality sampling site, Whatcom County, July 29, 2013.

Figure 2.44: *Chlorogonium* sp.2 (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, November 2, 2011.

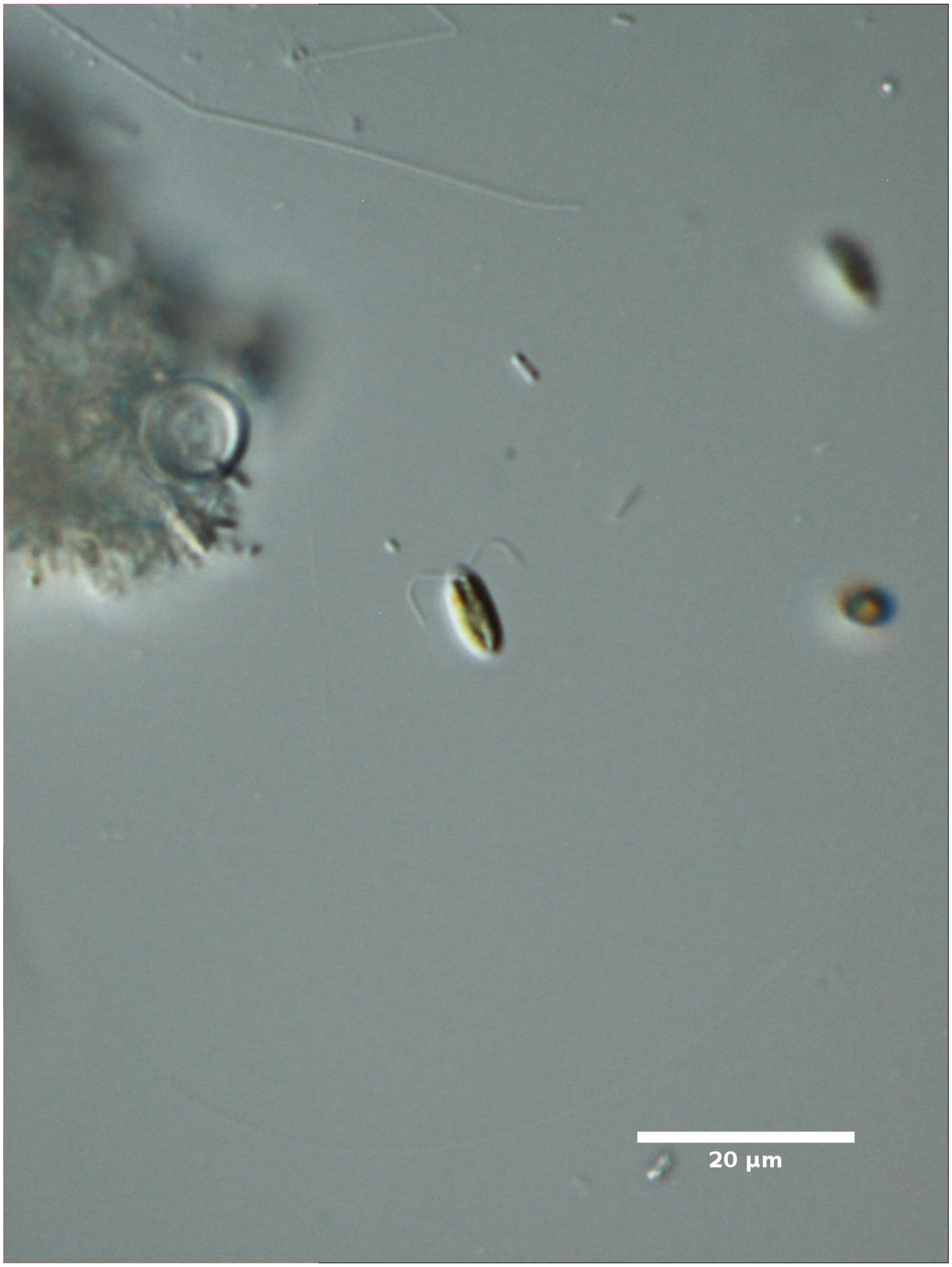


Figure 2.45: *Chlorogonium* sp.2 (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 5, 2011.

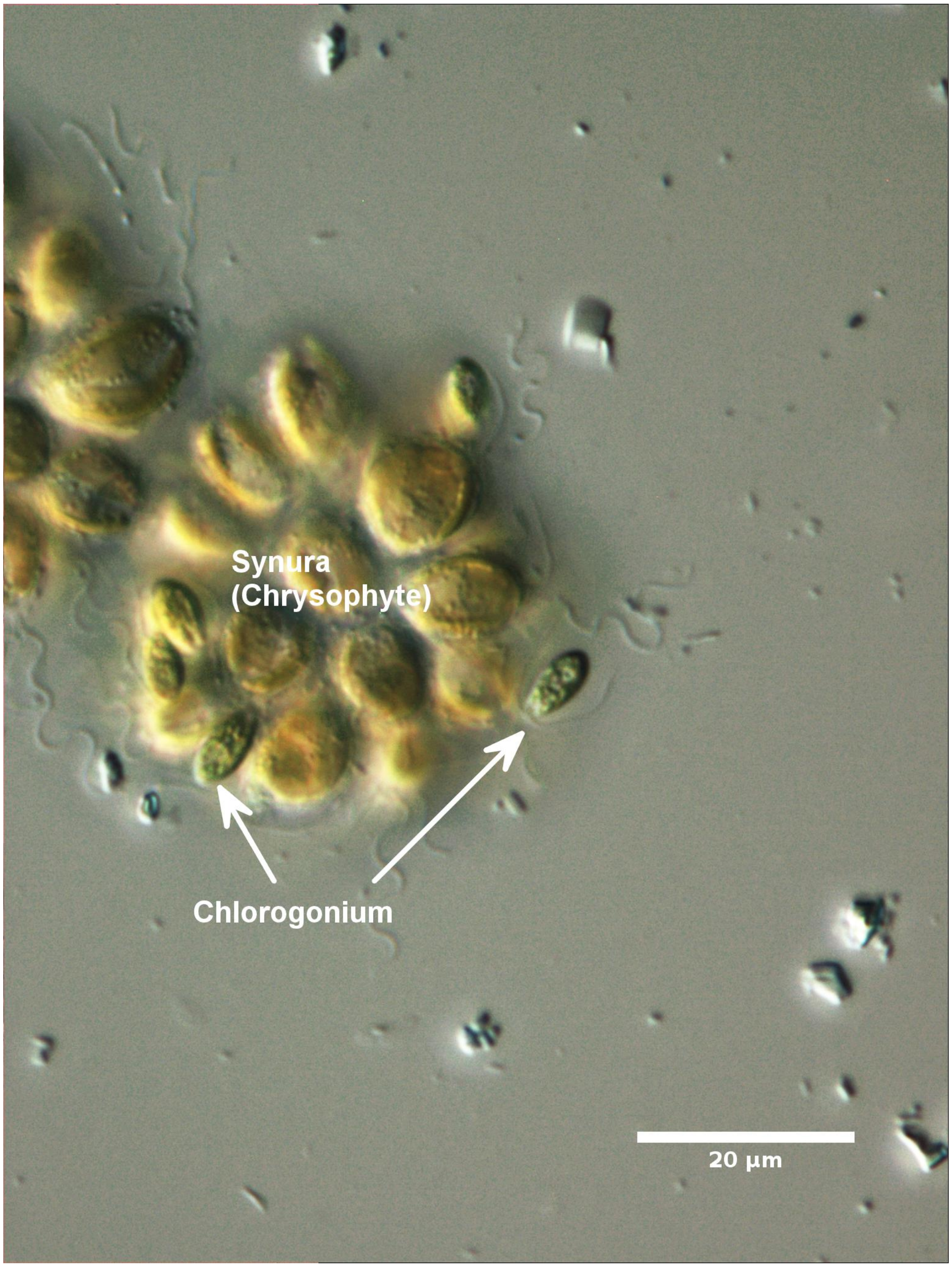


Figure 2.46: *Chlorogonium* sp.2 associated with *Synura* (600x DIC), Lake Geneva, IWS water quality sampling site, Whatcom County, July 12, 2011.

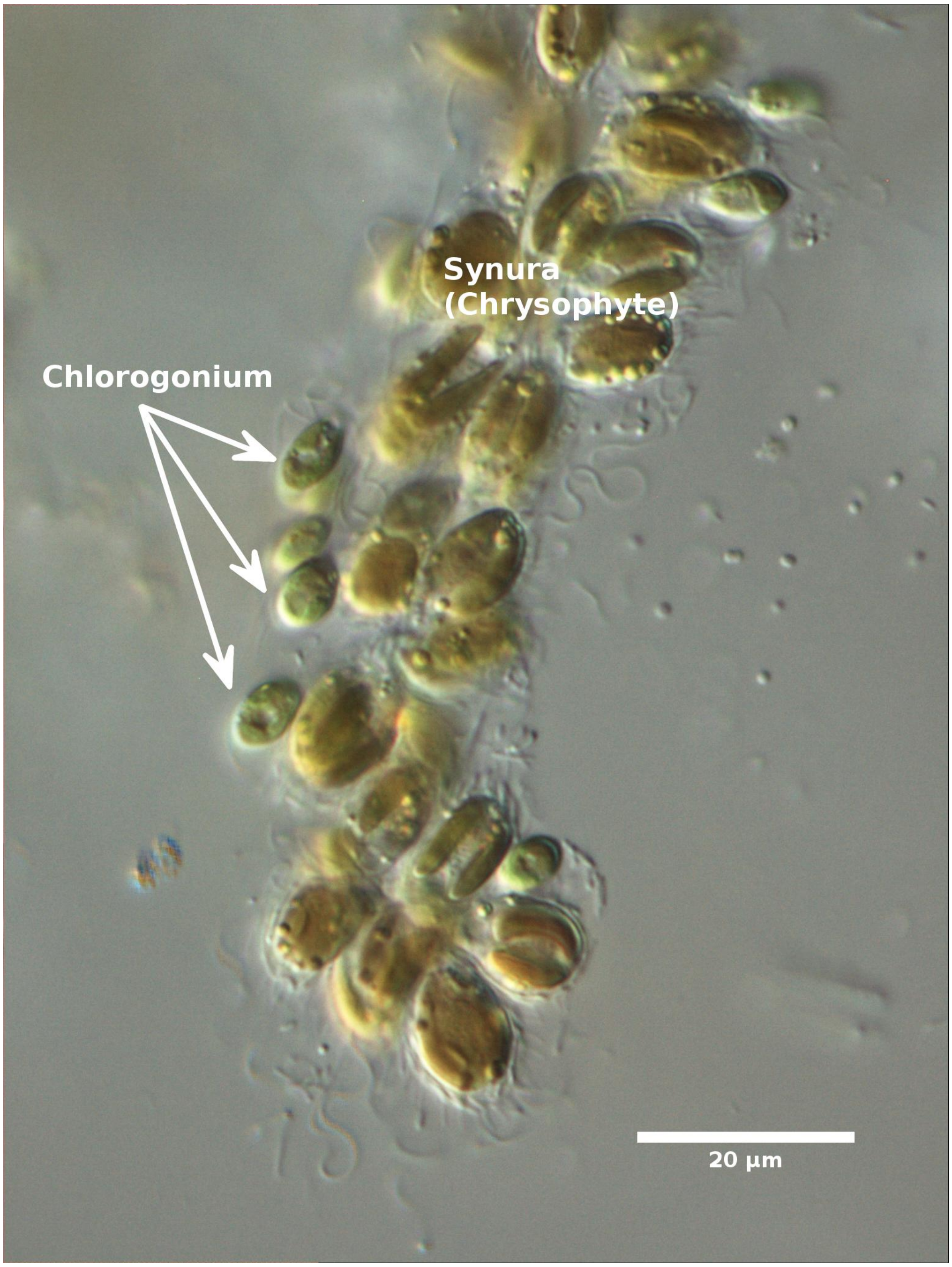


Figure 2.47: *Chlorogonium* sp.2 associated with *Synura* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, March 30, 2012.

2.5 *Chloromonas* Gobi

Local taxa
Chloromonas brevispina (F. E. Fritsch) Hoham, S. Roemer & Mullet;
Chloromonas nivalis (Chodat) Hoham & Mullet

Abundance
Infrequently collected; common in snow samples.

Local measurements		Width	Length	Biovolume†
Chloromonas brevispina	min	8.4 μm	16.6 μm	613 μm^3
cysts (spheroid)	med	12.2 μm	20.5 μm	1,560 μm^3
	max	14.4 μm	29.1 μm	3,160 μm^3
Chloromonas nivalis	min	16.5 μm	27.6 μm	4,030 μm^3
cysts (spheroid)	med	19.5 μm	38.5 μm	7,470 μm^3
	max	21.3 μm	43.4 μm	9,410 μm^3

†Calculated using original measurements, not summary values.

Description
The vegetative cells of *Chloromonas* resemble *Chlamydomonas*, with two equal length apical flagella, a cup-shaped chloroplast, and a prominent eyespot. Both of the local species are snow algae, so the taxa are usually collected in the form of nonmotile cysts (Figures 2.48–2.55). The cysts are extremely diverse in size, shape, and color, which resulted in misclassifications by early taxonomist, who assigned multiple species names for different stages of cyst development (Hoham, et al., 1979). The cells store oil and may not stain dark purple or brown in Lugol's iodine solution.

Chloromonas brevispina cysts are elliptical, with bluntly rounded ends, and are covered with short, knobby spines (Figures 2.48–2.49). Yellow-green chloroplasts may be visible in the immature cysts, but the chloroplasts become obscured by red pigments as the cyst develops. The mature cysts are easily distinguished from other snow algae by their smaller size, yellow-green or orange color, and distinctive spines.

Chloromonas nivalis cysts are oval, elliptical or fusiform, depending on the stage of development (Figures 2.49–2.55). The immature cysts are oval or broadly elliptical and yellow-green. Mature cysts are fusiform, with distinctive ribs running the length of the cell. The yellow-green color becomes obscured by red pigments, especially near the poles. The mature cysts are easily distinguished from other snow algae by their fusiform shape, orange color, and distinctive longitudinal ribs.

The cysts of *Chloromonas brevispina* and *Chloromonas nivalis* lack the intense, bright red color that characterizes cysts of *Chlamydomonas nivalis* (Section 2.3, page 35; see comparison in Figure 2.55), and *Chlainomonas rubra* (Section 2.2, page 30).

Figure 2.48: *Chloromonas brevispina* mature cyst (600x DIC), snow sample on Lake Dorothy trail, Alpine Lakes Wilderness Area, July 22, 2013.

Figure 2.49: *Chloromonas brevispina* and *Chloromonas nivalis* (200x DIC), snow sample on Lake Dorothy trail, Alpine Lakes Wilderness Area, July 12, 2013.

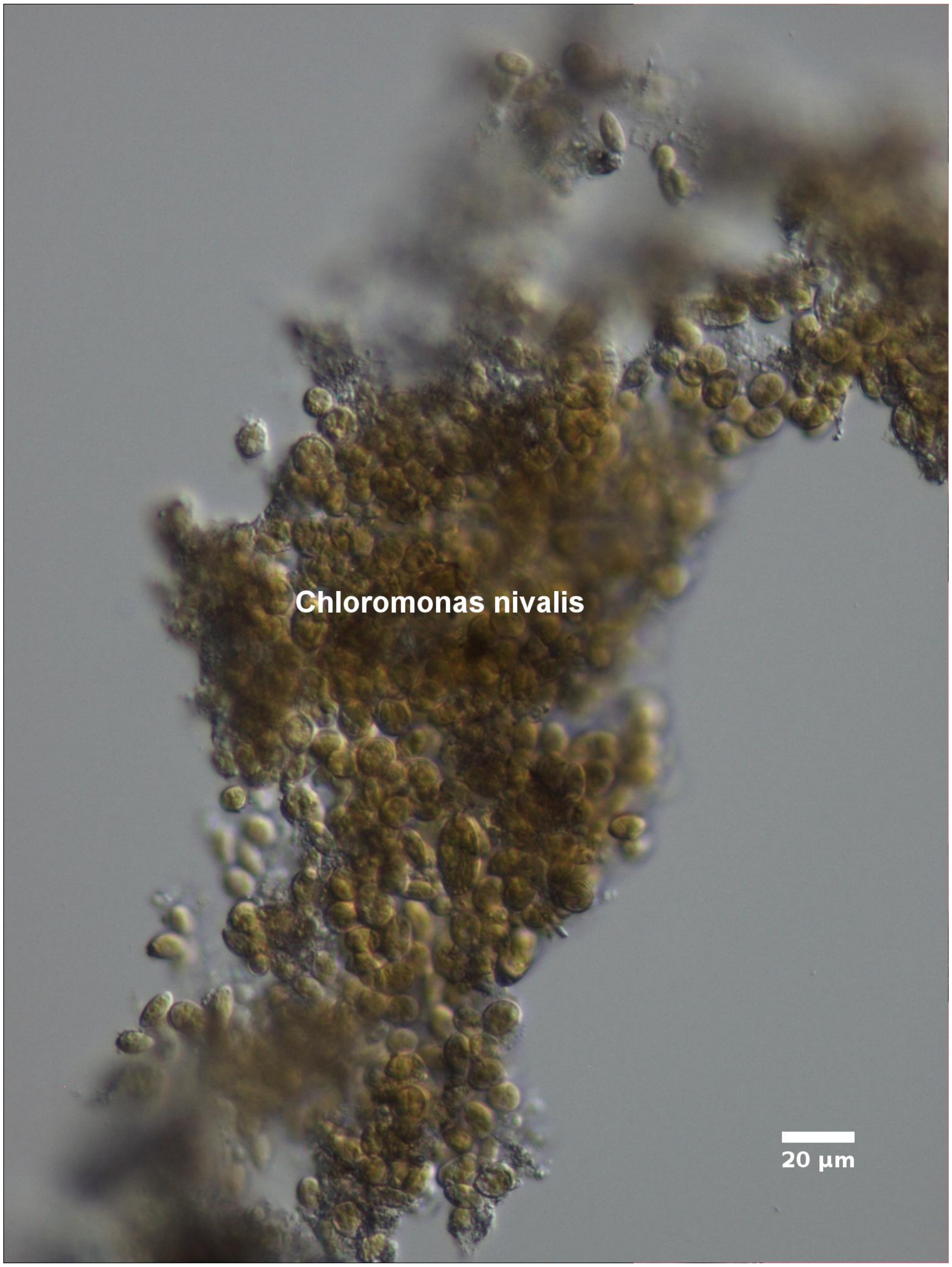


Figure 2.50: *Chloromonas nivalis* immature cysts (200x DIC), snow sample on Railroad Grade trail (Park Butte), North Cascades near Mt. Baker, September 6, 2011.

Figure 2.51: *Chloromonas nivalis* immature cysts (600x DIC), snow sample on Railroad Grade trail (Park Butte), North Cascades near Mt. Baker, September 6, 2011.

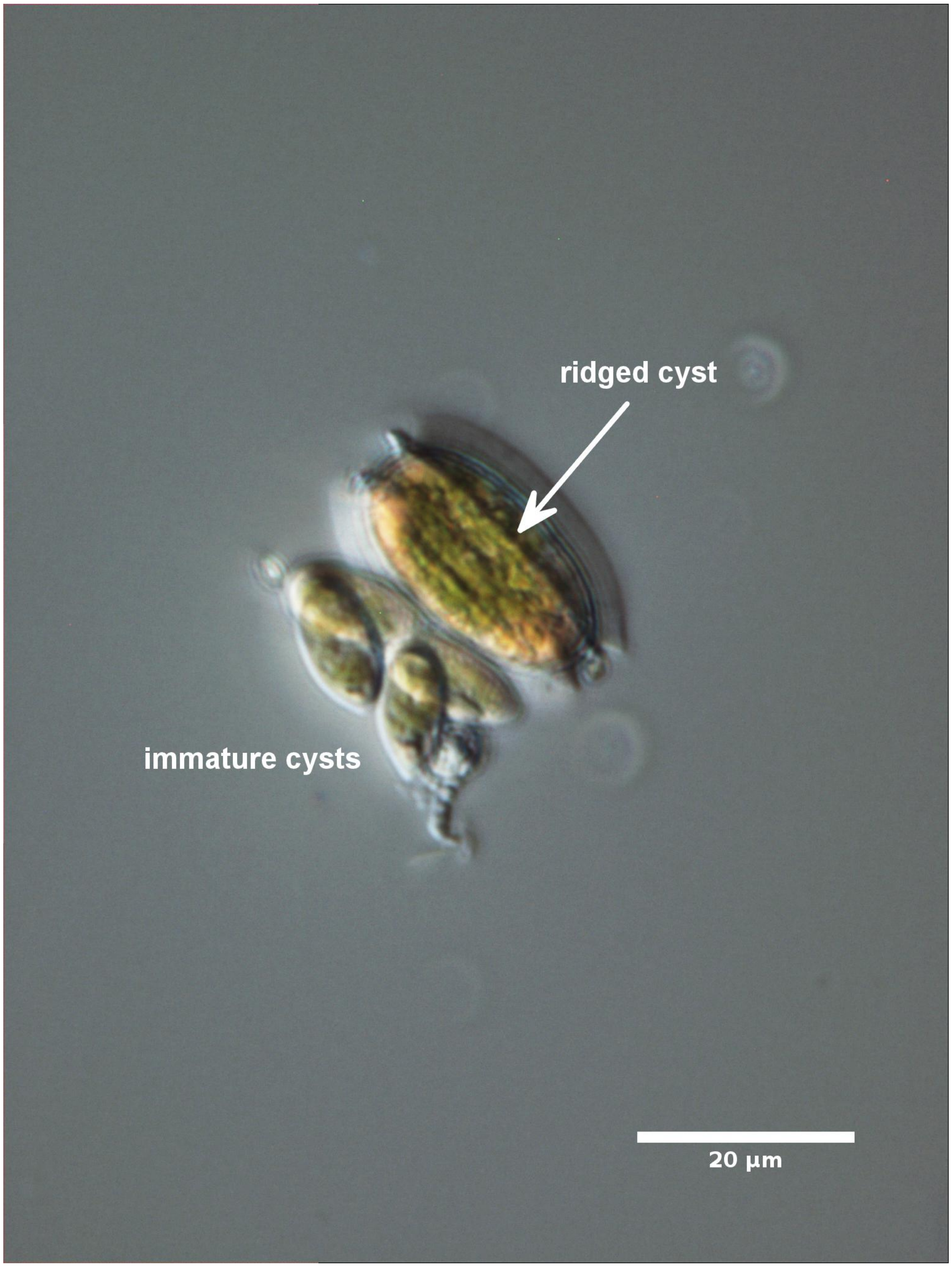


Figure 2.52: *Chloromonas nivalis* cysts (600x DIC), snow sample on Railroad Grade trail (Park Butte), North Cascades near Mt. Baker, September 6, 2011.

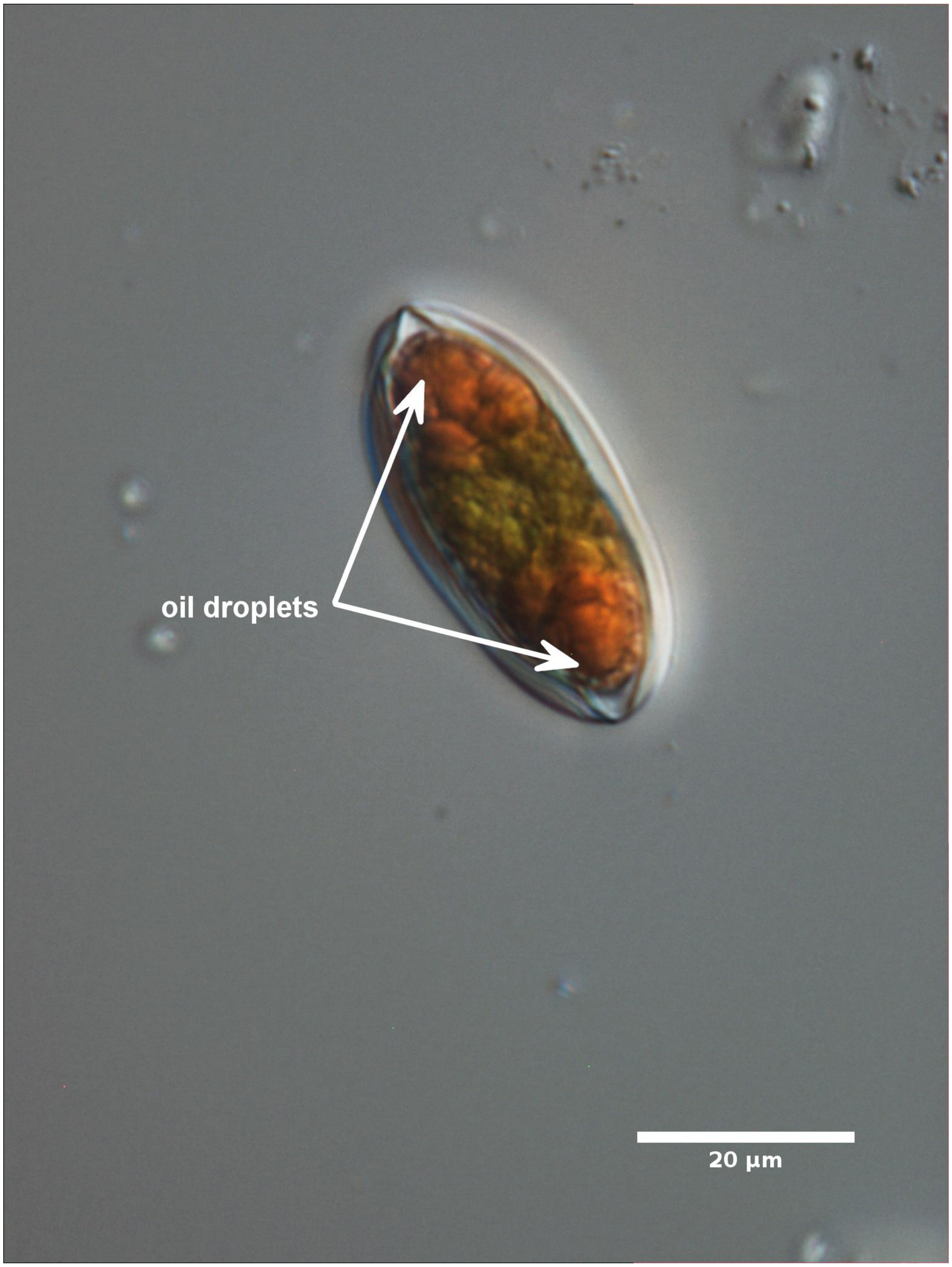


Figure 2.53: *Chloromonas nivalis* mature cyst (600x DIC), snow sample on Railroad Grade trail (Park Butte), North Cascades near Mt. Baker, September 6, 2011.

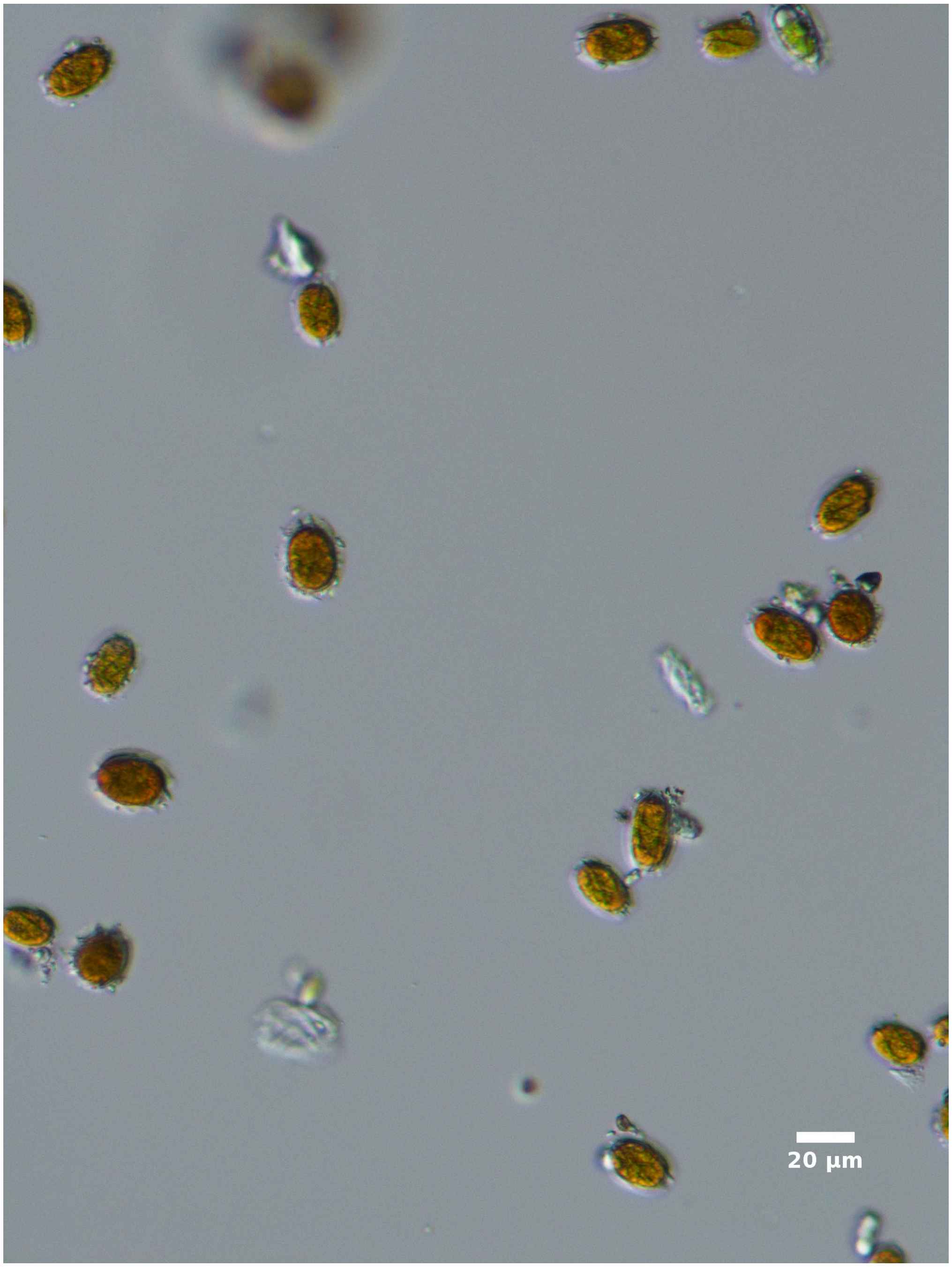


Figure 2.54: *Chloromonas nivalis* cysts (200x DIC), snow sample on Railroad Grade trail (Park Butte), North Cascades near Mt. Baker, August 2, 2015.

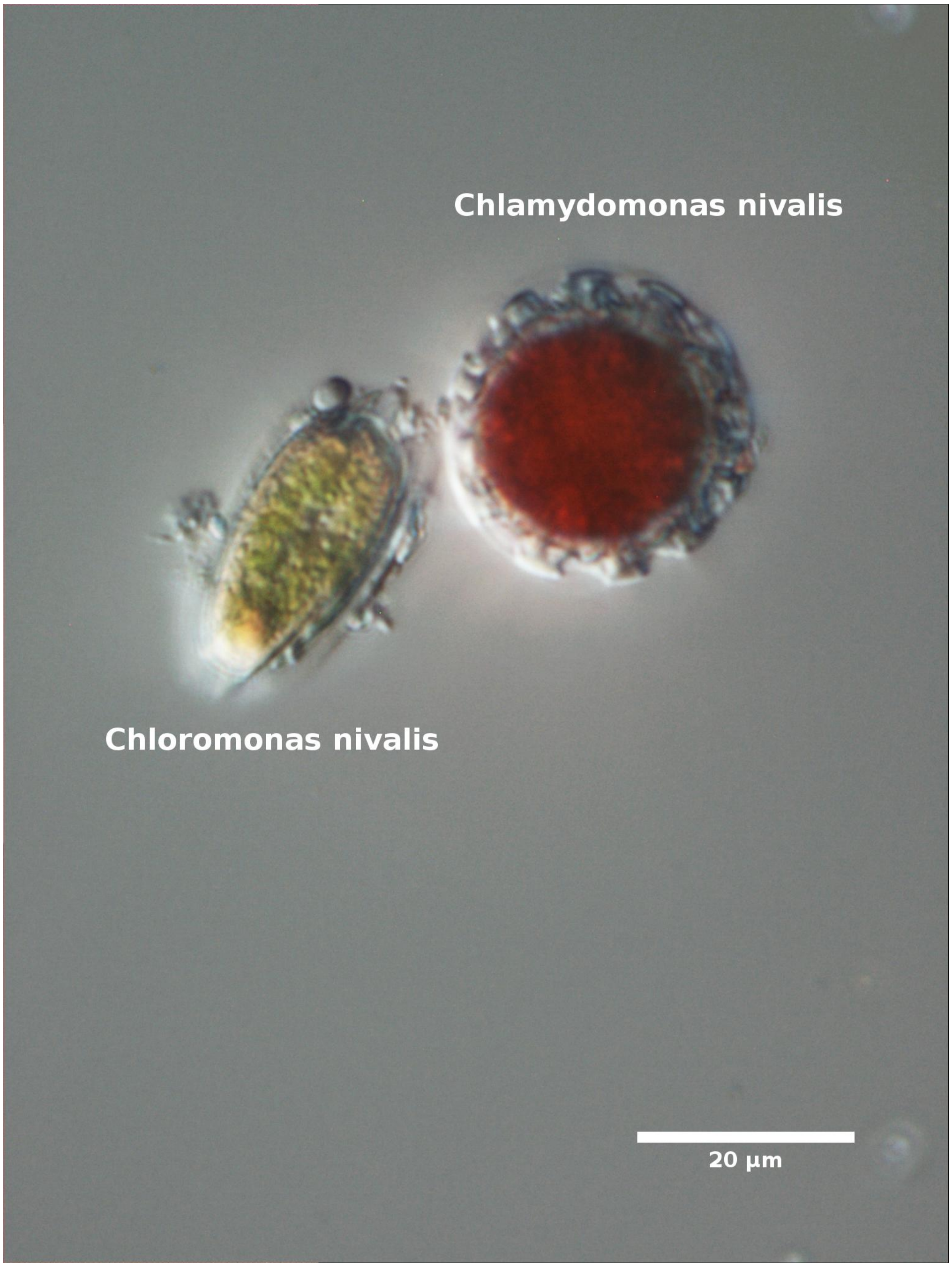


Figure 2.55: *Chlamydomonas nivalis* and *Chloromonas nivalis* (600x DIC), snow sample on Railroad Grade trail (Park Butte), North Cascades near Mt. Baker, September 6, 2011.

2.6 *Eudorina* Ehrenberg

Local taxa
Eudorina elegans Ehrenberg;
Eudorina unicocca G. M. Smith

Abundance
Eudorina elegans is moderately common and may be present in large numbers but rarely forms blooms; *Eudorina unicocca* is infrequently collected.

Local measurements		Width	Length	Biovolume†
Eudorina elegans	min	11.1 μm	12.4 μm	800 μm³
cells (spheroid)	med	16.4 μm	17.9 μm	2,510 μm³
	max	24.0 μm	24.0 μm	7,240 μm³
Eudorina elegans	min	59.8 μm	61.2 μm	–
colonies‡	med	73.9 μm	78.7 μm	–
	max	106.3 μm	130.9 μm	–
Eudorina unicocca	min	7.3 μm	8.1 μm	239 μm³
cells (spheroid)	med	8.6 μm	8.9 μm	341 μm³
	max	10.8 μm	12.0 μm	706 μm³
Eudorina unicocca	min	43.5 μm	48.1 μm	–
colonies‡	med	64.4 μm	69.6 μm	–
	max	82.6 μm	83.5 μm	–

†Calculated using original measurements, not summary values.
‡Colony biovolume can estimated using a spherical or spheroid shape.

Description
Eudorina cells are spherical, oval, or slightly compressed, but not wedge-shaped (compare to *Pandorina* in Section 2.10, page 115). The cells are grouped in spherical, elliptical, or cylindrical colonies that contain 8–64 cells (usually 16–32). The colony is surrounded by a firm, clear, colonial mucilage (Figures 2.56–2.64). Each cell has a large, cup-shaped chloroplast, a reddish anterior eyespot, and two equal length flagella that emerge from the colonial mucilage through

visible channels (Figure 2.57). Asexual reproduction is common, with each cell dividing to form daughter colonies of tightly packed cells inside the old mother colony (Figures 2.59–2.61). The daughter colonies briefly resemble *Pandorina* colonies, but the cells begin separating shortly after division. The new daughter colonies disperse as the mother colony mucilage breaks down. New daughter colonies are easily recognized by their small size (Figure 2.58).

The most common species is *Eudorina elegans* (Figures 2.56–2.61), which is characterized by spherical or broadly elliptical colonies containing 16–32 cells surrounded by a firm, smooth mucilage layer. The individual cells are spherical or slightly compressed, but not wedge-shaped. Each cell has a massive chloroplast with 1–5 pyrenoids that are often inconspicuous. The colony in Figure 2.62 is probably also *Eudorina elegans*, but the cells have a single, large pyrenoid, which is atypical for the species. But this colony was collected during a bloom of *Eudorina elegans* in Lake Terrell, so it is likely that the large pyrenoids are just part of the morphological variability of this extremely common species.

Eudorina unicocca has much smaller cells compared to *Eudorina elegans*. The cells have a large, cup-shaped chloroplast that contains a single, large, basal pyrenoid (Figures 2.63–2.64). The colonial mucilage layer is wide, homogeneous, and often has a wavy posterior edge. One of the most distinctive features is the large, red eyespot found in cells on the anterior side of the colony. Cells located on the opposite end of the colony either lack an eyespot or have a very small, inconspicuous stigma (see description by Yamada, et al., 2008)

Figure 2.56: *Eudorina elegans* (400x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, March 30, 2012.

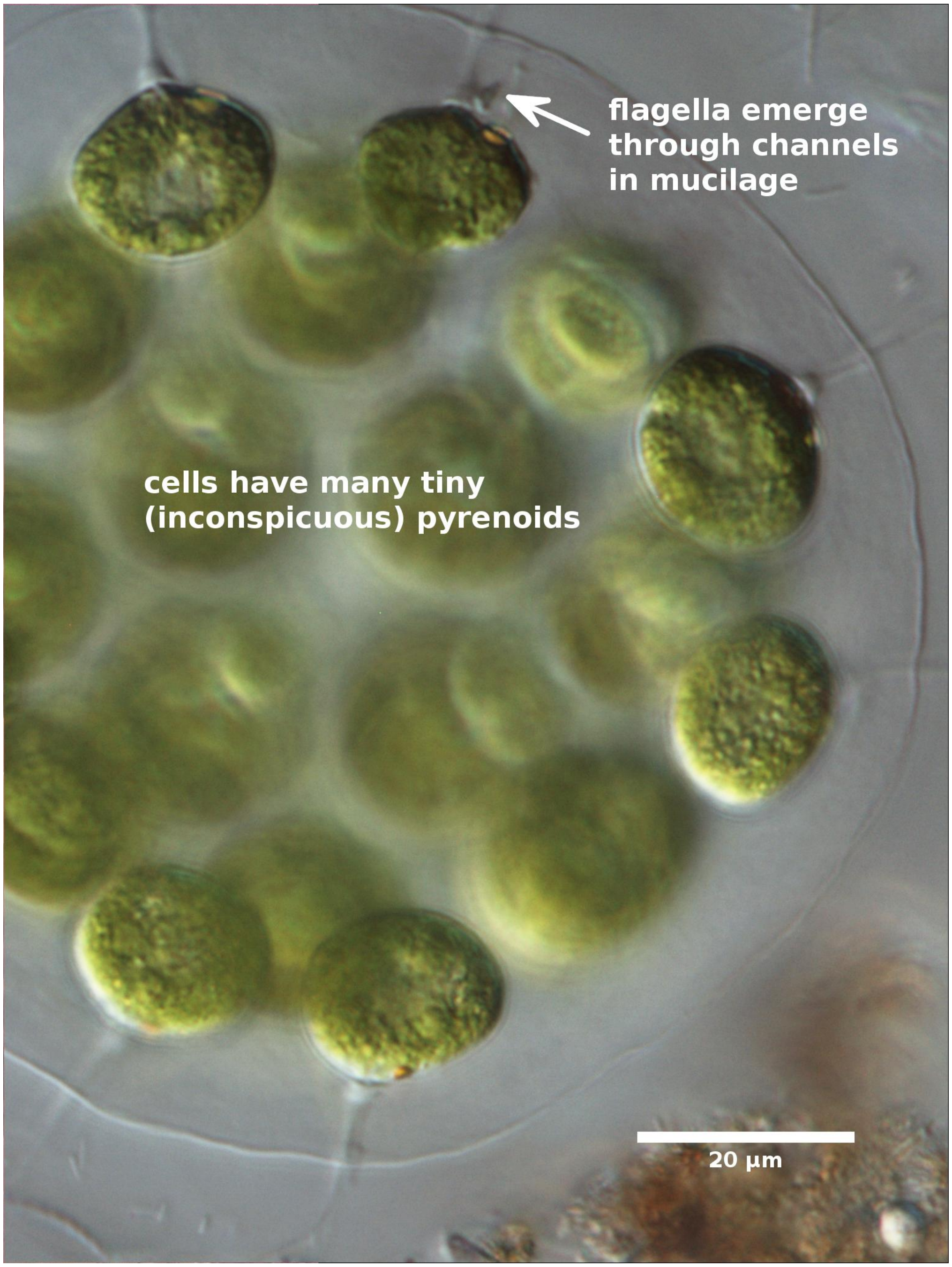


Figure 2.57: *Eudorina elegans* (600x DIC), Cranberry Lake, IWS water quality sampling site, Island County, September 1, 2008.

Figure 2.58: *Eudorina elegans* bloom (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, April 8, 2014.

Figure 2.59: *Eudorina elegans* reproduction (200x DIC), Cranberry Lake, IWS water quality sampling site, Island County, September 1, 2008.

Figure 2.60: *Eudorina elegans* reproduction (200x DIC), Lake Howard, IWS water quality sampling site, Snohomish County, September 22, 2009.

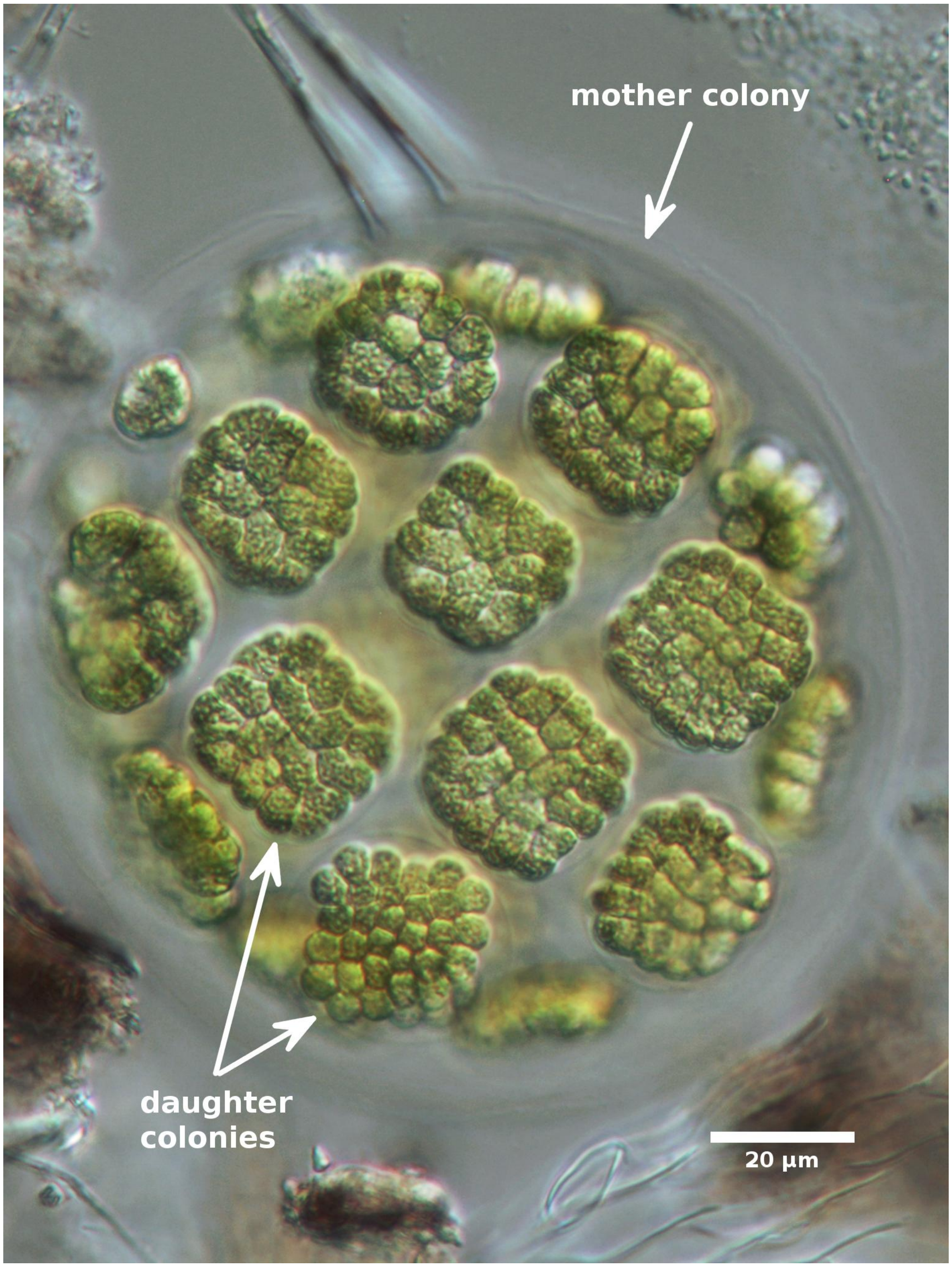


Figure 2.61: *Eudorina elegans* reproduction (400x DIC), Lake Sixteen, IWS water quality sampling site, Skagit County, September 11, 2012.

Figure 2.62: *Eudorina elegans*? (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, April 24, 2015.

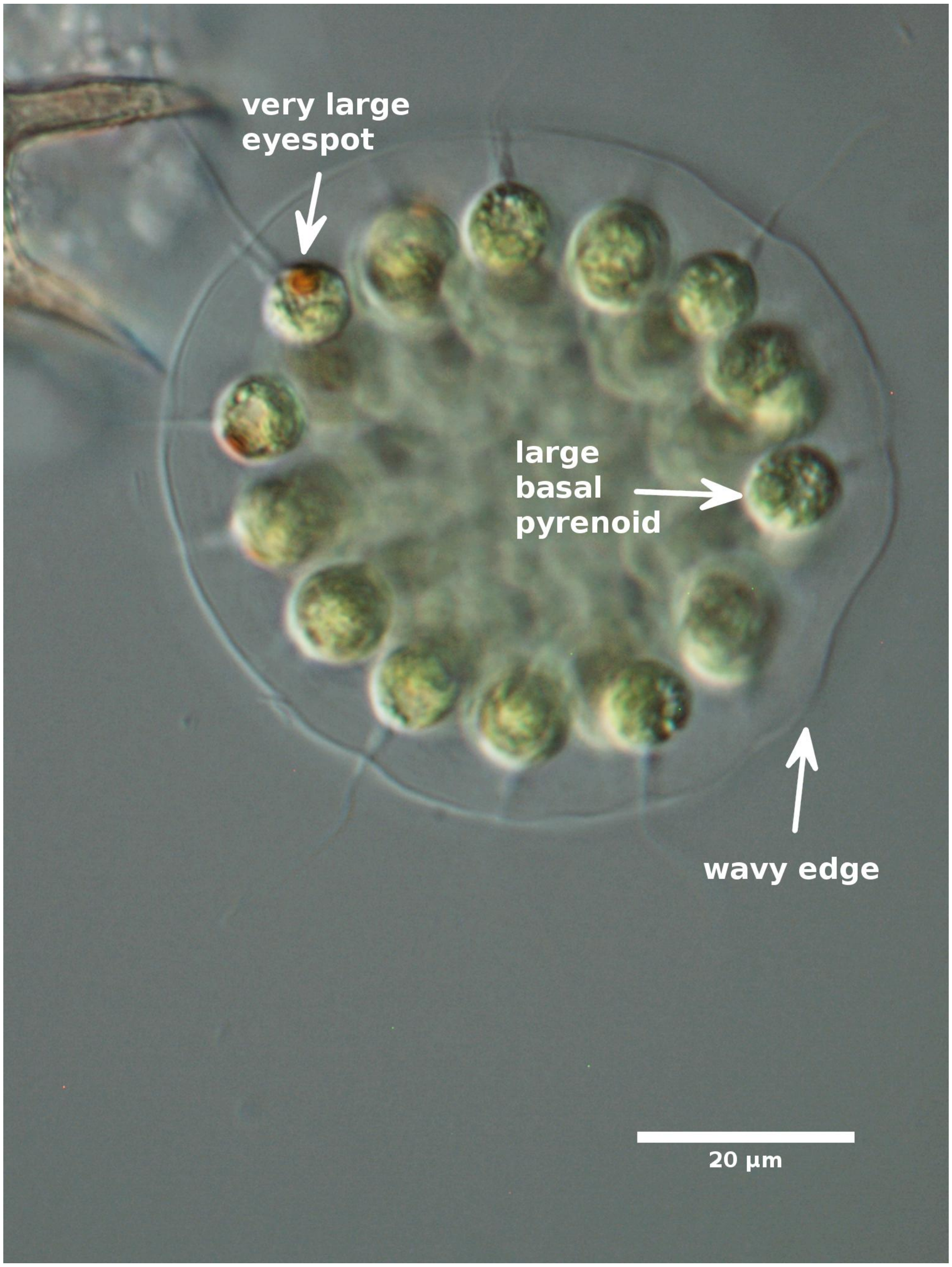


Figure 2.63: *Eudorina unicocca* (600x DIC), Grandy Lake, IWS water quality sampling site, Skagit County, August 7, 2013.

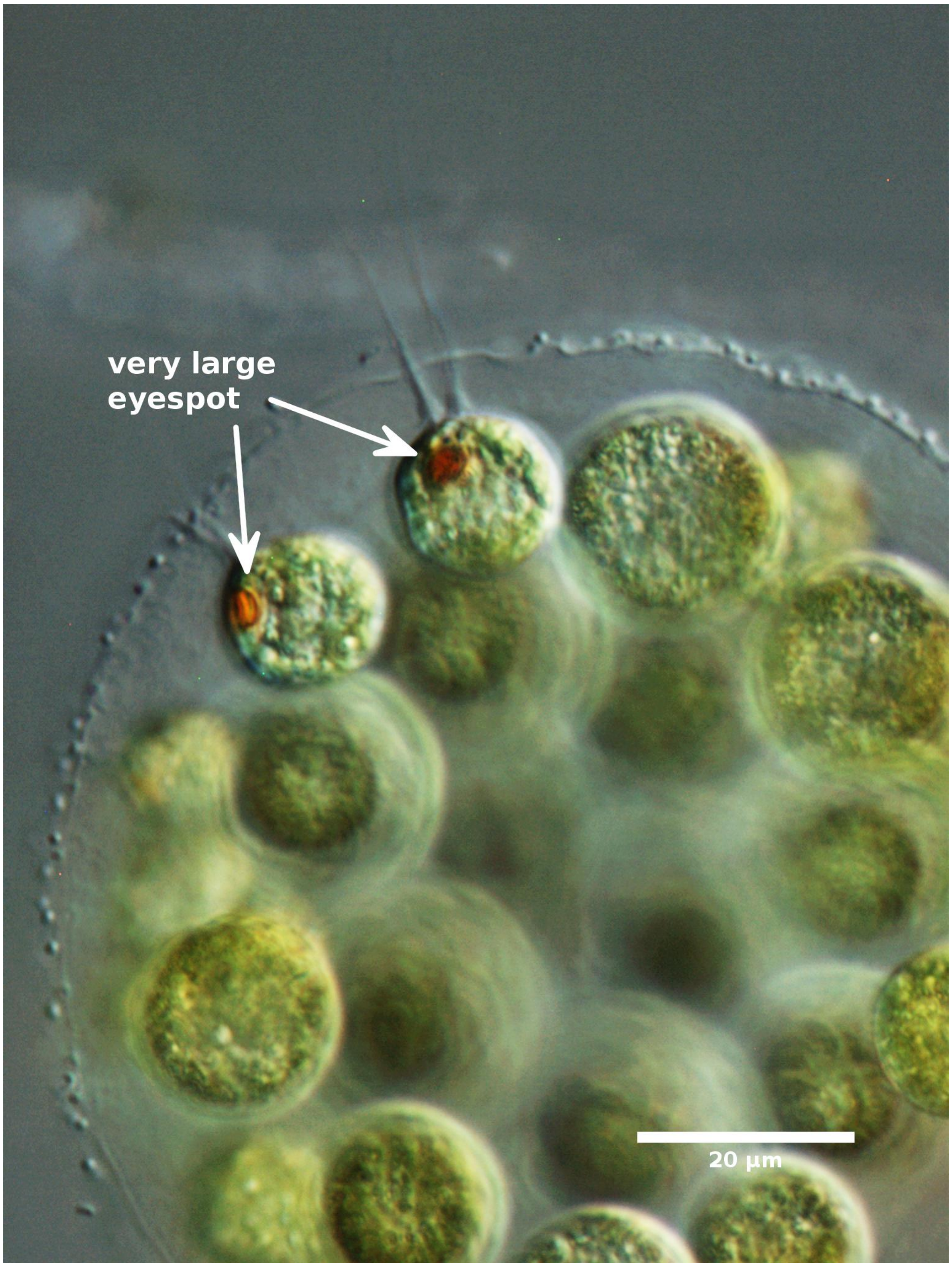


Figure 2.64: *Eudorina unicocca* (600x DIC), Grandy Lake, IWS water quality sampling site, Skagit County, August 6, 2013.

2.7 *Gonium* O. F. Müller and *Tetrabaena* (F. Dujardin) E. Fromentel

Local taxa
Gonium pectorale O. F. Müller;
Tetrabaena socialis (Dujardin) H. Nozaki & M. Itoh
(=*Gonium sociale* [Dujardin] Warming)

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Gonium pectorale	min	6.2 μm	7.6 μm	153 μm^3
cells (spheroid)	med	11.9 μm	14.8 μm	1,140 μm^3
	max	14.3 μm	18.5 μm	1,870 μm^3
Gonium pectorale	min	34.5 μm	37.1 μm	–
colonies‡	med	55.0 μm	59.5 μm	–
	max	69.5 μm	72.4 μm	–
Tetrabaena socialis	min	6.2 μm	7.9 μm	169 μm^3
cells (spheroid)	med	7.2 μm	9.6 μm	264 μm^3
	max	8.1 μm	10.7 μm	361 μm^3
Tetrabaena socialis	min	14.9 μm	16.7 μm	–
colonies‡	med	16.8 μm	18.0 μm	–
	max	18.7 μm	19.3 μm	–

†Calculated using original measurements, not summary values.
‡Colony biovolume can estimated using a rectangular box or elliptical prism shape.

Description
Gonium pectorale colonies are flat, forming a square or rhomboidal plate, which makes this species distinctive and easy to identify (Figures 2.65–2.68). The colony contains 16 cells, with 4 interior cells and 12 exterior cells. The individual

cells are spherical, oval, broadly elliptical, or pear-shaped, with two equal length flagella that are directed away from the colony center. The cells contain a cup-shaped chloroplast, an anterior eyespot, and are surrounded by a mucilage layer that forms net-like strands between the cells.

Asexual reproduction is common, with each cell dividing to form flat daughter colonies inside the old mother colony (Figures 2.67). *Gonium pectorale* colonies usually contain 16 cells, but 4-cell colonies may also be present (Figure 2.68). The 4-cell *Gonium pectorale* colonies can be distinguished from 4-celled *Tetrabaena socialis* colonies by the net-like mucilage and flagella that are directed away from the colony center.

Tetrabaena socialis colonies are tiny, consisting of four pear-shaped cells connected to each other by a thin, nearly invisible, mucilage strand (Figures 2.69–2.71). Each cell has a cup-shaped chloroplast, an apical eyespot, and a small apical knob (papilla). The cells are arranged cross-wise in the colony (like bowling pins) so that the flagella are directed upward from the colony surface. *Tetrabaena socialis* is listed as *Gonium sociale* in most older taxonomic keys.

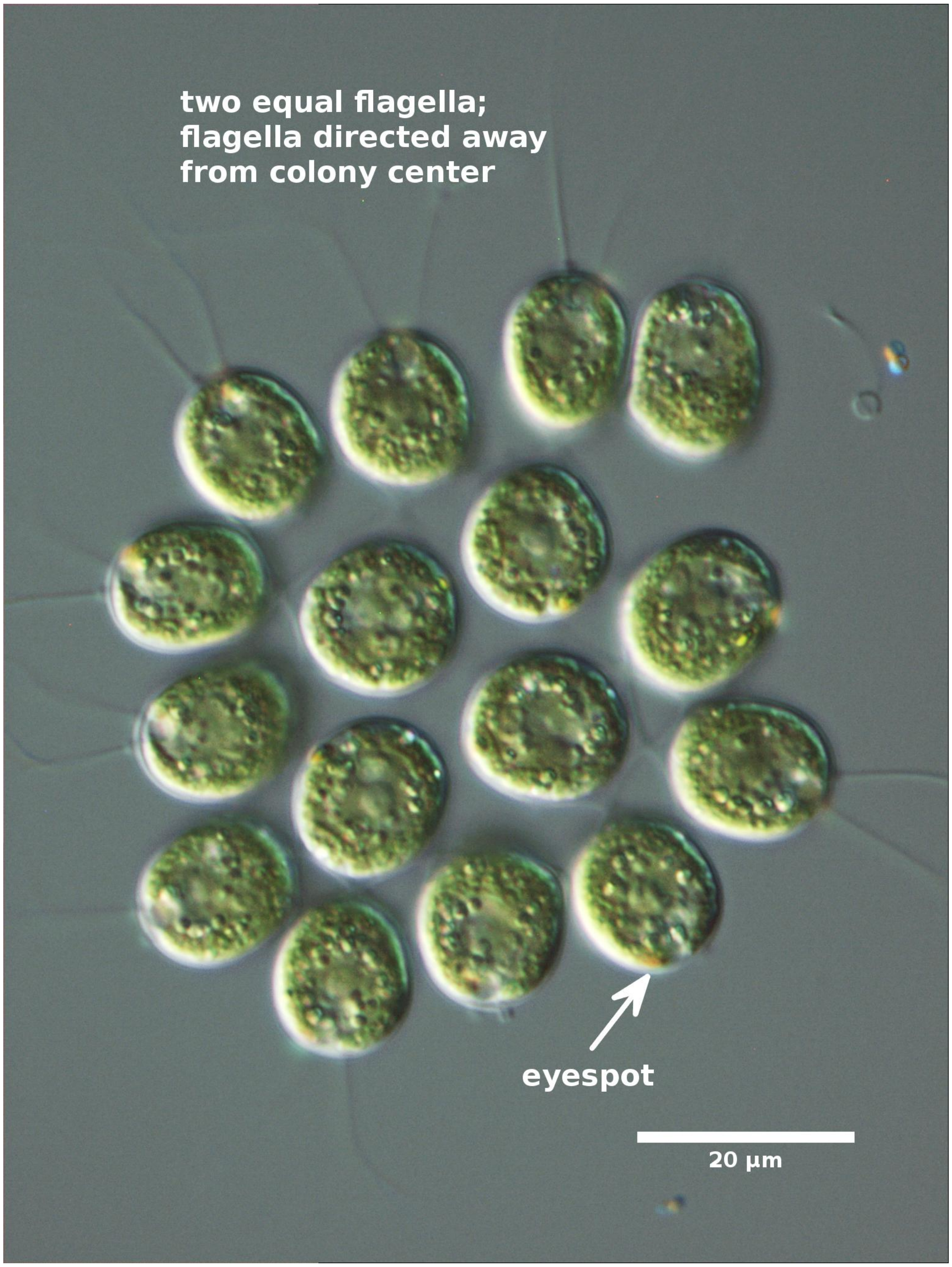


Figure 2.65: *Gonium pectorale* (600x DIC), Toad Lake, IWS water quality sampling site, Whatcom County, March 27, 2012.

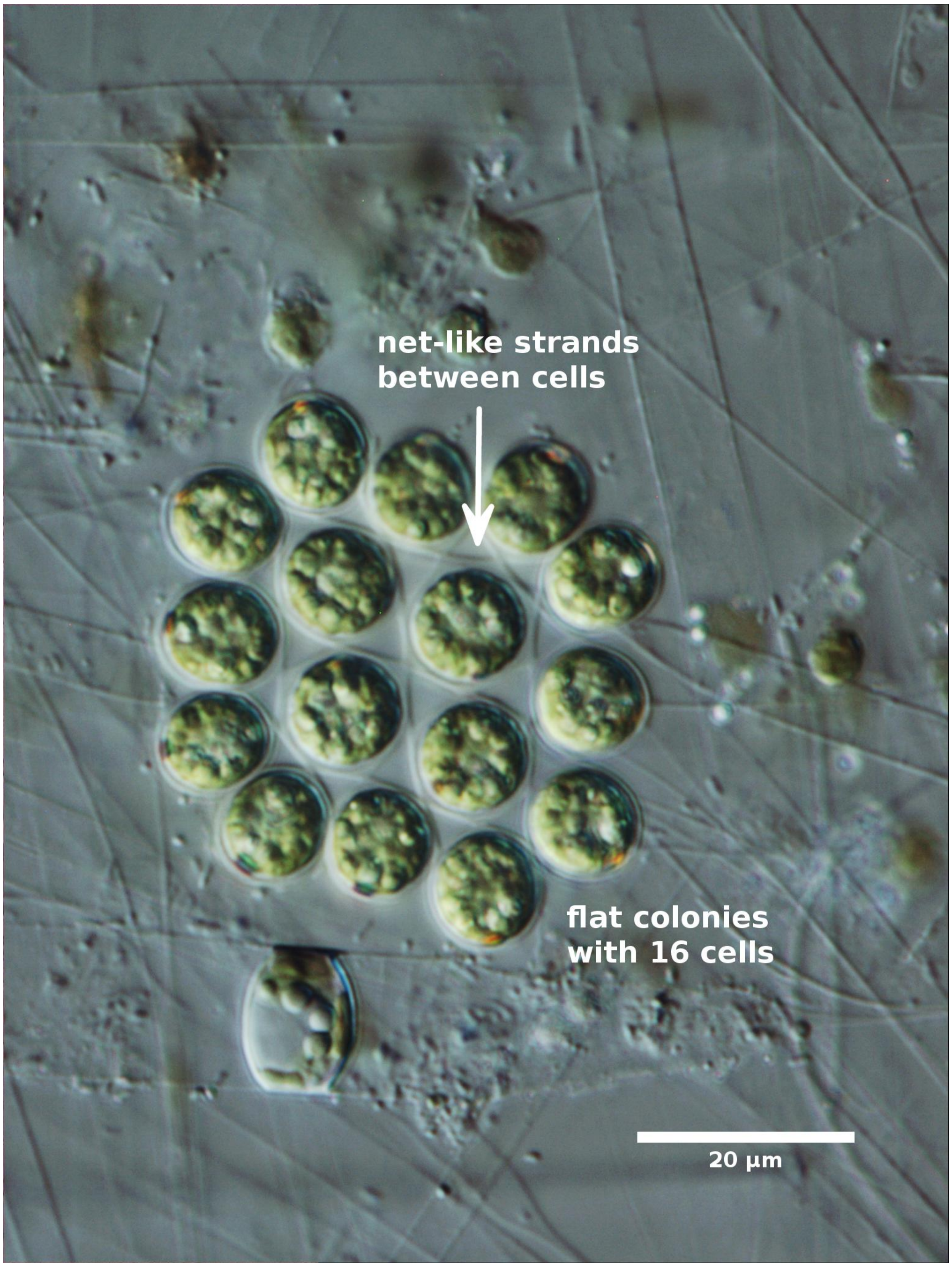


Figure 2.66: *Gonium pectorale* (600x DIC), Squalicum Lake, IWS water quality sampling site, Whatcom County, May 20, 2011.

Figure 2.67: *Gonium pectorale* reproducing (400x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, March 30, 2012.

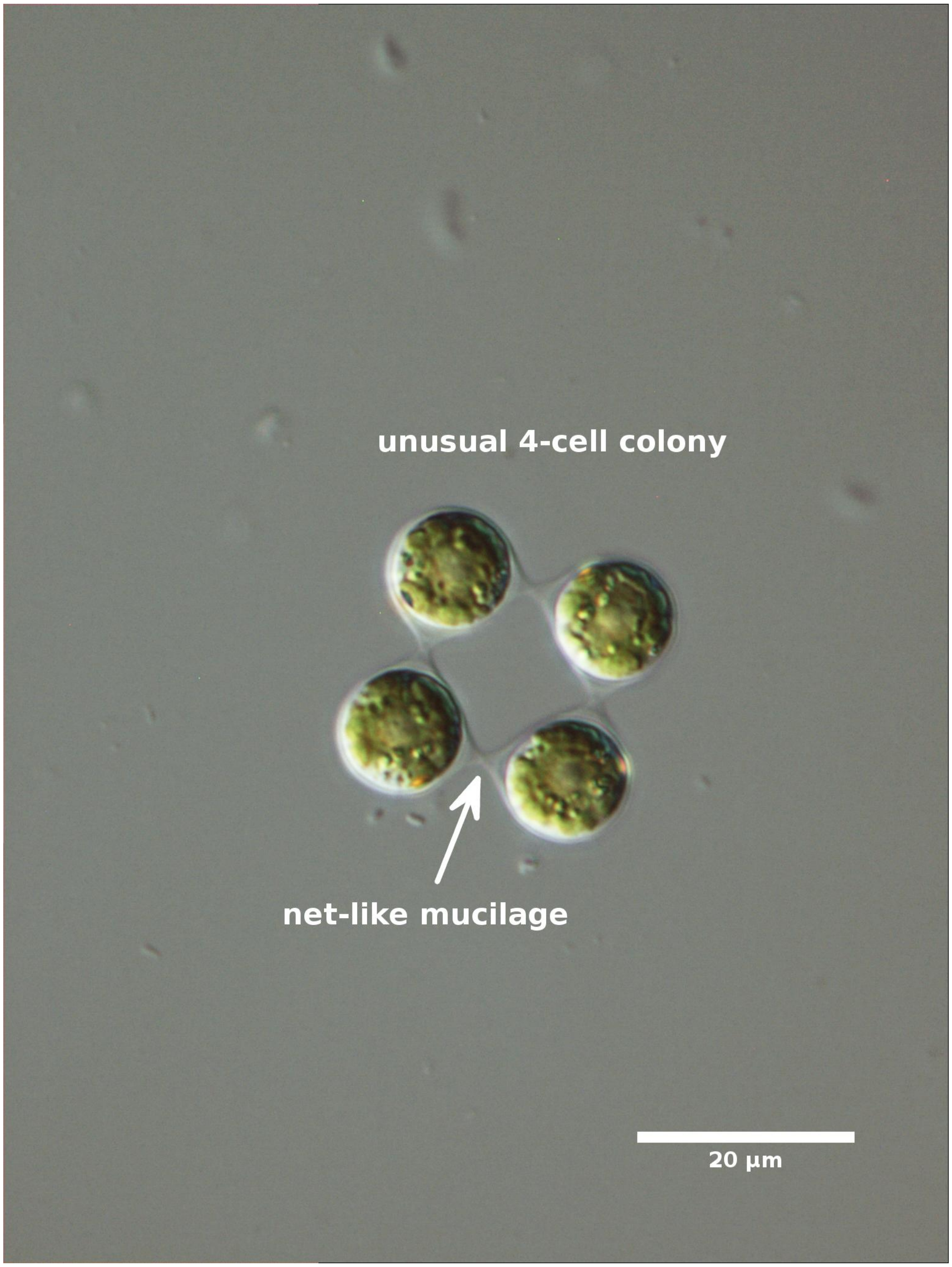


Figure 2.68: *Gonium pectorale* (600x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, March 30, 2012.

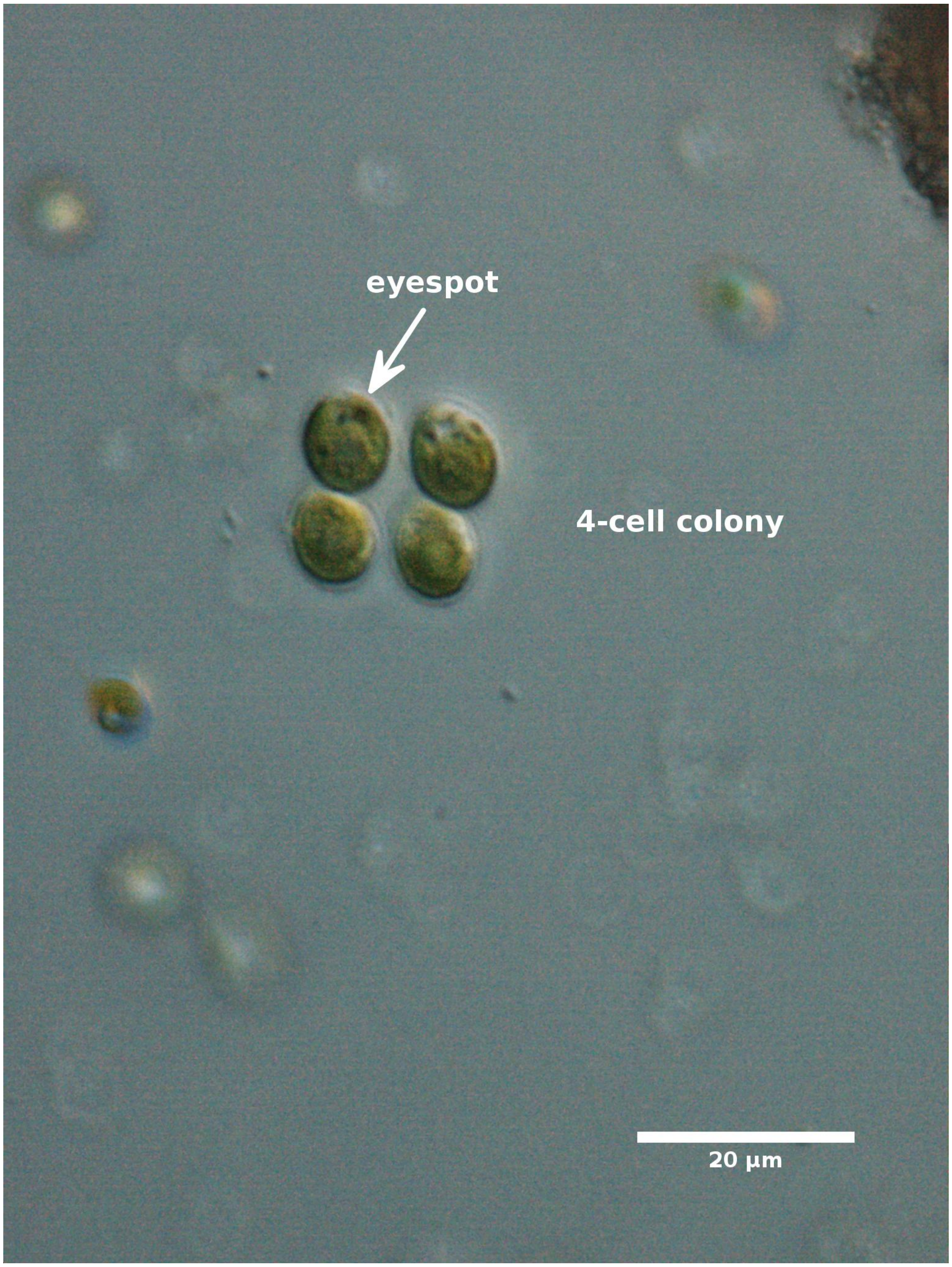


Figure 2.69: *Tetrabaena socialis* (600x DIC), Lake Geneva, IWS water quality sampling site, Whatcom County, April 18, 2011.

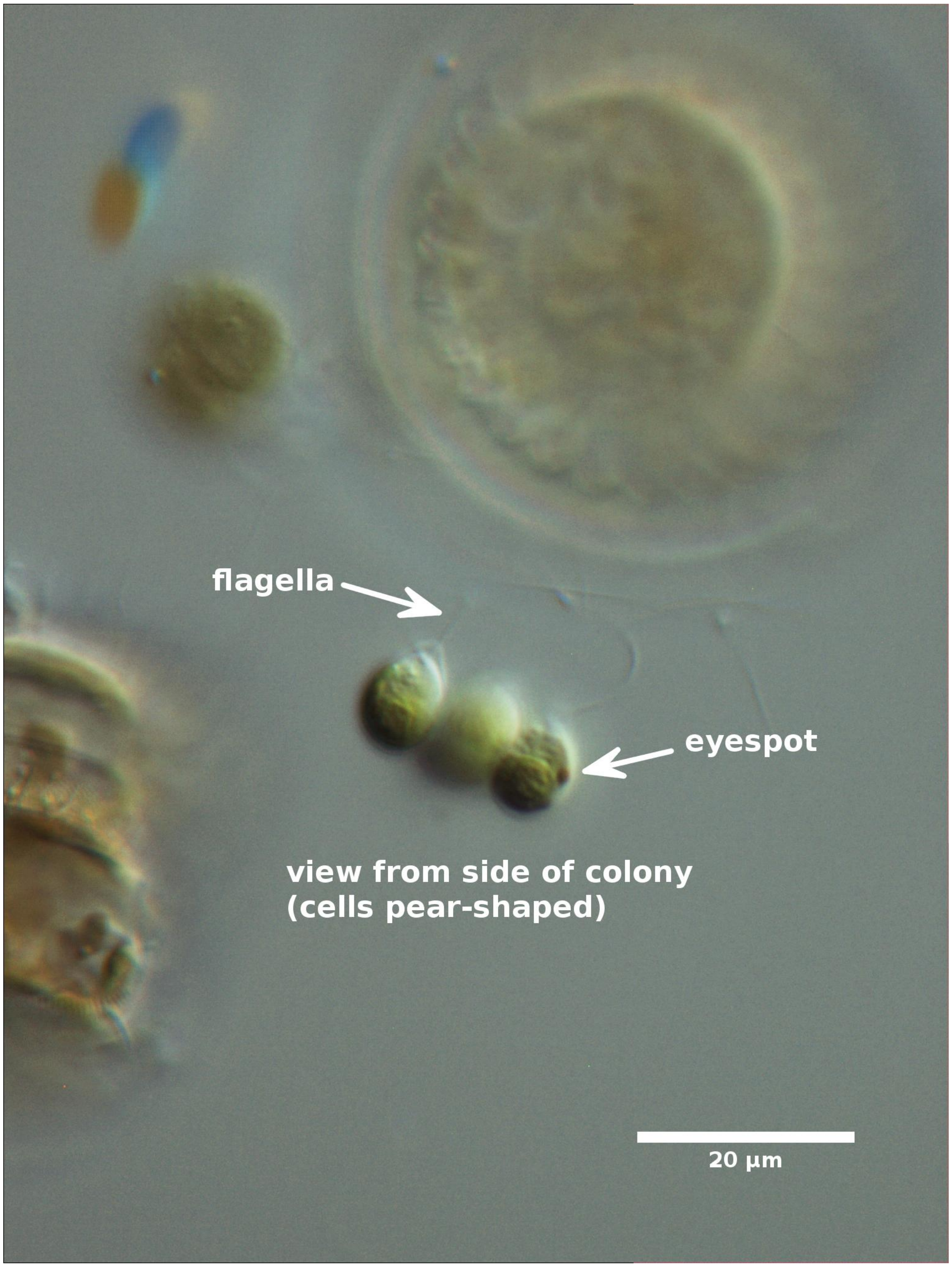


Figure 2.70: *Tetrabaena socialis* (600x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, March 29, 2012.

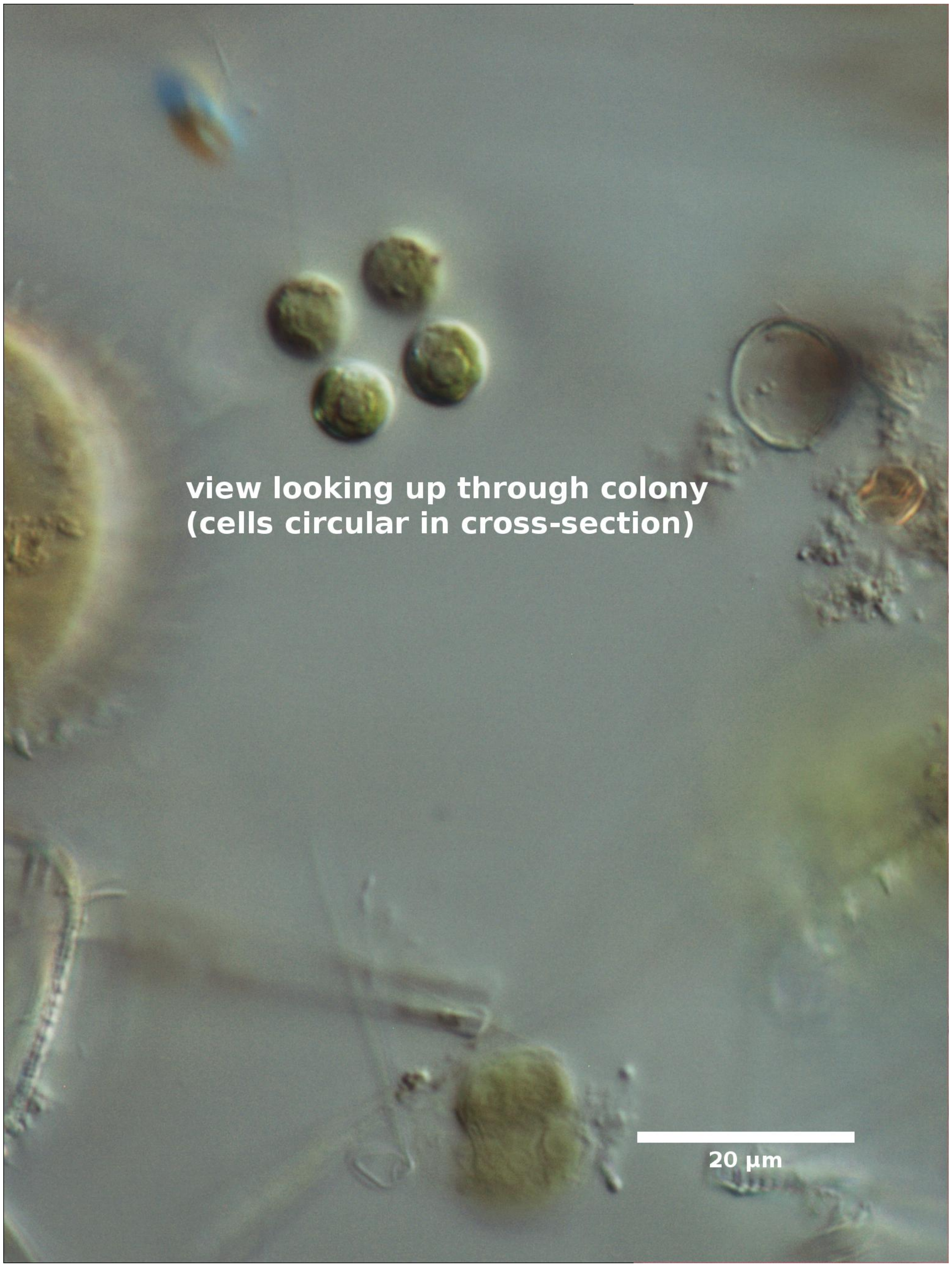


Figure 2.71: *Tetrabaena socialis* (600x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, March 29, 2012.

2.8 *Haematococcus* Flotow

Local taxon
Haematococcus pluvialis Flotow

Abundance
Moderately common in standing water; occasionally forms blooms in fountains, bird baths, and other shallow containers.

Local measurements		Width	Length	Biovolume†
Haematococcus pluvialis	min	12.7 μm	16.1 μm	1,360 μm^3
cells not including	med	16.8 μm	21.7 μm	3,270 μm^3
mucilage (spheroid)	max	28.5 μm	40.4 μm	17,200 μm^3
Haematococcus pluvialis	min	21.0 μm	24.2 μm	5,590 μm^3
cells including mucilage	med	26.5 μm	29.8 μm	11,000 μm^3
(spheroid)	max	43.4 μm	50.1 μm	49,400 μm^3
Haematococcus pluvialis	min	15.1 μm	–	1,800 μm^3
cysts (sphere)	med	18.7 μm	–	3,420 μm^3
	max	27.4 μm	–	10,800 μm^3

†Calculated using original measurements, not summary values.

Description
Haematococcus pluvialis is a common "bird bath" species that accumulates red pigment to protect the cell from excess light (Figures 2.72–2.76). The bright red cysts look similar to the cysts of *Chlamydomonas nivalis* (Section 2.3, page 35), but *Haematococcus* is not common in snow samples. Instead, it is found in outdoor fountains, isolated rocky pools, water troughs, buckets containing standing water, and other types of standing water and temporary ponds. *Haematococcus* cells also resemble *Vitreochlamys* (Section 2.3, page 35), which will be green, not bright red.

The motile vegetative cells are spherical or broadly elliptical, consisting of a pear-shaped protoplast inside a thick, clear mucilage (Figures 2.72–2.73). Very fine protoplasmic strands extend from the protoplast outward through the mucilage.

The cell has two equal length flagella that emerge through visible channels in the mucilage. The chloroplast is large, and may be bright green in some cells, but more often shows at least some accumulation of red pigment. The nonmotile cysts are spherical and bright red (Figures 2.74–2.76). Massive accumulations of the cysts may color the sides of the fountain, trough, or pond blood-red.

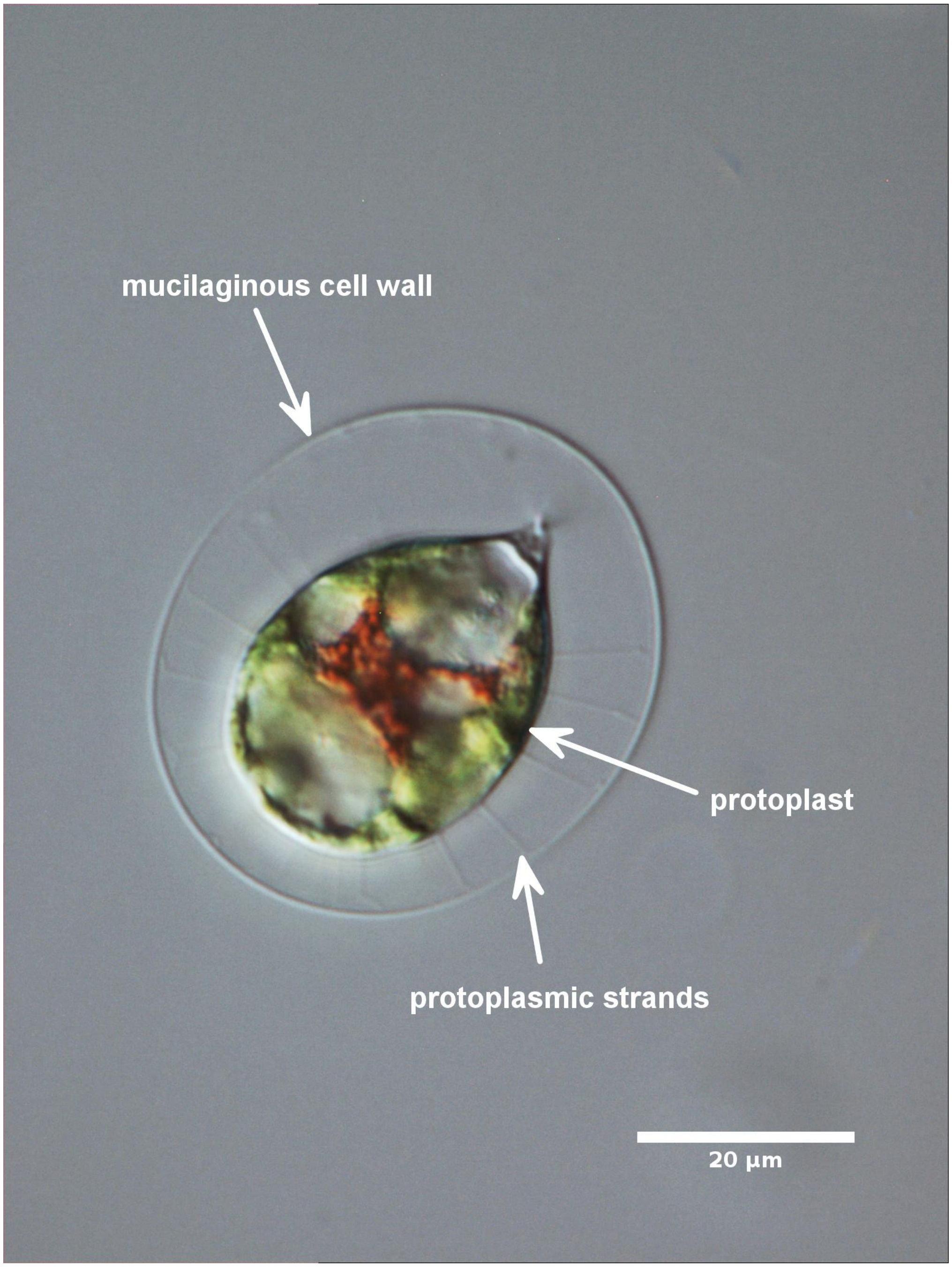


Figure 2.72: *Haematococcus pluvialis* motile vegetative cell (600x DIC), stagnant water in plant saucer, May 20, 2011.

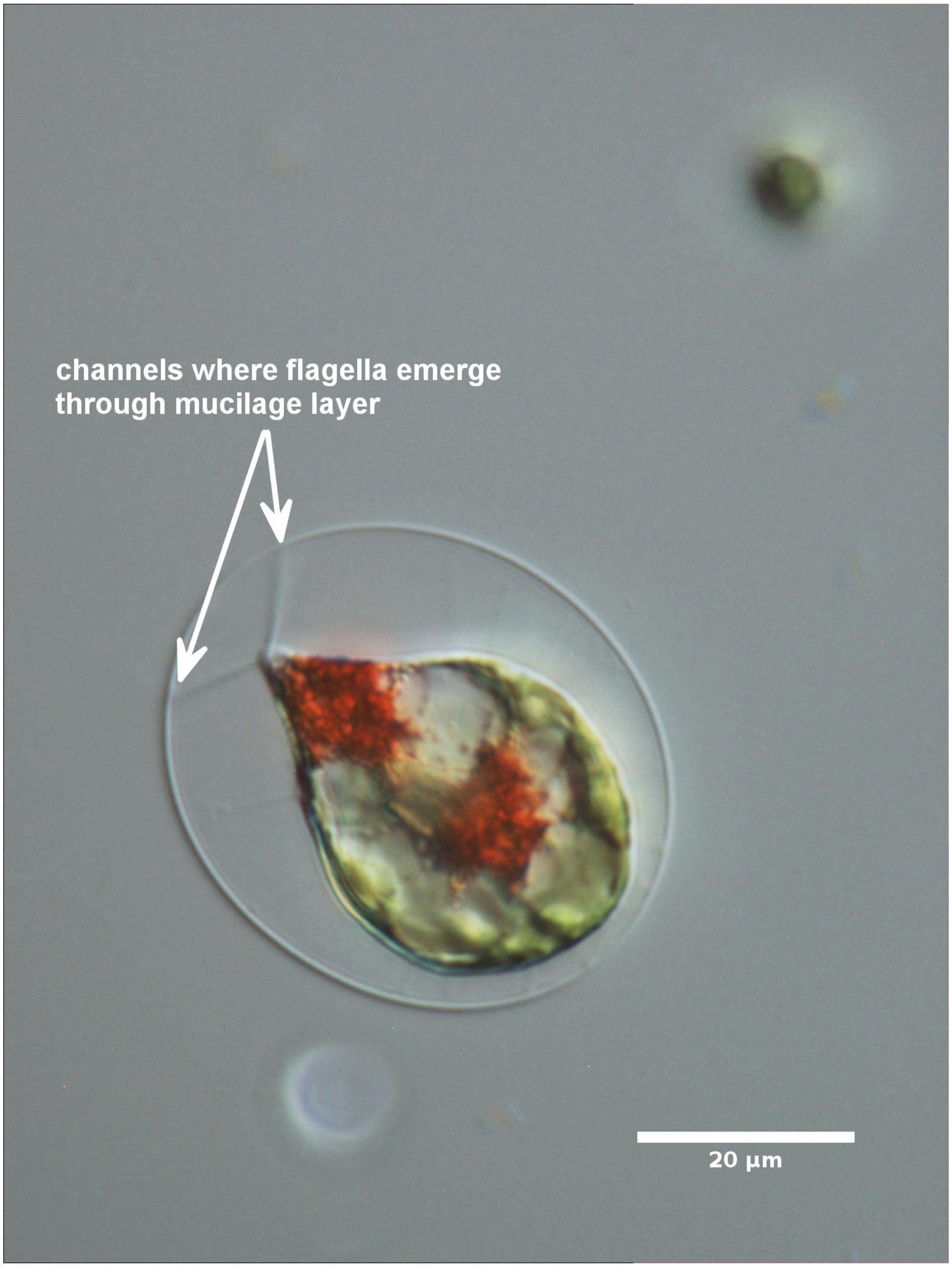


Figure 2.73: *Haematococcus pluvialis* motile vegetative cell (600x DIC), stagnant water in plant saucer, May 20, 2011.

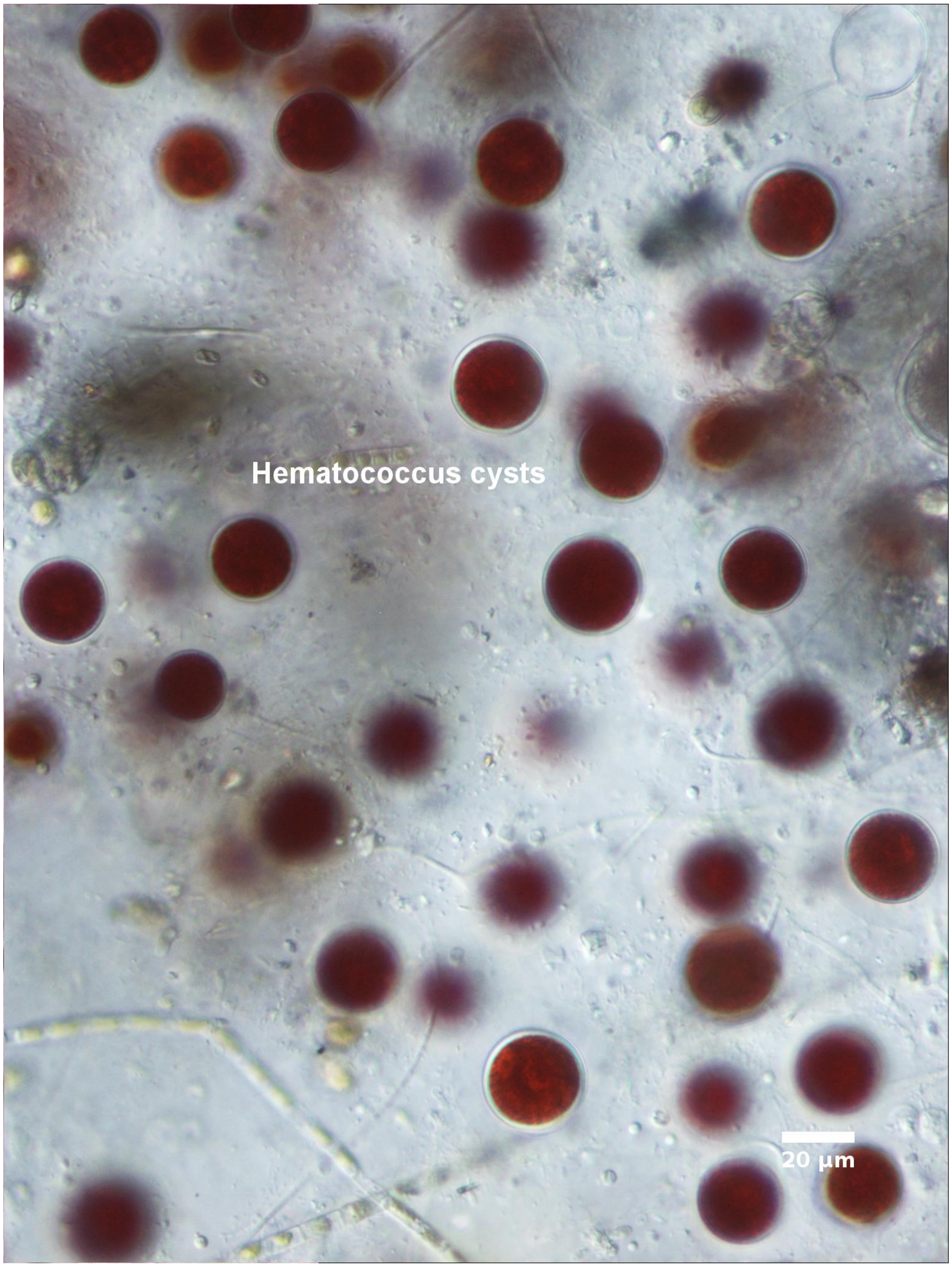


Figure 2.74: *Haematococcus pluvialis* nonmotile cysts (600x DIC), stagnant water in bucket, Whatcom County, May 23, 2011.

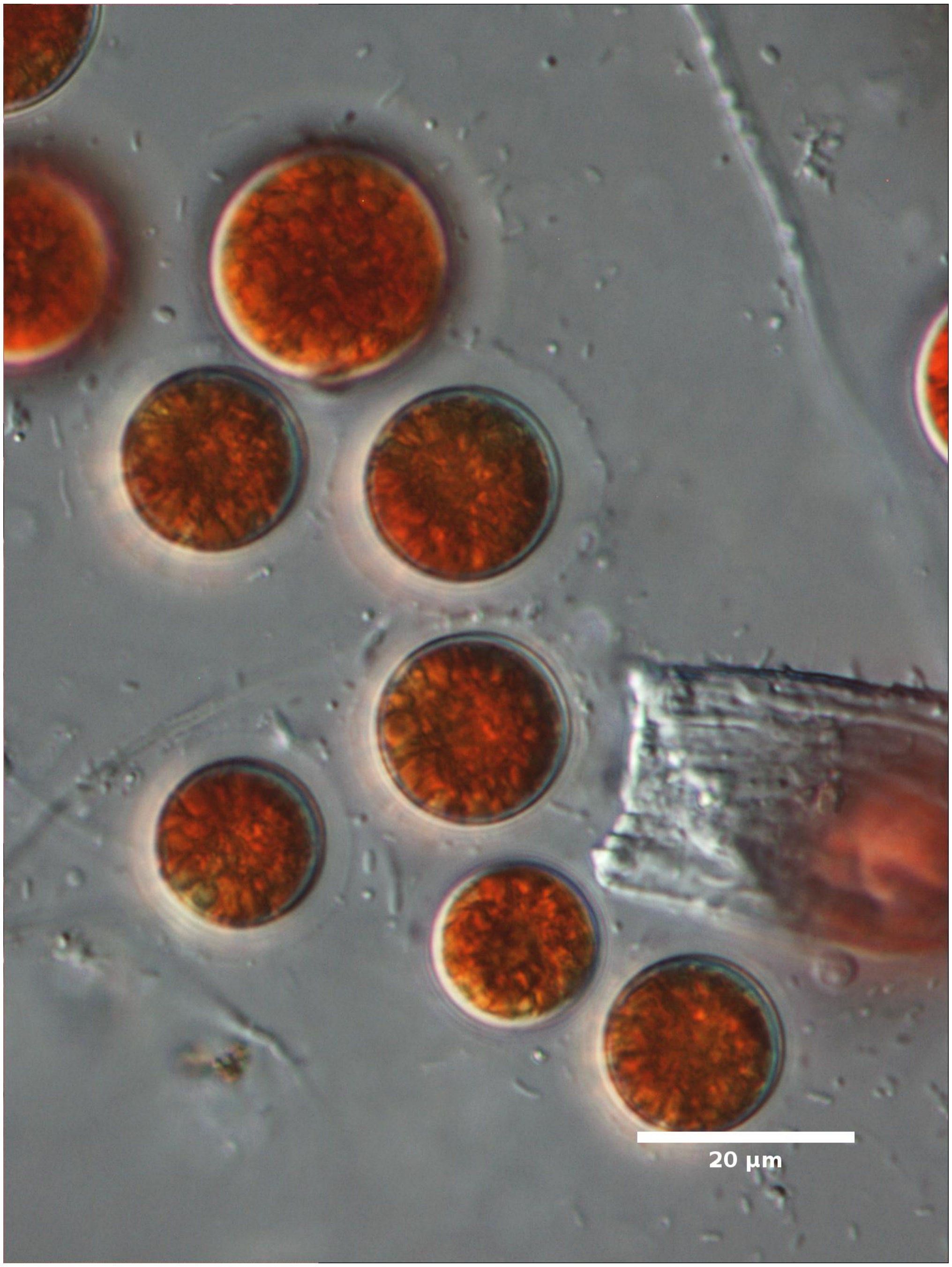


Figure 2.75: *Haematococcus pluvialis* nonmotile cysts (600x DIC), standing water, Whatcom County, April 20, 2012.

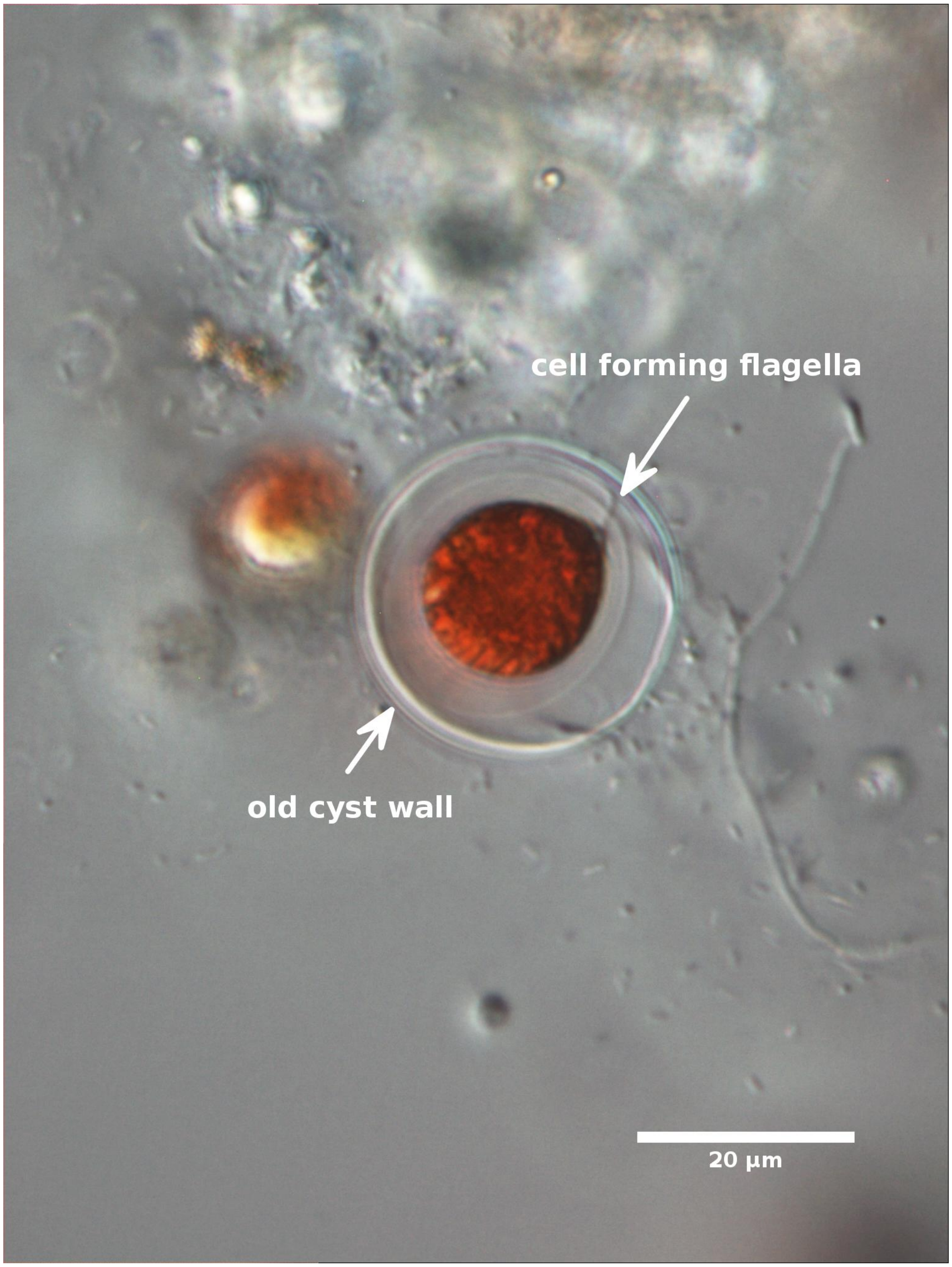


Figure 2.76: *Haematococcus pluvialis* motile cell emerging from cyst (600x DIC), standing water, Whatcom County, April 20, 2012.

2.9 *Hemitoma* Skuja

Local taxon
Hemitoma meandrocystis Skuja

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Hemitoma meandrocystis	min	13.4 μm	14.4 μm	1,390 μm^3
cells (spheroid)	med	14.0 μm	15.5 μm	1,530 μm^3
	max	15.6 μm	18.4 μm	2,340 μm^3

†Calculated using original measurements, not summary values.

Description
Hemitoma meandrocystis is a very unusual Chlorophyta species. The solitary motile cells are enclosed inside a pale yellow-brown lorica (Figures 2.77–2.79).[11] Although the protoplast is sometimes difficult to see through the lorica, it has a cup-shaped chloroplast, an apical eyespot, and two equal length flagella. The lorica is spherical or oval, and is covered with a fine, net-like reticulation. The most distinctive feature is that the lorica is split into two equal hemispheres, divided at the equator or mid-section of the cell (Figures 2.77–2.78).

Hemitoma cells resemble *Trachelomonas* (Euglenophyta), which are common in Lake Geneva, the only location where *Hemitoma* has been collected. *Trachelomonas* cells are solitary, motile by means of a single flagellum, and consist of a bright green protoplast inside an rigid, yellow, orange, or brown lorica. The *Trachelomonas* lorica may be smooth or ornamented with granules, warts, net-like reticulation, and spines, but will not have a central groove indicating hemispherical separation.

[11] A lorica is a rigid cell covering the protoplast of the cell. The lorica is not as firmly attached to the protoplast, so the protoplast can emerge from the lorica and swim away. Most loricate algae are either Chrysophyta or Euglenophyta (see **Freshwater Algae in Northwest Washington, Volume IV. Chrysophyceae, Xanthophyceae, and Haptophyta** and **Freshwater Algae in Northwest Washington, Volume V. Cryptophyta, Dinophyta, and Euglenophyta**.

Figure 2.77: *Hemitoma meandrocystis* (600x DIC), Lake Geneva, IWS water quality sampling site, Whatcom County, April 18, 2011.

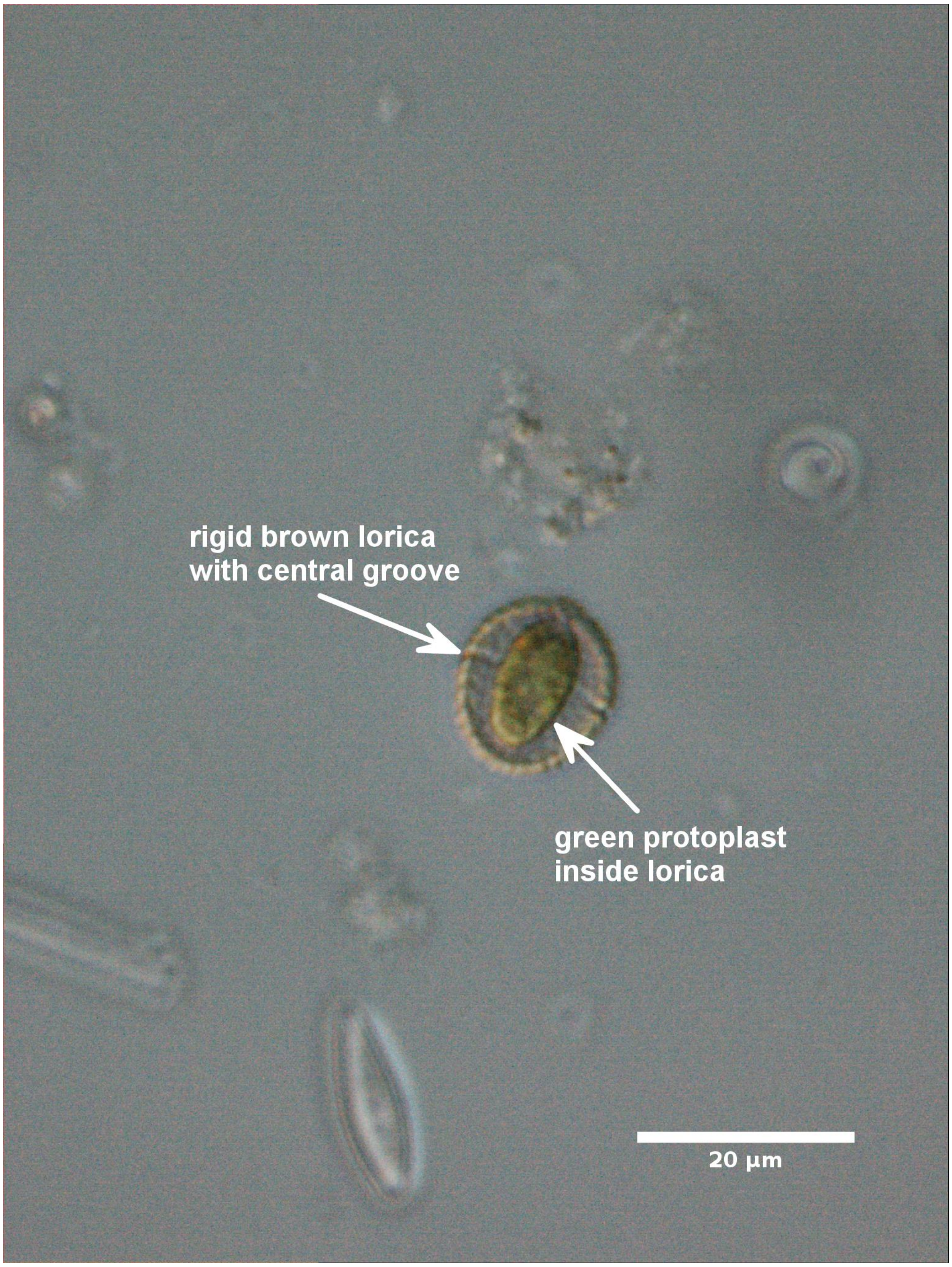


Figure 2.78: *Hemitoma meandrocystis* (600x DIC), Lake Geneva, IWS water quality sampling site, Whatcom County, April 18, 2011.

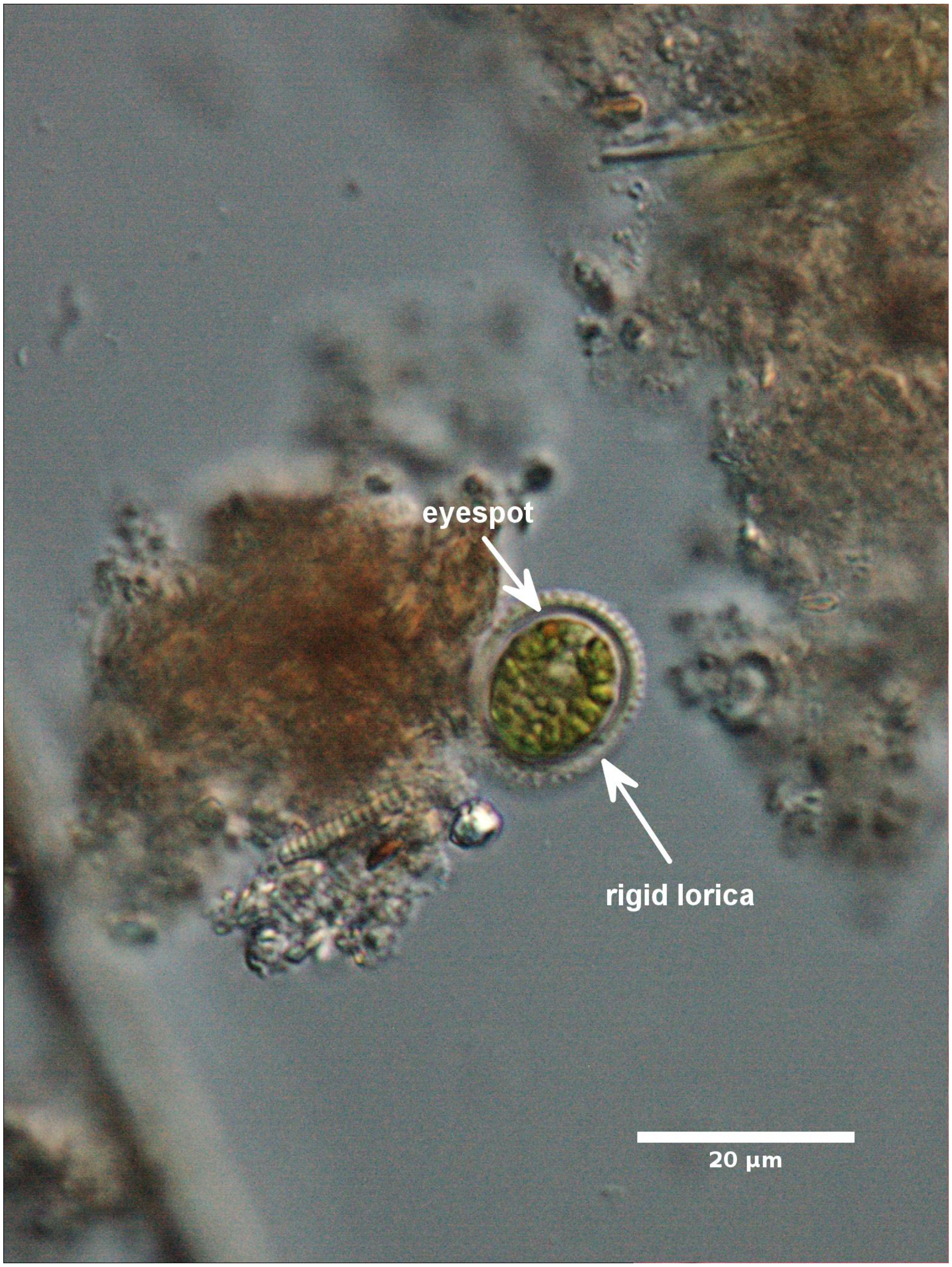


Figure 2.79: *Hemitoma meandrocystis* (600x DIC), Lake Geneva, IWS water quality sampling site, Whatcom County, April 18, 2011.

2.10 *Pandorina* Bory

Local taxon

Pandorina morum (O. F. Müller) Bory

Abundance

Moderately common; may be present in large numbers but rarely forms blooms.

Local measurements		Width	Length	Biovolume†
Pandorina morum	min	7.2 μm	8.0 μm	232 μm^3
cells (spheroid)	med	13.3 μm	12.6 μm	1,170 μm^3
	max	28.9 μm	27.4 μm	12,000 μm^3
Pandorina morum	min	22.5 μm	24.5 μm	–
colonies‡	med	35.1 μm	39.6 μm	–
	max	80.9 μm	81.3 μm	–

†Calculated using original measurements, not summary values.
‡Colony biovolume can estimated using a spherical or spheroid shape.

Description

Pandorina morum colonies are spherical or broadly elliptical, and contain 4–32 tightly packed, wedge-shaped cells surrounded by a firm colonial mucilage (Figures 2.80–2.84). Each cell has two equal flagella, a cup-shaped chloroplast, and an anterior eyespot. The individual cells are difficult to measure accurately, so biovolume calculations are often estimated using the entire colony.

Pandorina morum colonies briefly resemble asexually reproducing *Eudorina* daughter colonies (compare Figures 2.60 and 2.84). The resemblance is short-lived. *Eudorina* daughter cells separate quickly, so even small daughter colonies quickly lose their similarity to *Pandorina*. *Pandorina* cells remain wedge-shaped and tightly packed, regardless of colony size and age.

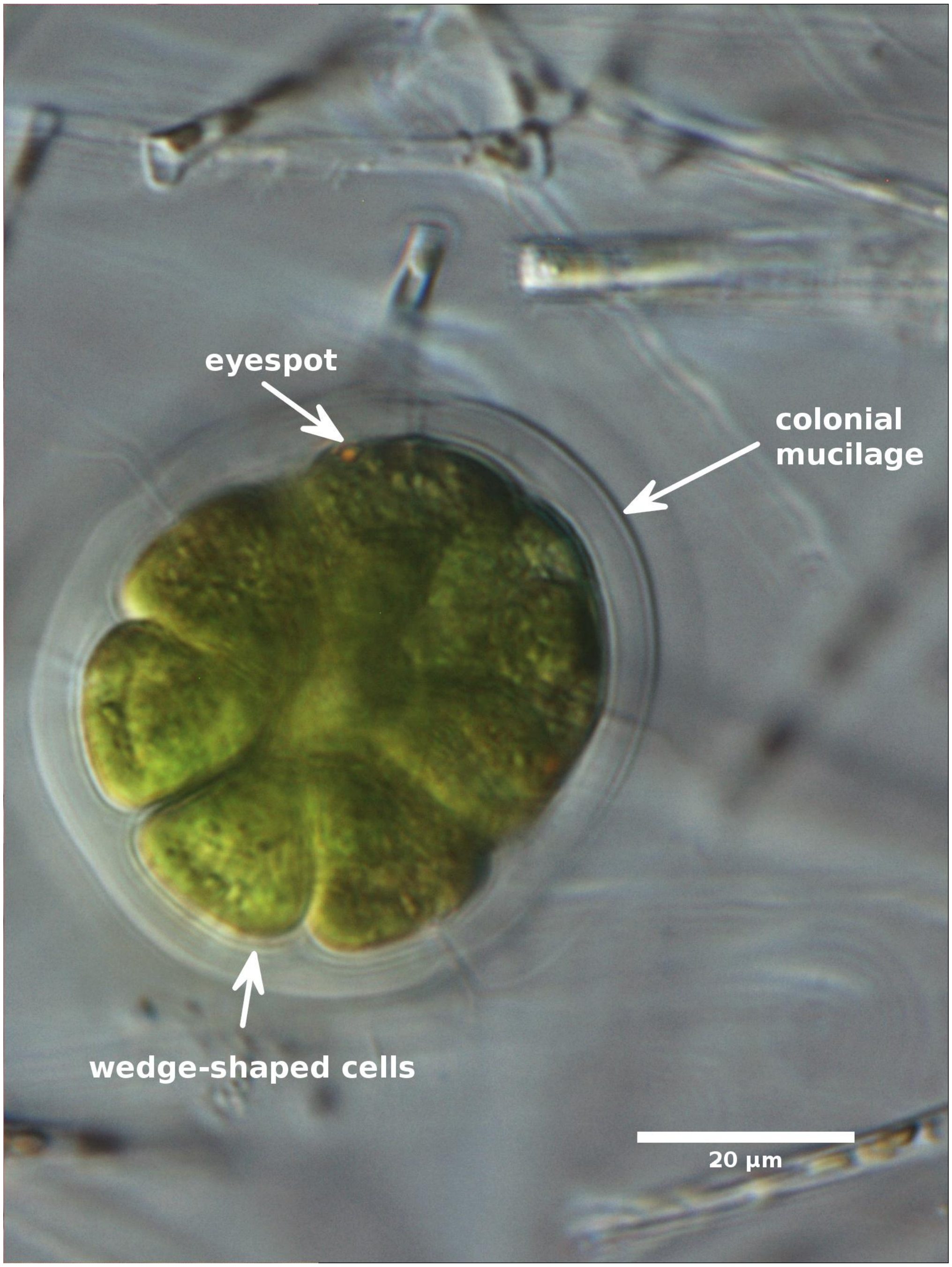


Figure 2.80: *Pandorina morum* (600x DIC), Squalicum Lake, IWS water quality sampling site, Whatcom County, March 30, 2012.

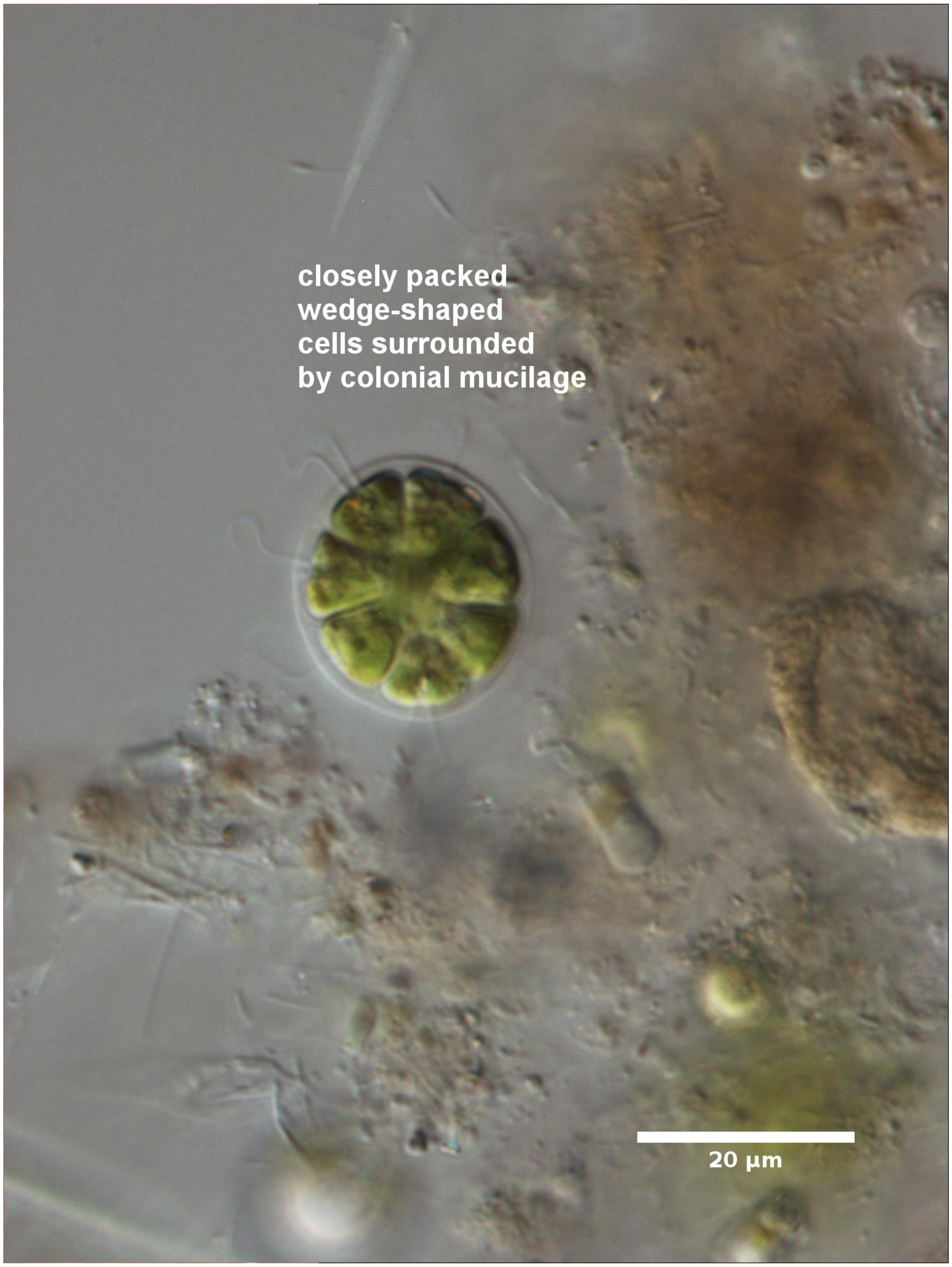


Figure 2.81: *Pandorina morum* (600x DIC), Squalicum Lake, IWS water quality sampling site, Whatcom County, April 24, 2009.

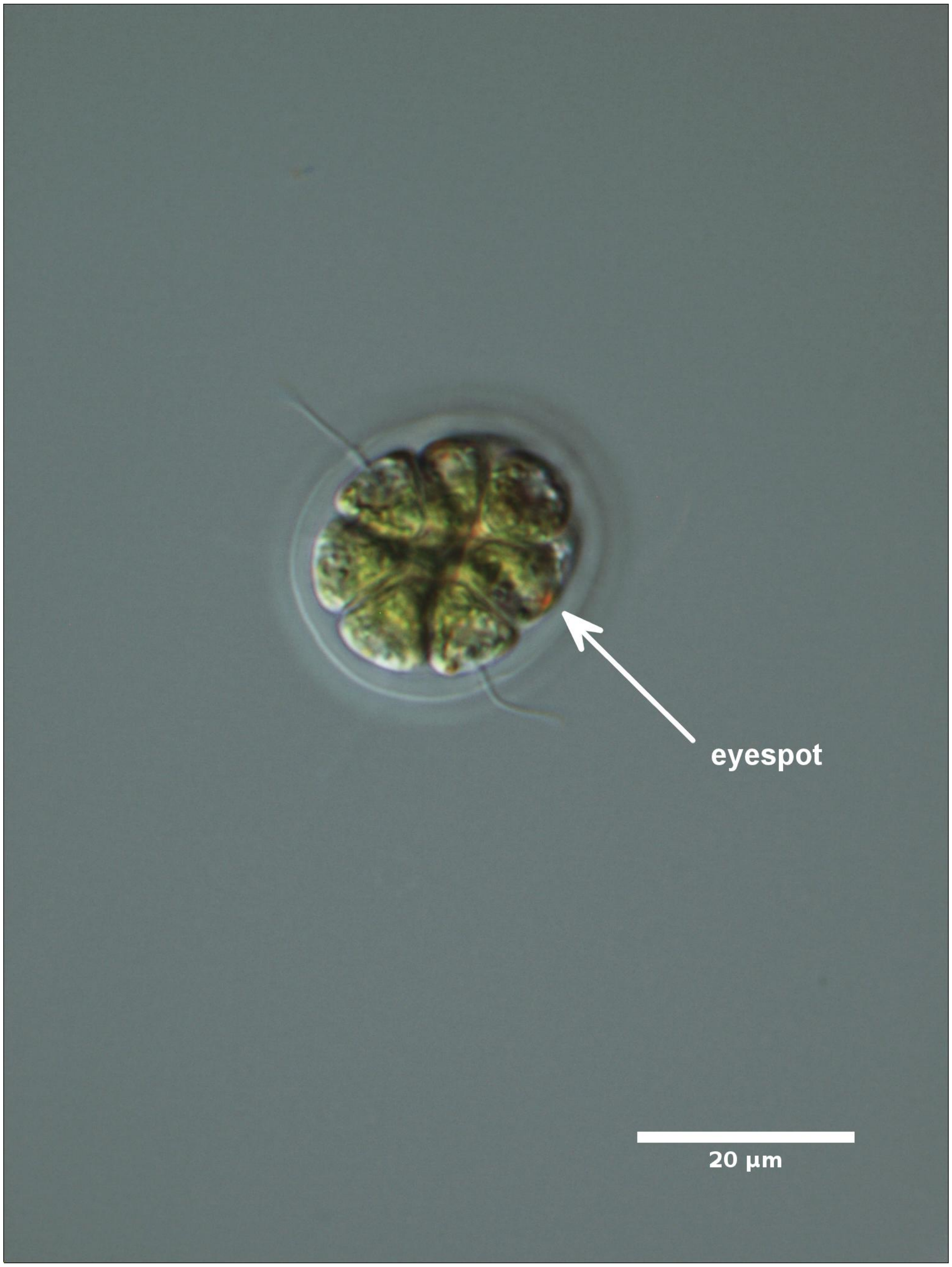


Figure 2.82: *Pandorina morum* (600x DIC), Heart Lake, IWS water quality sampling site, Skagit County, August 15, 2007.

Figure 2.83: *Pandorina morum* (400x phase contrast), Wards Biological Supply Co., May 29, 2009.

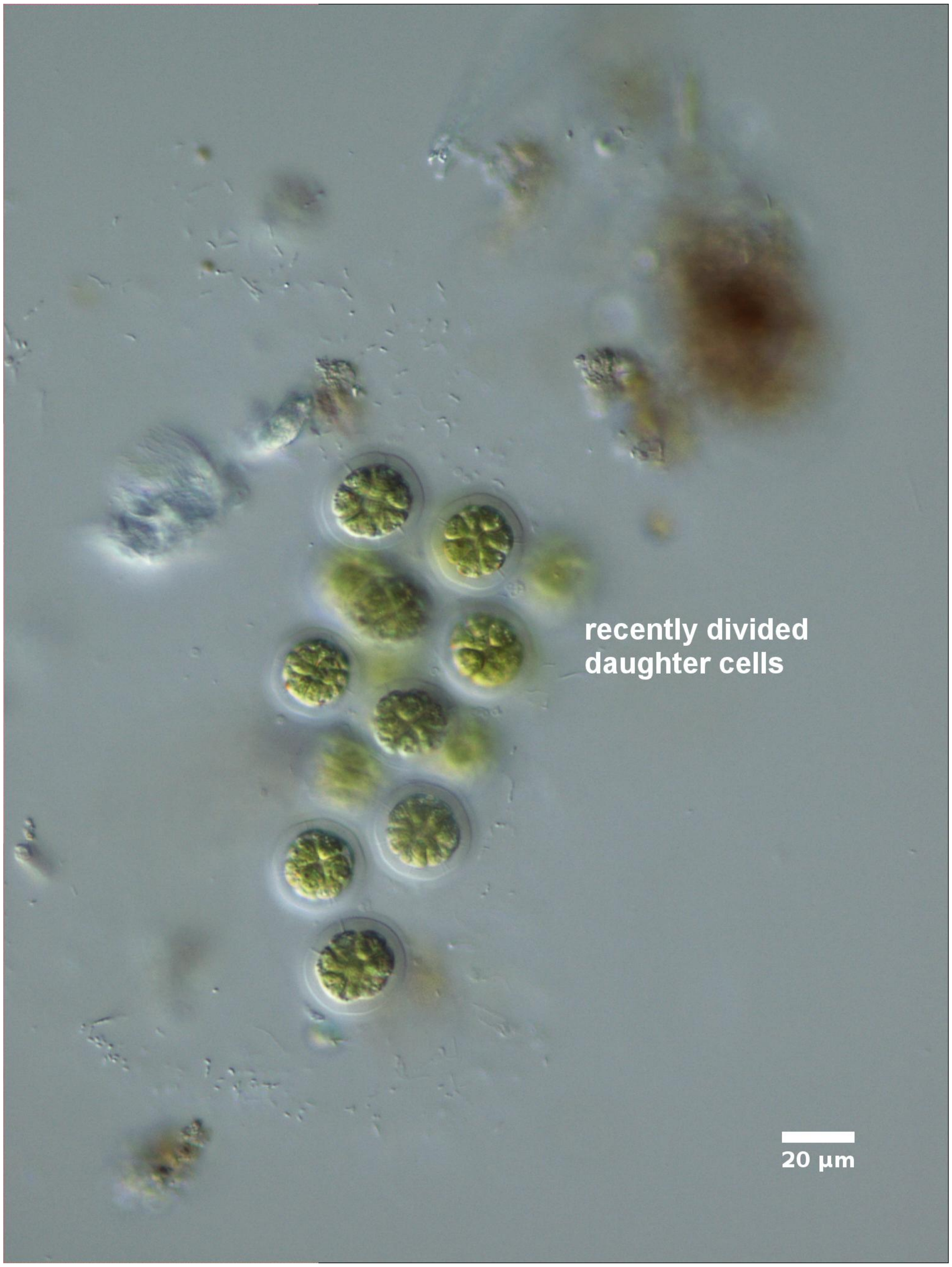


Figure 2.84: *Pandorina morum* (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 21, 2008.

2.11 *Pleodorina* W. Shaw

Local taxon
Pleodorina californica W. Shaw

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Pleodorina californica	min	10.6 μm	–	624 μm^3
vegetative cells (sphere)	med	13.0 μm	–	1,150 μm^3
	max	14.6 μm	–	1,630 μm^3
Pleodorina californica	min	15.8 μm	–	2,070 μm^3
reproductive cells (sphere)	med	26.8 μm	–	10,400 μm^3
	max	33.5 μm	–	19,700 μm^3
Pleodorina californica	min	274.5 μm	–	–
colonies‡	med	341.8 μm	–	–
	max	378.2 μm	–	–

†Calculated using original measurements, not summary values.
‡Colony biovolume can estimated using a spherical shape.

Description
Pleodorina californica colonies are spherical or slightly elliptical and contain 64–128 spherical cells embedded in a firm colonial matrix (Figures 2.85–2.89). The colony is divided into hemispheres that contain approximately equal numbers of small vegetative cells and large reproductive cells. Each cell has two equal length flagella, a dense, cup-shaped chloroplast, and a red eyespot. The eyespot is much larger and more distinct in the vegetative cells than in the reproductive cells (Figures 2.88–2.89).

Figure 2.85: *Pleodorina californica* (100x DIC), Lone Lake, IWS water quality sampling site, Island County, July 22, 2013.

Figure 2.86: *Pleodorina californica* (100x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 1, 2009.

Figure 2.87: *Pleodorina californica* (100x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 21, 2008.

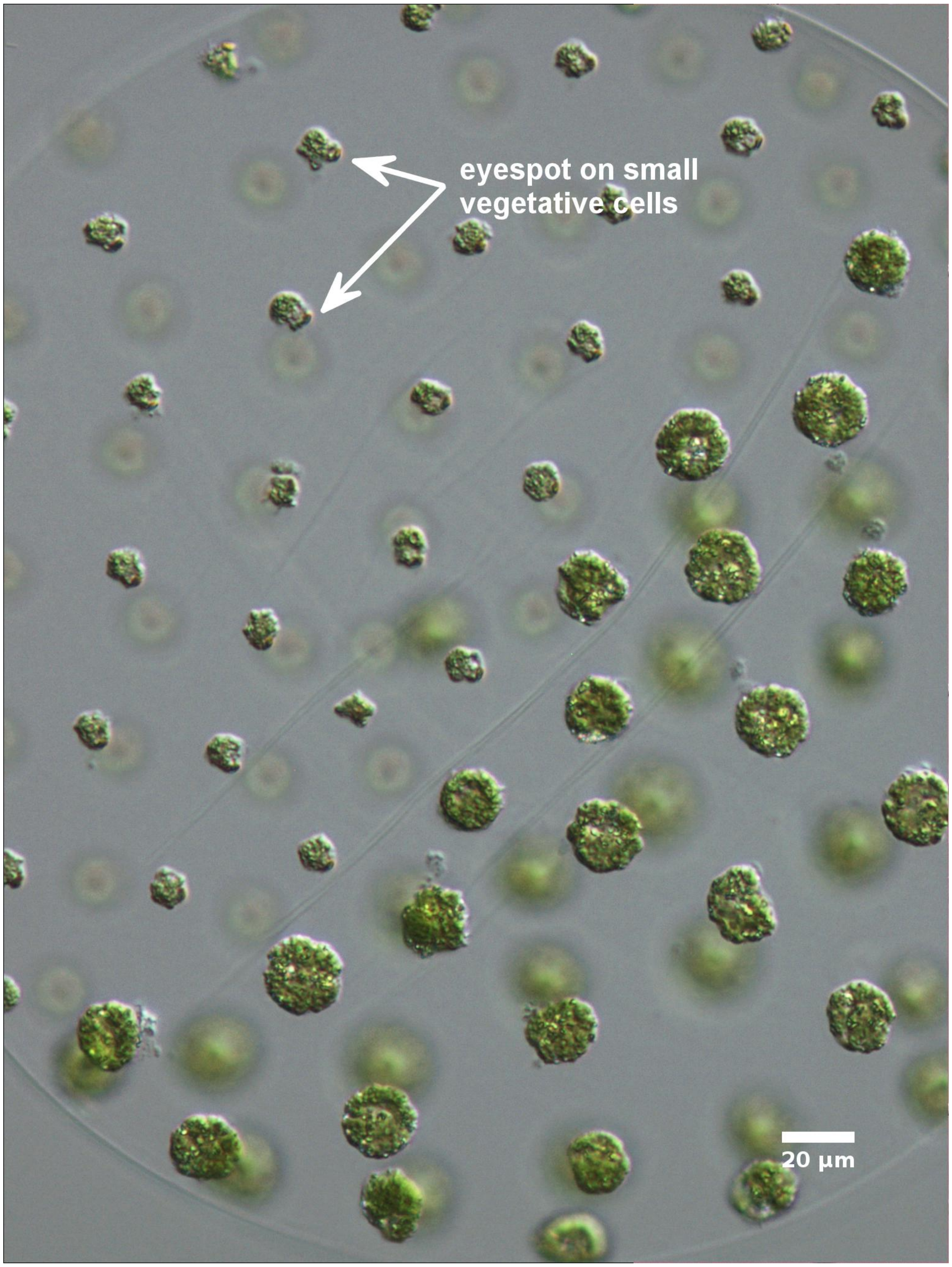


Figure 2.88: *Pleodorina californica* (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 21, 2008.

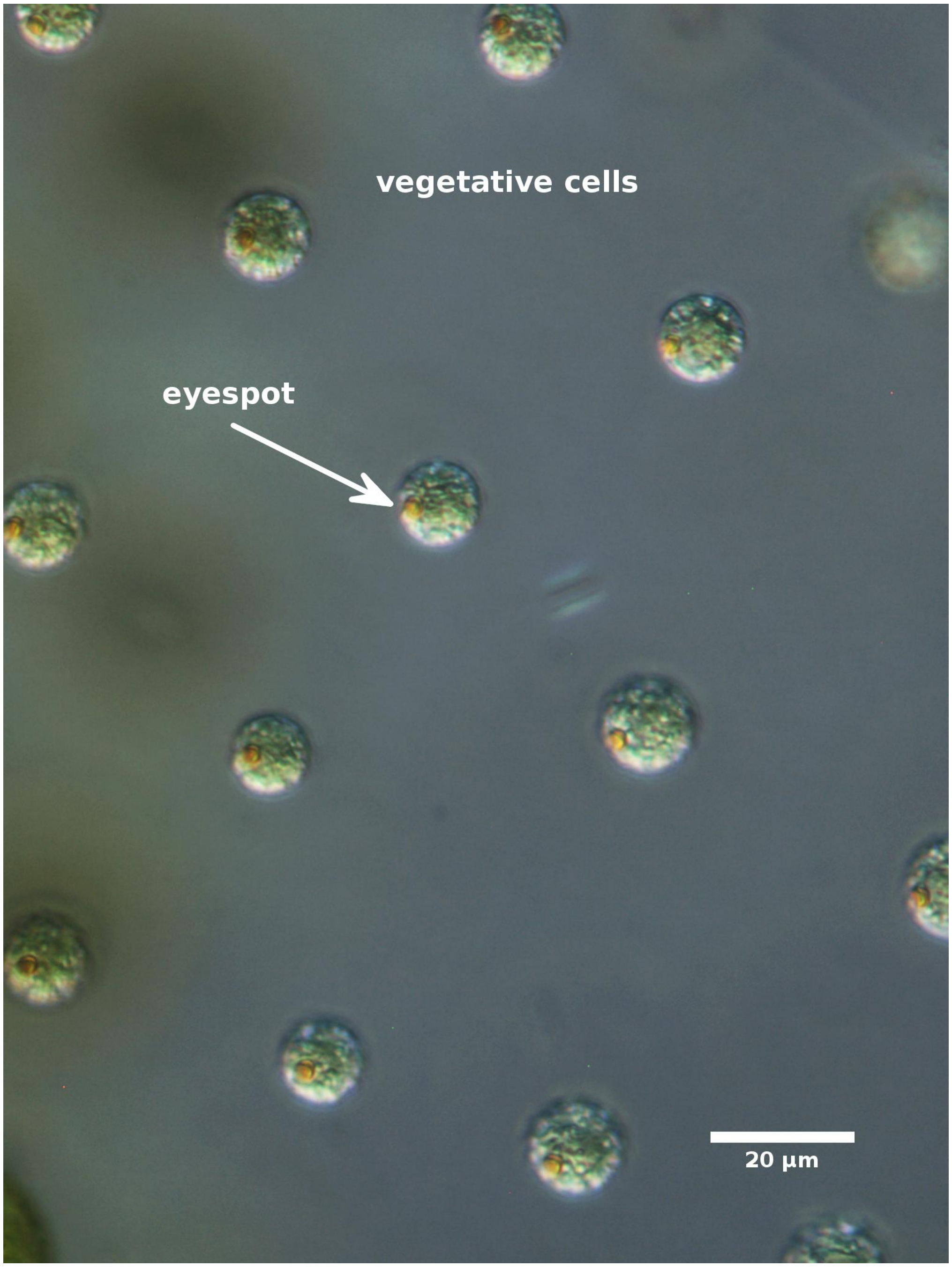


Figure 2.89: *Pleodorina californica* (400x DIC), Lone Lake, IWS water quality sampling site, Island County, July 22, 2013.

2.12 *Tetraselmis* F. Stein

Local taxon
Tetraselmis cordiformis (H.J. Carter) Stein

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume[†]
Tetraselmis cordiformis[‡]	min	8.9 μm	12.7 μm	317 μm^3
cells (ellipsoid)	med	11.6 μm	15.7 μm	636 μm^3
	max	14.1 μm	17.7 μm	1,010 μm^3

[†]Calculated using original measurements, not summary values.
[‡]Cell depth was estimated as 0.56 $\times$ cell width based on John, et al. (2011).

Description
Tetraselmis cordiformis cells are solitary, oval or heart-shaped, with a slight apical indentation (Figures 2.90–2.95). The cells contain a cup-shaped chloroplast, a large basal pyrenoid, and a distinct eyespot. *Tetraselmis* cells have four equal length flagella, which distinguishes them from *Chlamydomonas*, and are slightly flattened, which distinguishes them from *Carteria*. Some species of *Tetraselmis* form nonmotile, thick-walled cysts (Figures 2.94–2.95). The cell wall in this genus is covered with tiny scales, but this feature is rarely visible using light microscopy.

AlgaeBase describes *Tetraselmis cordiformis* as a marine species, but John, et al. (2011) and Wehr, et al. (2015) describe it as a freshwater species. Some of the local *Tetraselmis* samples were collected from Thunderbird Lake and Kwan Lake, which are adjacent to Birch Bay, WA (marine) and have slightly brackish water. But other samples were collected from Ross Lake, which is located in the North Cascades and is not brackish.

Figure 2.90: *Tetraselmis cordiformis* (600x DIC), Thunderbird Lake, IWS water quality sampling site, Whatcom County, September 16, 2010.

Figure 2.91: *Tetraselmis cordiformis* (600x DIC), Kwan Lake, IWS water quality sampling site, Whatcom County, August 24, 2009.

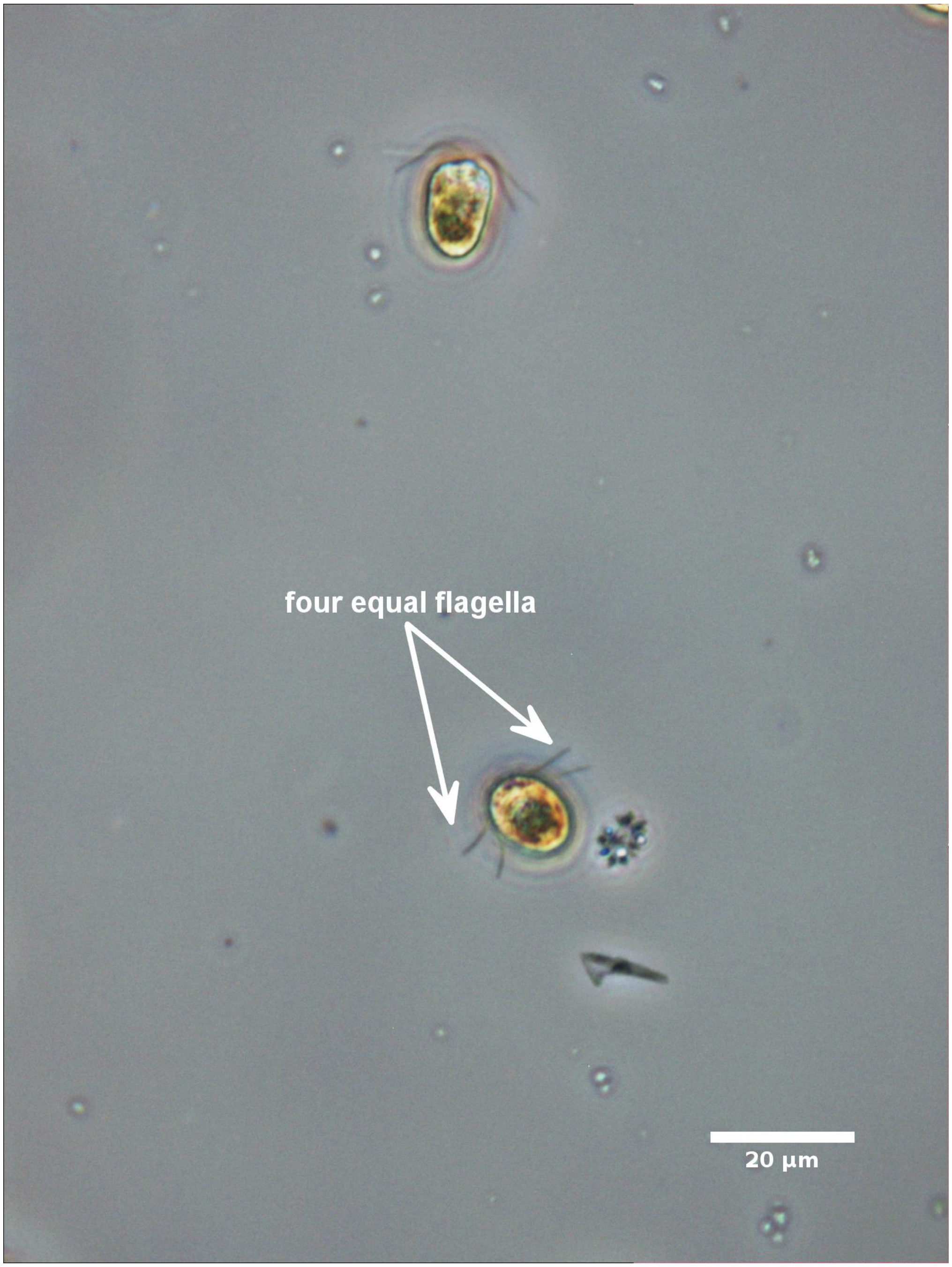


Figure 2.92: *Tetraselmis cordiformis* (400x phase contrast), Kwan Lake, IWS water quality sampling site, Whatcom County, August 24, 2009.

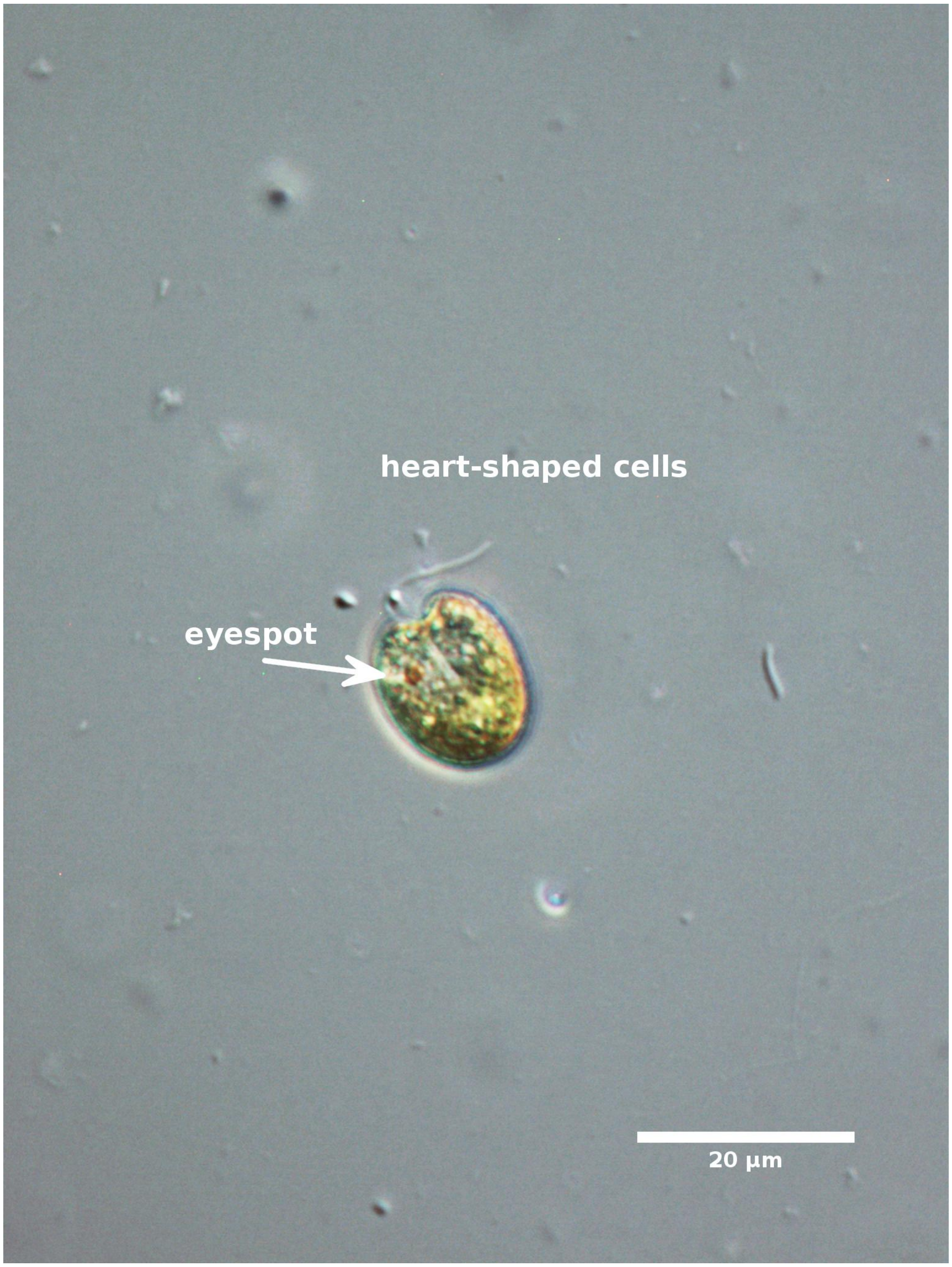


Figure 2.93: *Tetraselmis cordiformis* (600x DIC), Ross Lake, Ross Lake National Recreation Area, May 6, 2013.

Figure 2.94: *Tetraselmis cordiformis* (400x phase contrast), Kwan Lake, IWS water quality sampling site, Whatcom County, August 24, 2009.

Figure 2.95: *Tetraselmis cordiformis* cysts (600x DIC), Ross Lake, Ross Lake National Recreation Area, May 6, 2013.

2.13 *Volvox* Linnaeus

Local taxa
Volvox aureus Ehrenberg;
Volvox globator Linnaeus;
Volvox tertius A. Meyer

Abundance
Moderately common; may be present in large numbers but rarely forms blooms.

Local measurements		Width	Length	Biovolume†
Volvox aureus	min	5.0 μm	–	65.4 μm^3
cells (sphere)	med	7.0 μm	–	183 μm^3
	max	9.4 μm	–	435 μm^3
Volvox aureus	min	17.4 μm	–	2,760 μm^3
zygotes (sphere)	med	25.1 μm	–	8,230 μm^3
	max	27.2 μm	–	10,500 μm^3
Volvox aureus	min	165.5 μm	173.9 μm	–
colonies‡	med	386.4 μm	396.1 μm	–
	max	636.4 μm	668.6 μm	–
Volvox globator	min	4.0 μm	–	33.5 μm^3
cells (sphere)	med	7.3 μm	–	204 μm^3
	max	8.7 μm	–	345 μm^3
Volvox globator	min	34.1 μm	–	20,800 μm^3
zygotes (sphere)	med	43.4 μm	–	42,700 μm^3
	max	54.5 μm	–	84,800 μm^3
Volvox globator	min	270.0 μm	272.7 μm	–
colonies‡	med	386.4 μm	394.8 μm	–
	max	638.8 μm	667.0 μm	–

continued on next page

Local measurements		Width	Length	Biovolume[†]
Volvox tertius	min	4.8 μm	–	57.9 μm^3
cells (sphere)	med	6.7 μm	–	157 μm^3
	max	9.1 μm	–	395 μm^3
Volvox tertius	min	43.6 μm	–	43,400 μm^3
zygotes (sphere)	med	49.6 μm	–	63,900 μm^3
	max	56.1 μm	–	92,400 μm^3
Volvox tertius	min	184.0 μm	194.7 μm	–
colonies[‡]	med	217.1 μm	230.2 μm	–
	max	428.3 μm	445.6 μm	–

[†]Calculated using original measurements, not summary values.
[‡]Colony biovolume can estimated using a spherical or spheroid shape.

Description

Volvox colonies are large, with $>$100 cells ($>$15,000 in some species) arranged in a uniform layer around the outer margin of a hollow mucilaginous sphere. The individual cells may be spherical, broadly elliptical, pear-shaped, or stellate. Each cell has two equal flagella, a cup-shaped or irregular chloroplast containing one or more pyrenoids, and a red eyespot. The cells are separated from each other, but may be connected by protoplasmic strands. Like most Chlorophyta, *Volvox* reproduces asexually, producing cloned daughter colonies, and sexually, producing thick-walled zygotes.

Species identification can be difficult because the cells and colonies are quite variable in size and shape. Important taxonomic features like cell shape and the presence of protoplasmic threads may change as the colony ages, and reproductive features like zygotes may not be present when you examine the colony. To verify species identifications, try to examine more than one colony and look for examples at different stages of development. It may help to measure the colony size and estimate the number of cells in the colony. John, et al. (2011) provide a simple formula for estimating cell numbers based on the colony radius (r) and average cell-to-cell distance (a):

$$\text{Cell estimate} := 15 \times \frac{r^2}{a^2}$$

Volvox aureus colonies are slightly elliptical and contain approximately 500–3500 cells (Figures 2.96–2.97). The cells are interconnected by very fine protoplasmic threads that are about the width of one flagellum (Figure 2.98). Staining with methylene blue will reveal that the mucilage surrounding each cell is confluent with neighboring cells (Figure 2.99). This is an important distinguishing feature because most other local species of *Volvox* have a separate mucilage layer surrounding each cell. Colonies may contain 4–12 immature daughter colonies, most of which are located in one hemisphere of the mother colony (Figures 2.96 and 2.100–2.101). The zygotes are smooth and spherical. Immature zygotes are green (Figure 2.102); the mature zygotes turn orange.

Volvox globator colonies are slightly elliptical and may contain >10,000 (Figure 2.103); however, local specimens often contained fewer cells (1300–5000). The cells are connected by thick protoplasmic strands that are thicker than one flagellum (Figures 2.104–2.107). The individual cells are stellate when viewed from the surface of the colony and flattened or teardrop-shaped with viewed from the side (Figure 2.106). Each cell is surrounded by a separate (zoned) mucilage that is clearly visible when the colony is stained with methylene blue (Figure 2.107). Zygotes, when present, are nearly spherical and are covered with straight, blunt spines (Figures 2.108–2.110). Immature zygotes are green; the mature zygotes turn orange.

Volvox tertius colonies are slightly elliptical and contain approximately 500–2000 cells (Figures 2.111–2.112). This species can be difficult to identify because some of the features change as the colony ages. According to Smith (1944), the cells do not have protoplasmic connections. John, et al. (2011) state that only young or small colonies have protoplasmic strands. The local specimens usually had faint protoplasmic connections between *some*, but not all, of the cells. The strands were more visible in samples stained with methylene blue (Figure 2.113). Each cell is surrounded by a distinct, zoned mucilage layer that looks polygonal when stained (Figures 2.113–2.114). Zygotes, when present, are nearly spherical and smooth (Figure 2.115). Parasitic rotifers are occasionally found inside *Volvox tertius* colonies (and other species of *Volvox*), where they slowly consume the *Volvox* cells (Figure 2.116).

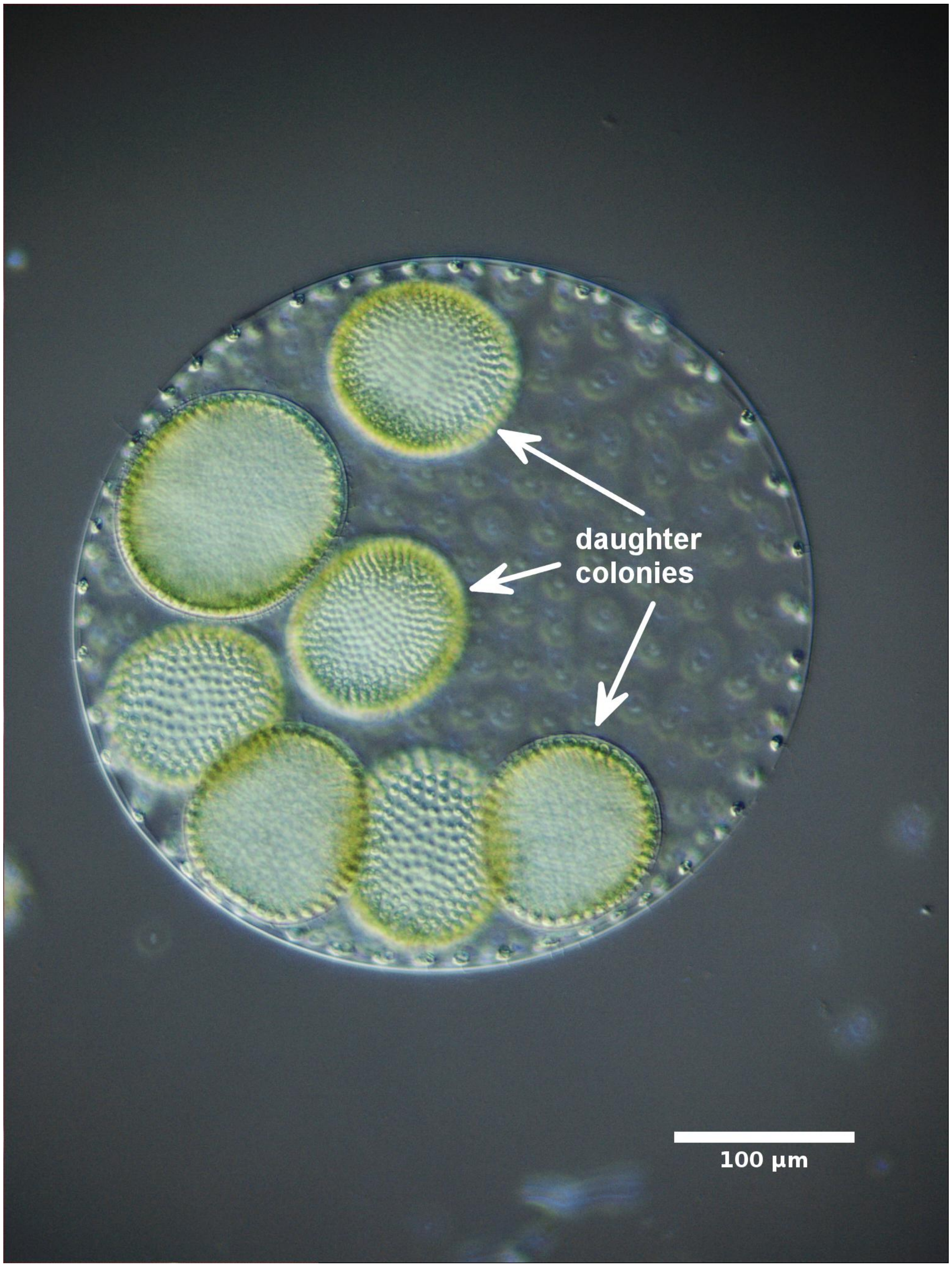
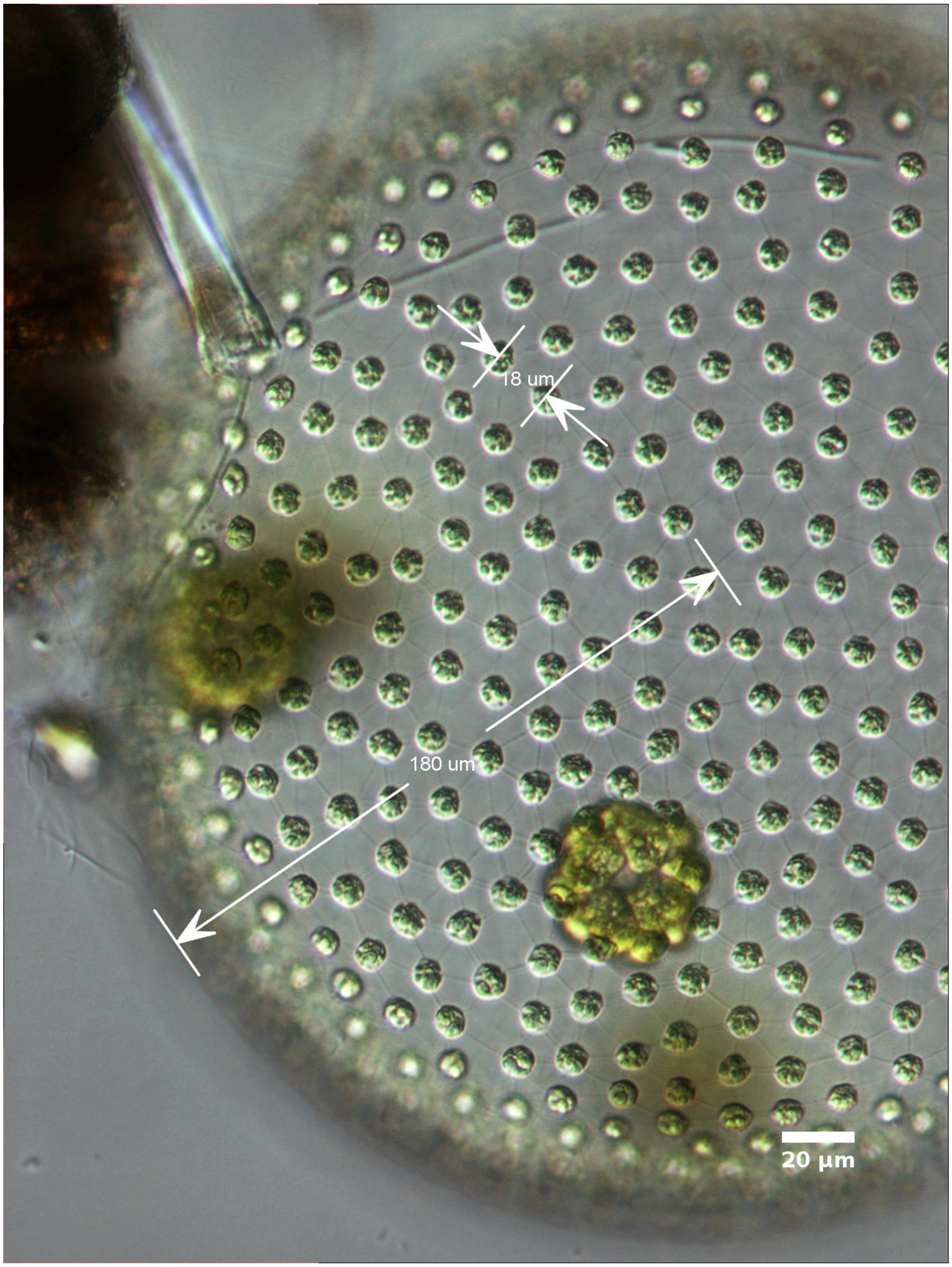


Figure 2.96: *Volvox aureus* (100x DIC), Lake Sixteen, IWS water quality sampling site, Skagit County, September 14, 2009.



$$\text{Cell estimate} = 15 \times \frac{180^2}{18^2} = 1,500$$

Figure 2.97: *Volvox aureus* cell estimate (200x DIC), Grandy Lake, IWS water quality sampling site, Skagit County, September 9, 2009.

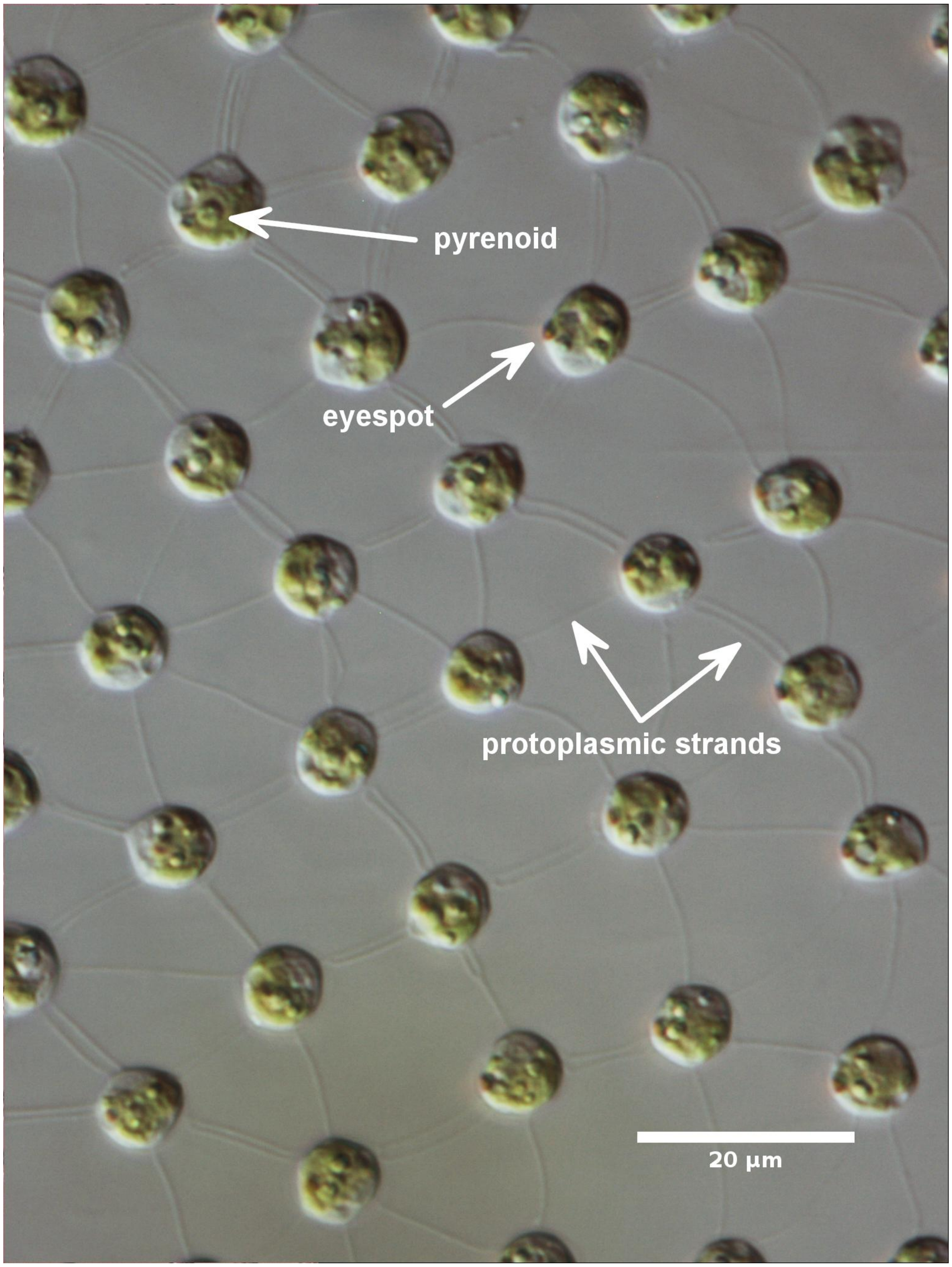


Figure 2.98: *Volvox aureus* (600x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, May 5, 2009.

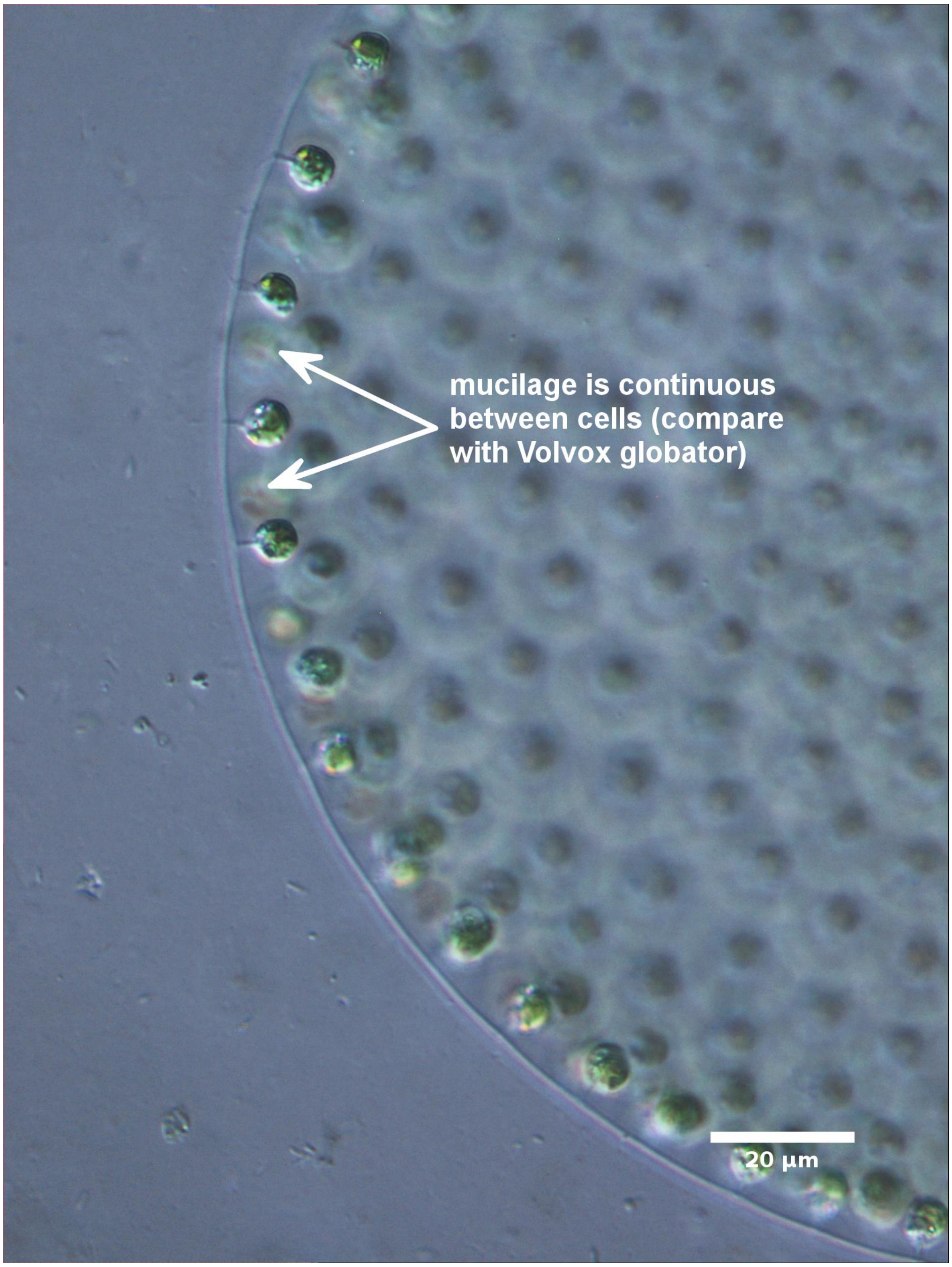


Figure 2.99: *Volvox aureus* stained with methylene blue (400x DIC), Beaver Lake, IWS water quality sampling site, Skagit County, September 16, 2009.

Figure 2.100: *Volvox aureus* (100x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, May 5, 2009.

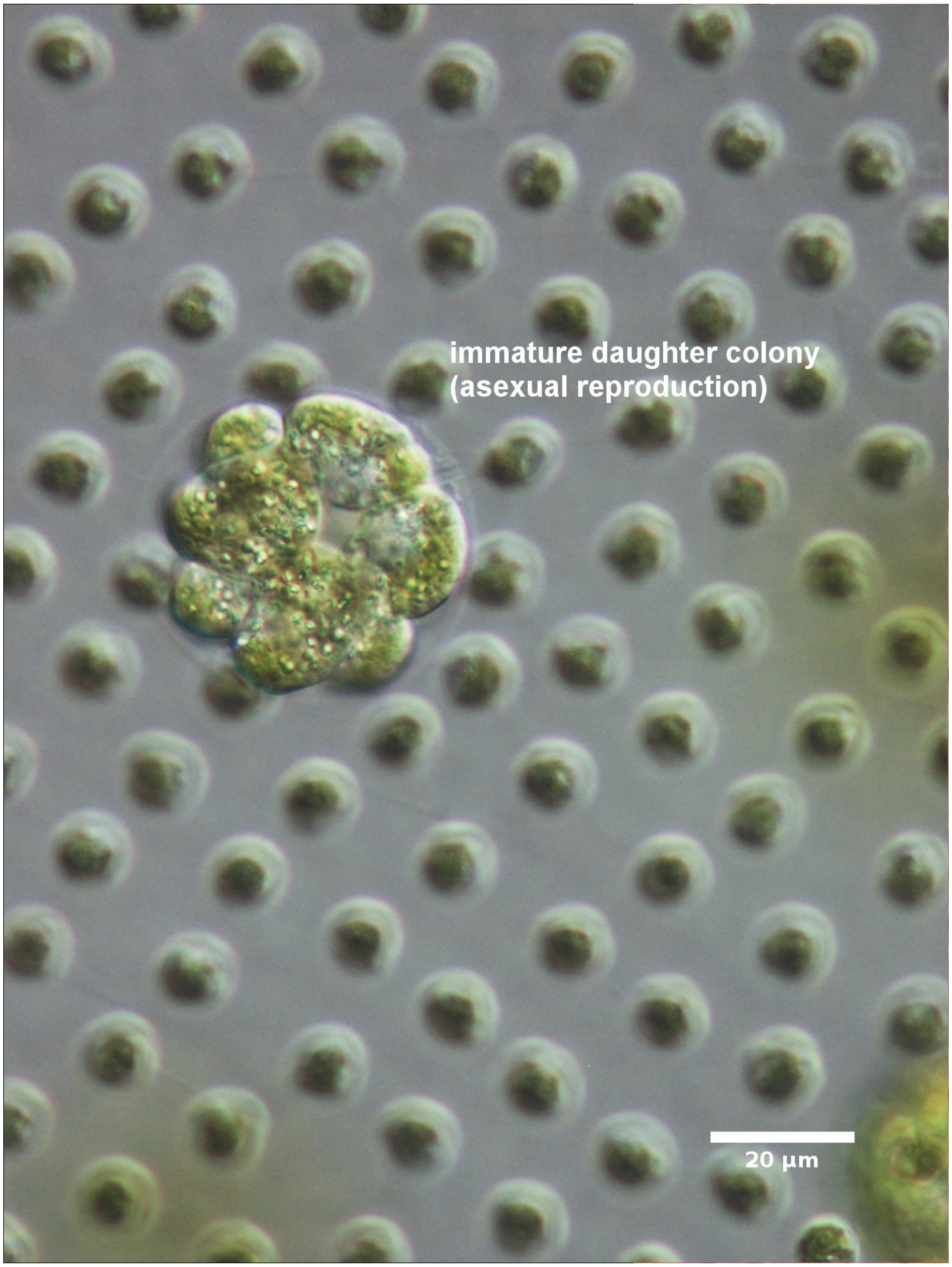


Figure 2.101: *Volvox aureus* (400x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, May 5, 2009.

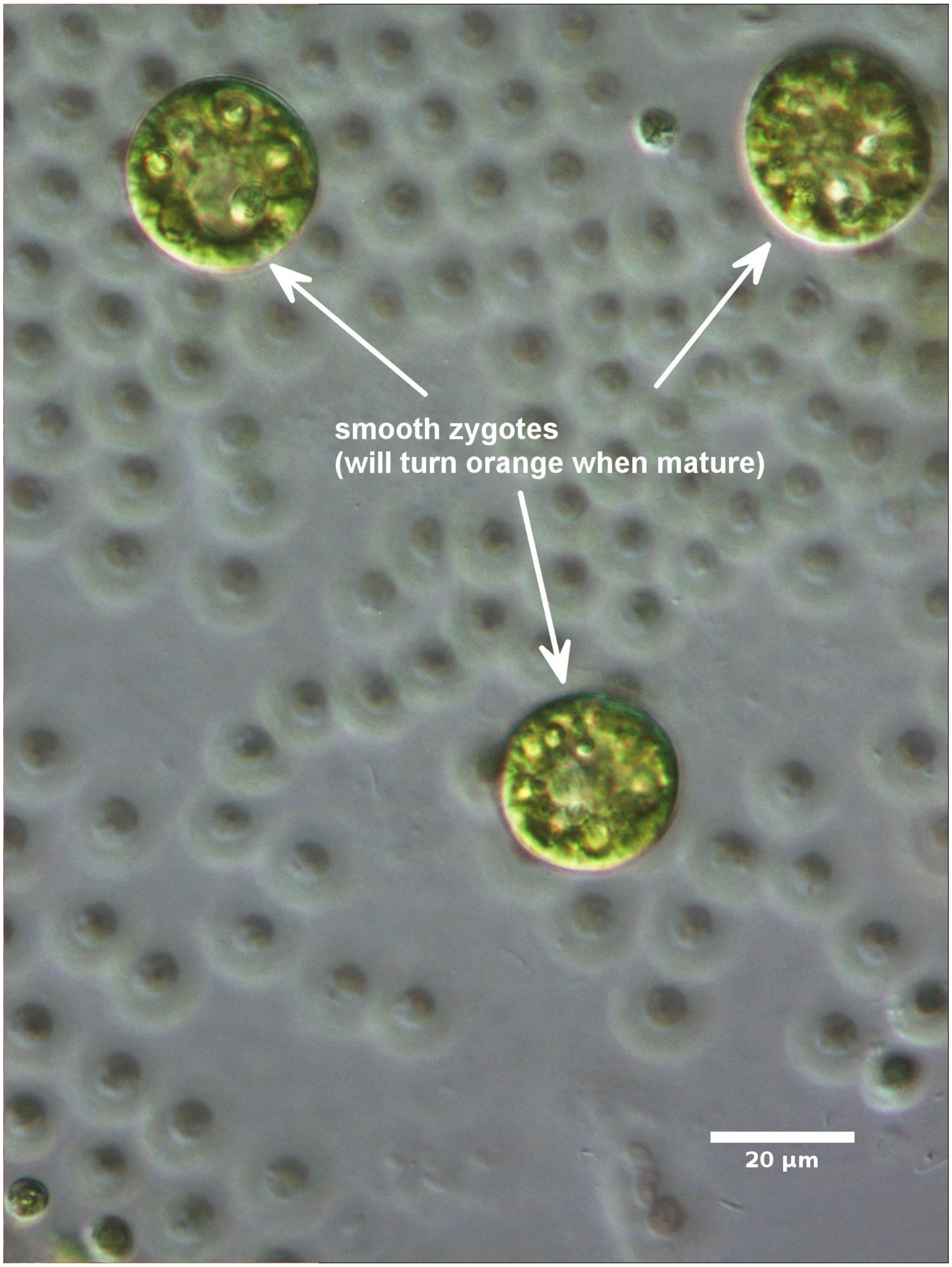


Figure 2.102: *Volvox aureus* zygotes (400x DIC), Beaver Lake, IWS water quality sampling site, Skagit County, September 16, 2009.

$$\text{Cell estimate} = 15 \times \frac{210^2}{8^2} = 10,336$$

Figure 2.103: *Volvox globator* cell estimate (100x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, September 9, 2009.

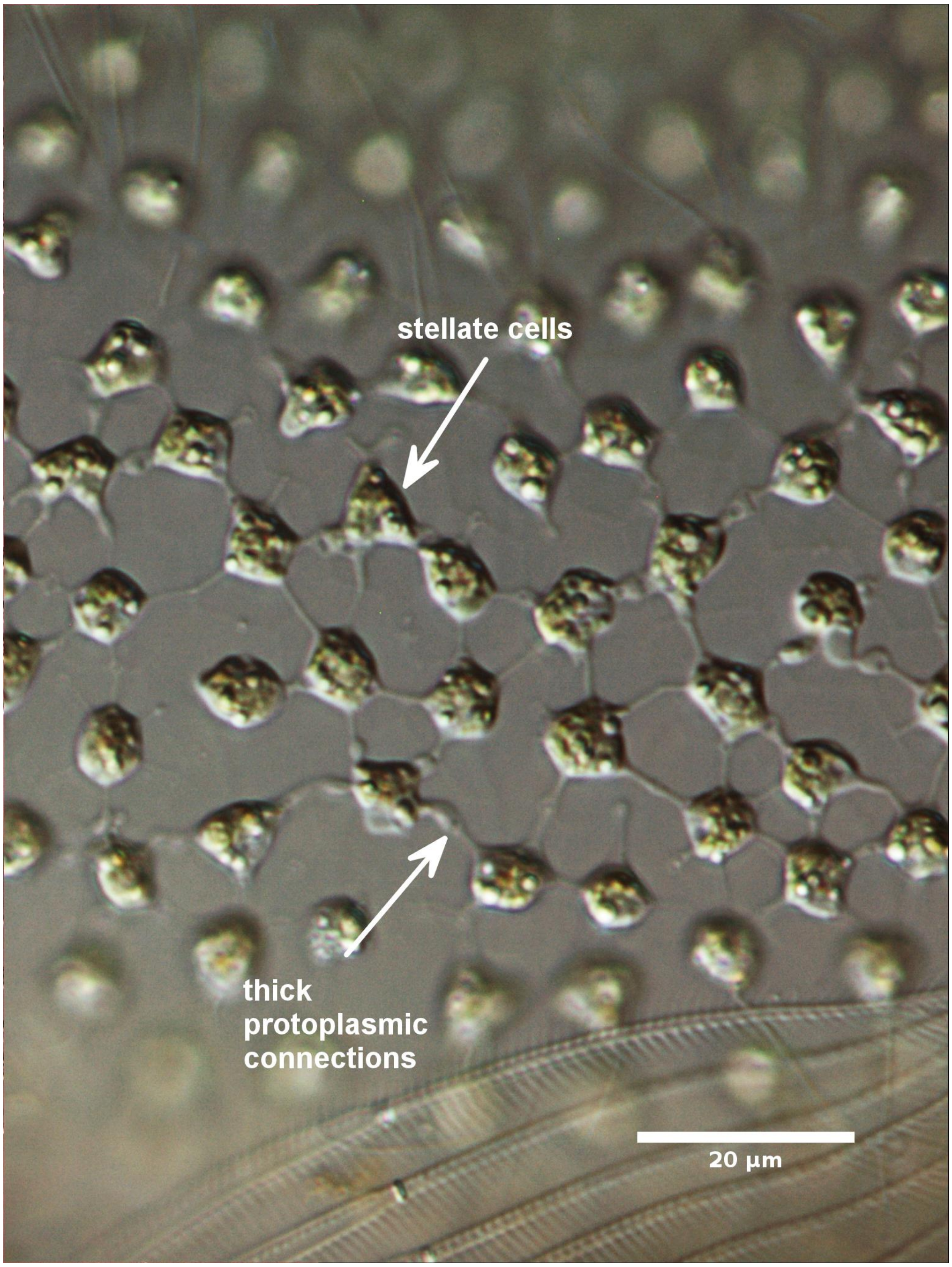


Figure 2.104: *Volvox globator* (600x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, September 9, 2009.

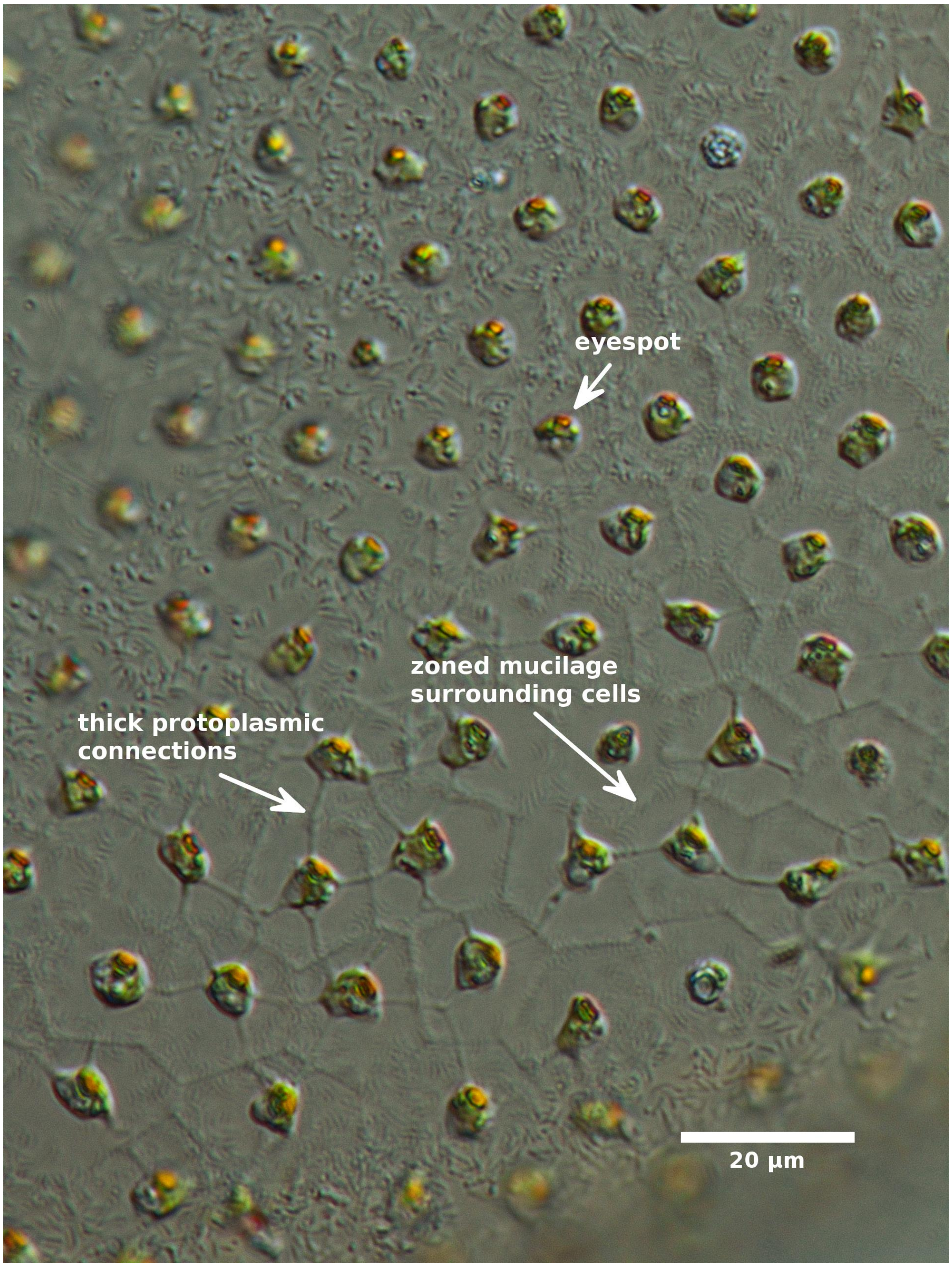


Figure 2.105: *Volvox globator* (600x DIC), Lake Campbell (Winthrop area), eastern Washington, June 19, 2014.

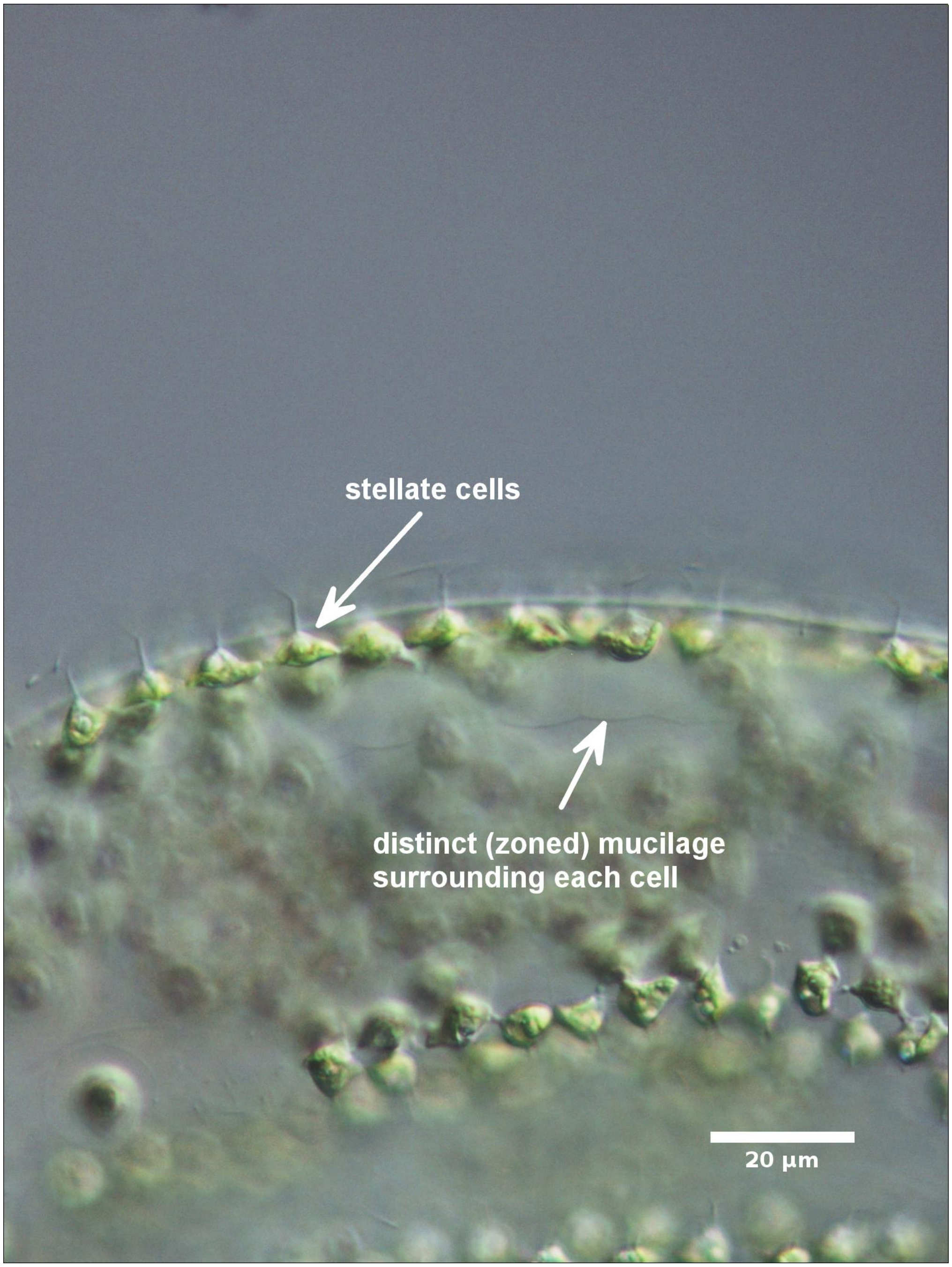


Figure 2.106: *Volvox globator* (400x DIC), Tennant Lake, IWS water quality sampling site, Whatcom County, August 16, 2007.

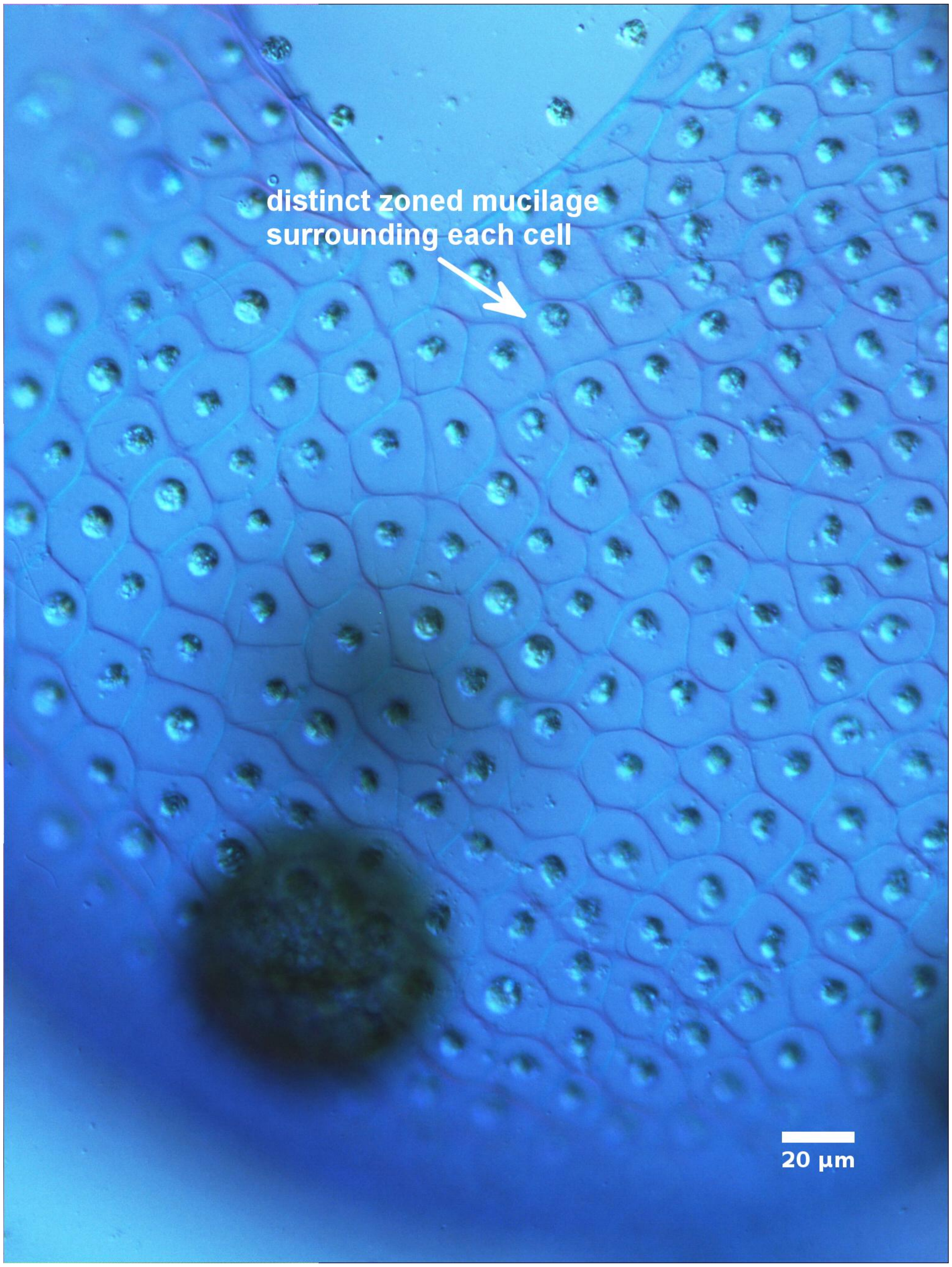


Figure 2.107: *Volvox globator* stained with methylene blue (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 1, 2009.

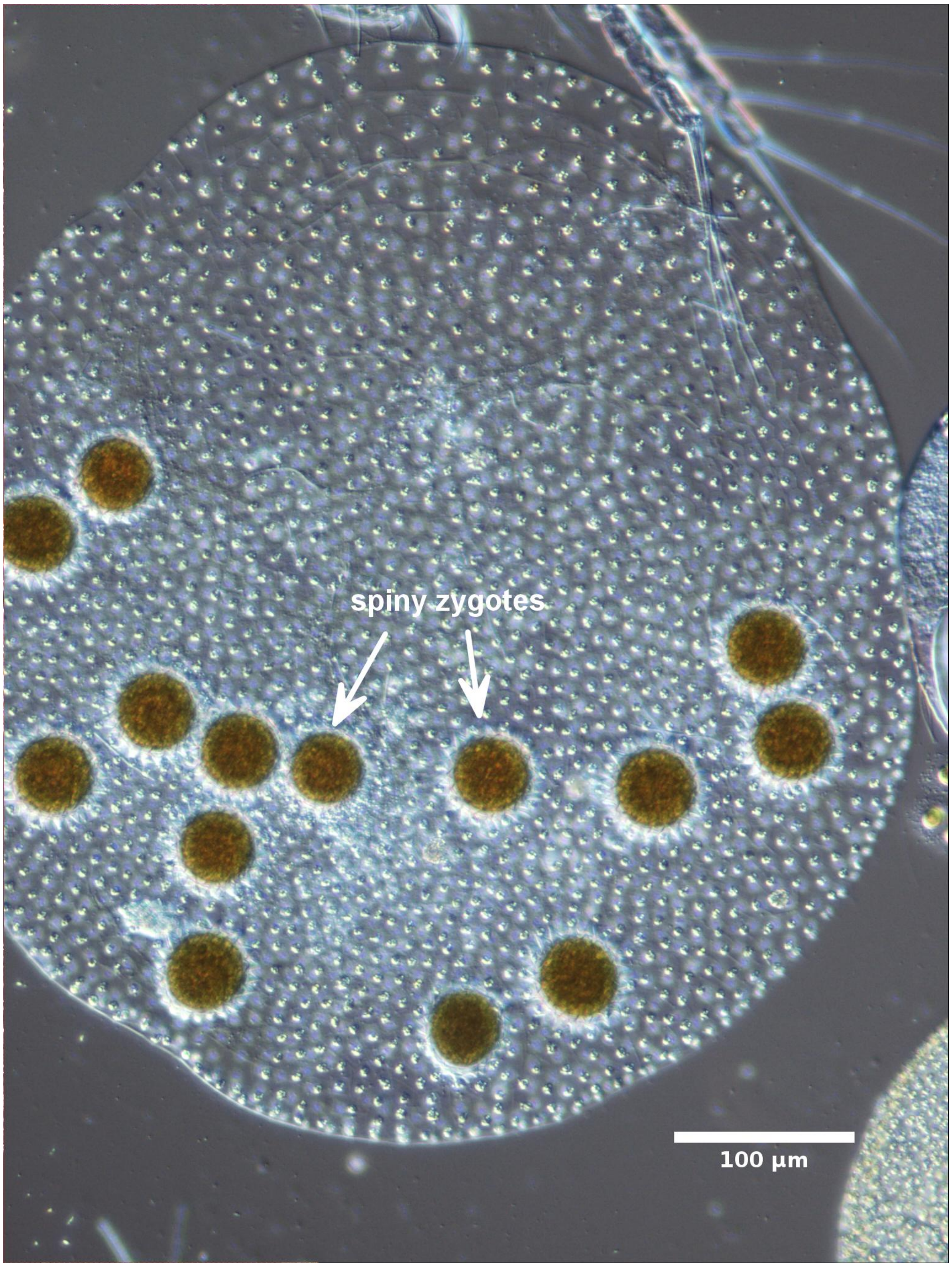


Figure 2.108: *Volvox globator* (100x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, June 17, 2009.

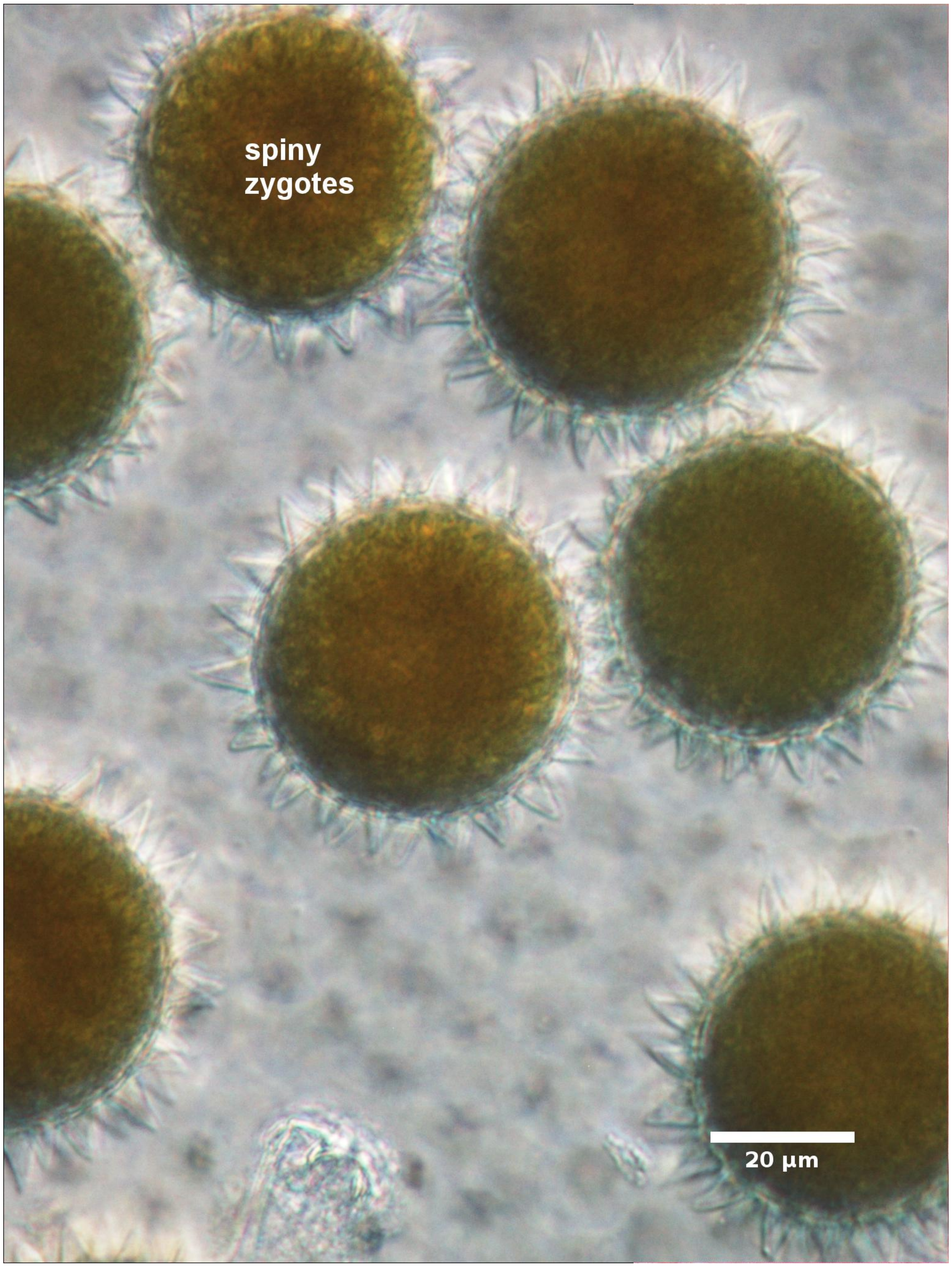


Figure 2.109: *Volvox globator* zygotes (400x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, June 17, 2009.

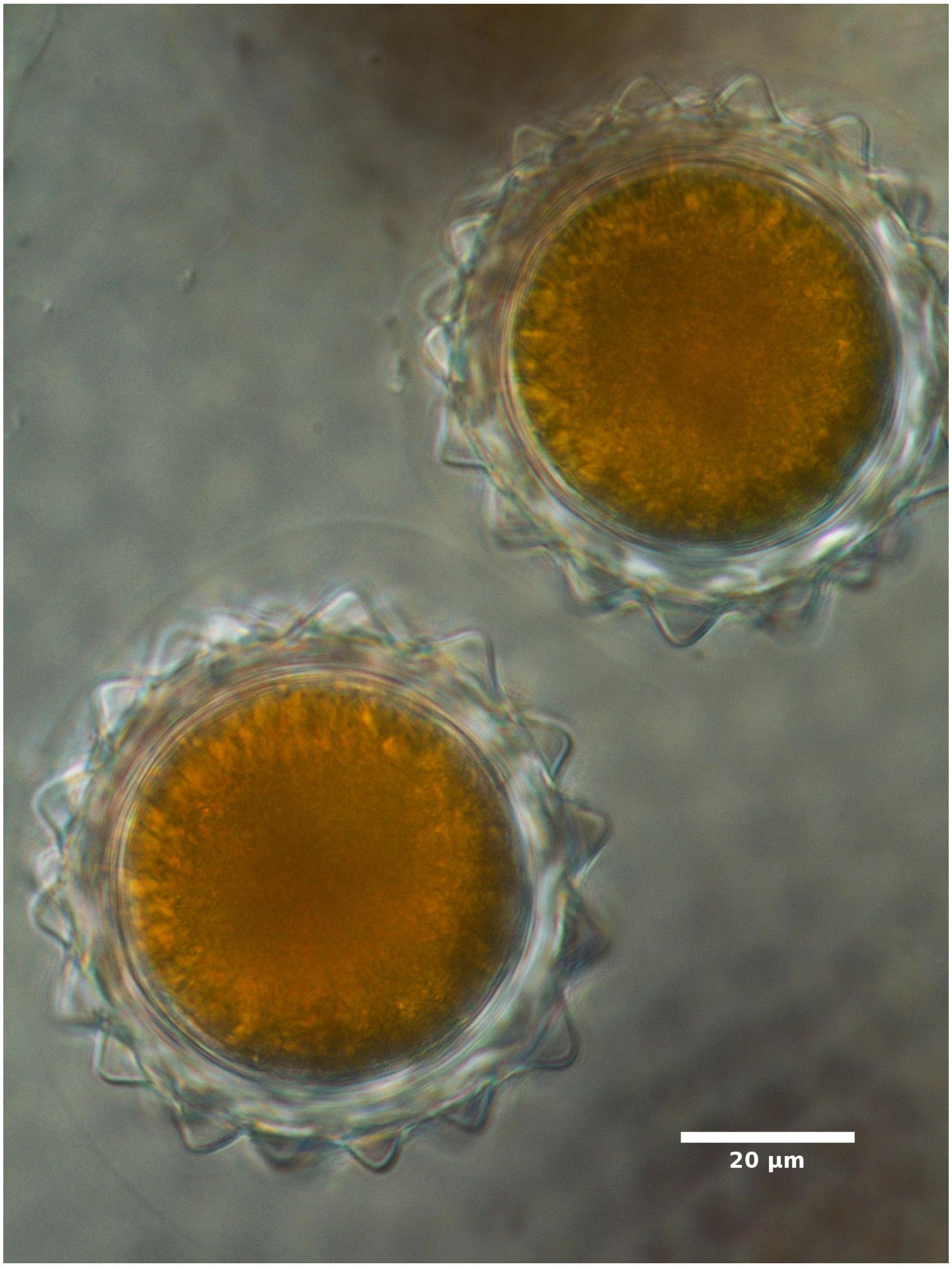


Figure 2.110: *Volvox globator* zygotes (600x DIC), Lake Campbell (Winthrop area), eastern Washington, June 19, 2014.

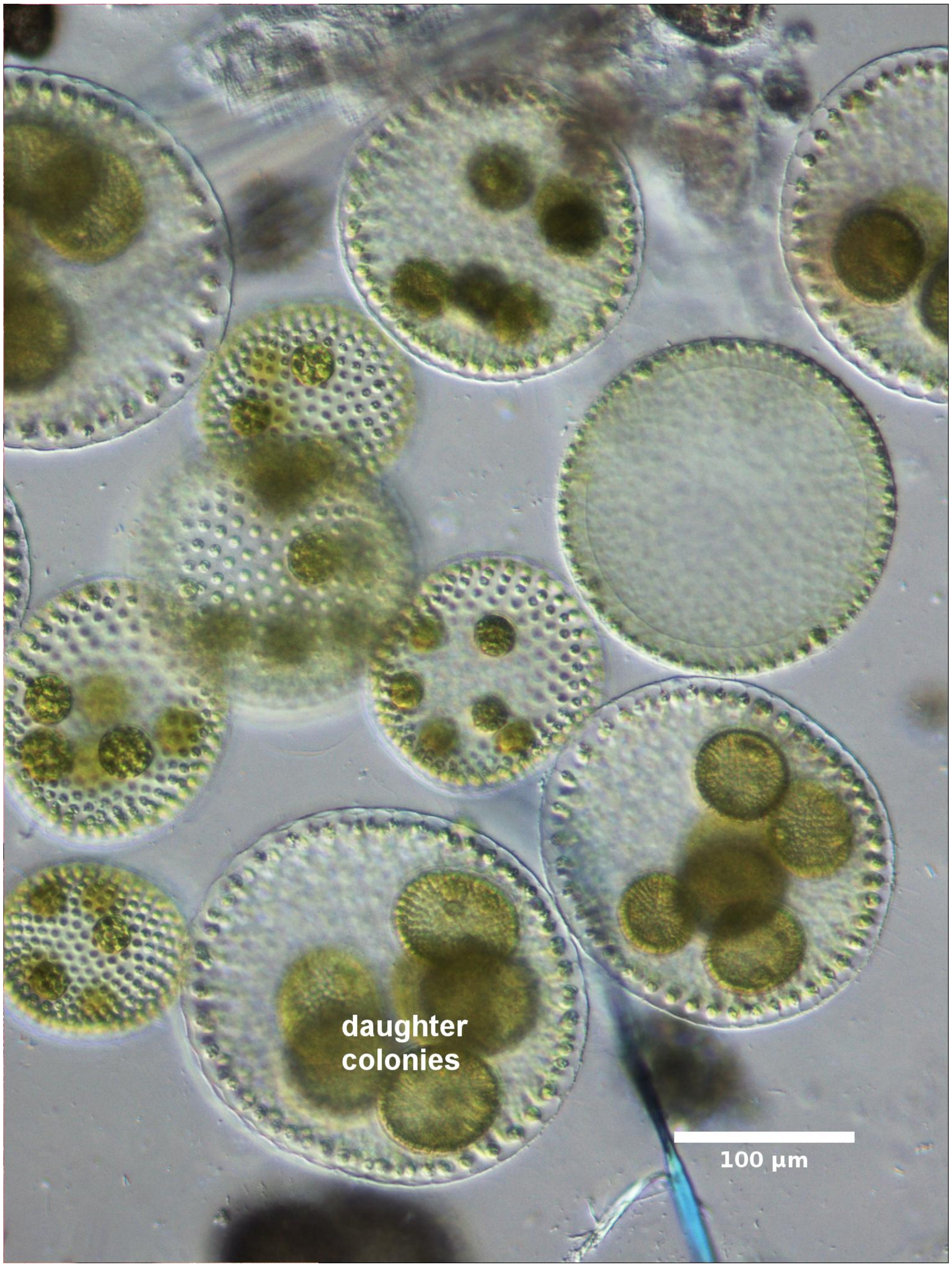


Figure 2.111: *Volvox tertius* bloom (100x DIC), Lone Lake, IWS water quality sampling site, Island County, October 1, 2009.

$$\text{Cell estimate} = 15 \times \frac{100^2}{12^2} = 1,042$$

Figure 2.112: *Volvox tertius* cell estimate (200x DIC), Lone Lake, IWS water quality sampling site, Island County, September 30, 2009.

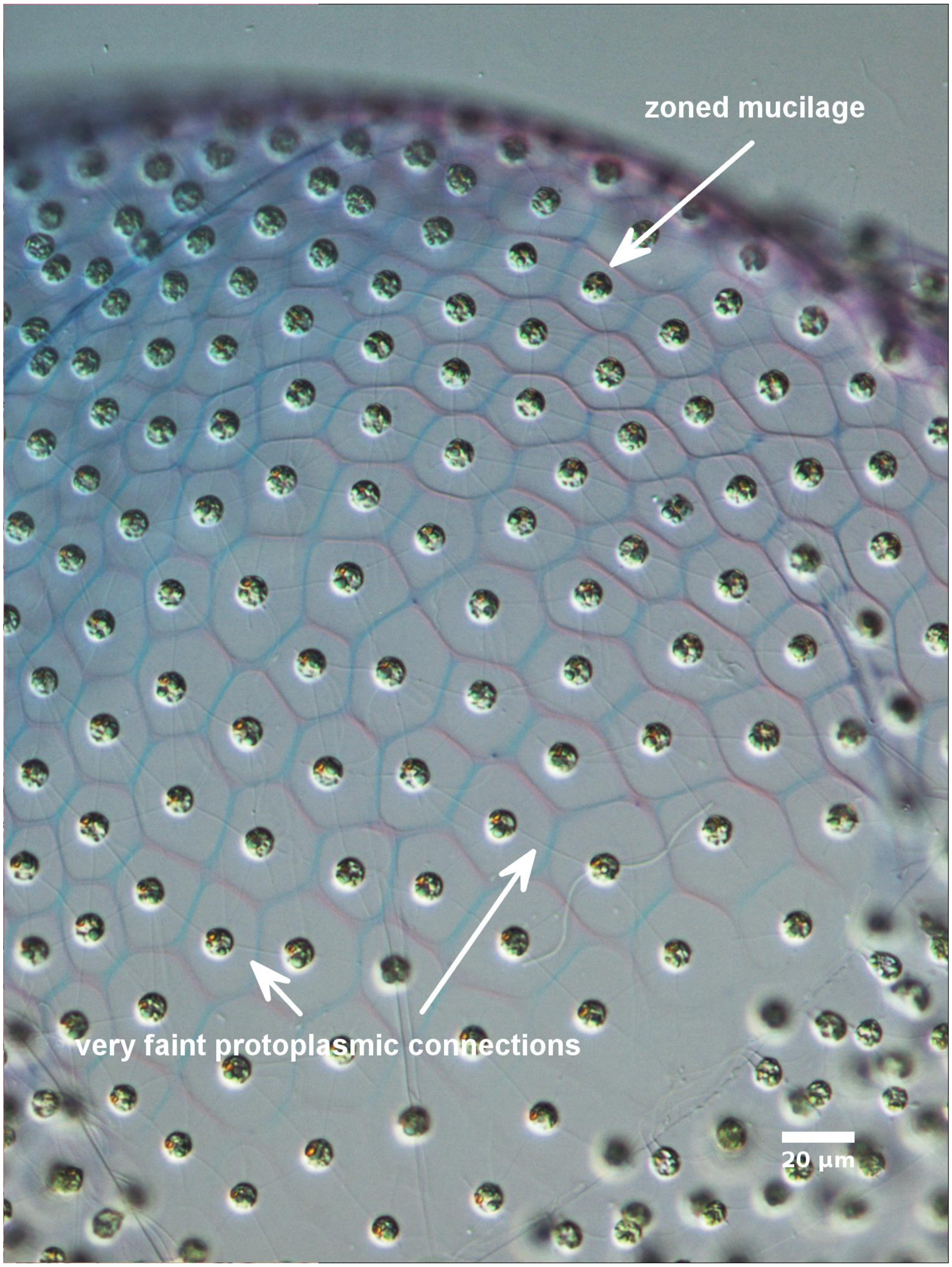


Figure 2.113: *Volvox tertius* stained with methylene blue (200x DIC), Reed Lake, IWS water quality sampling site, Whatcom County, September 17, 2009.

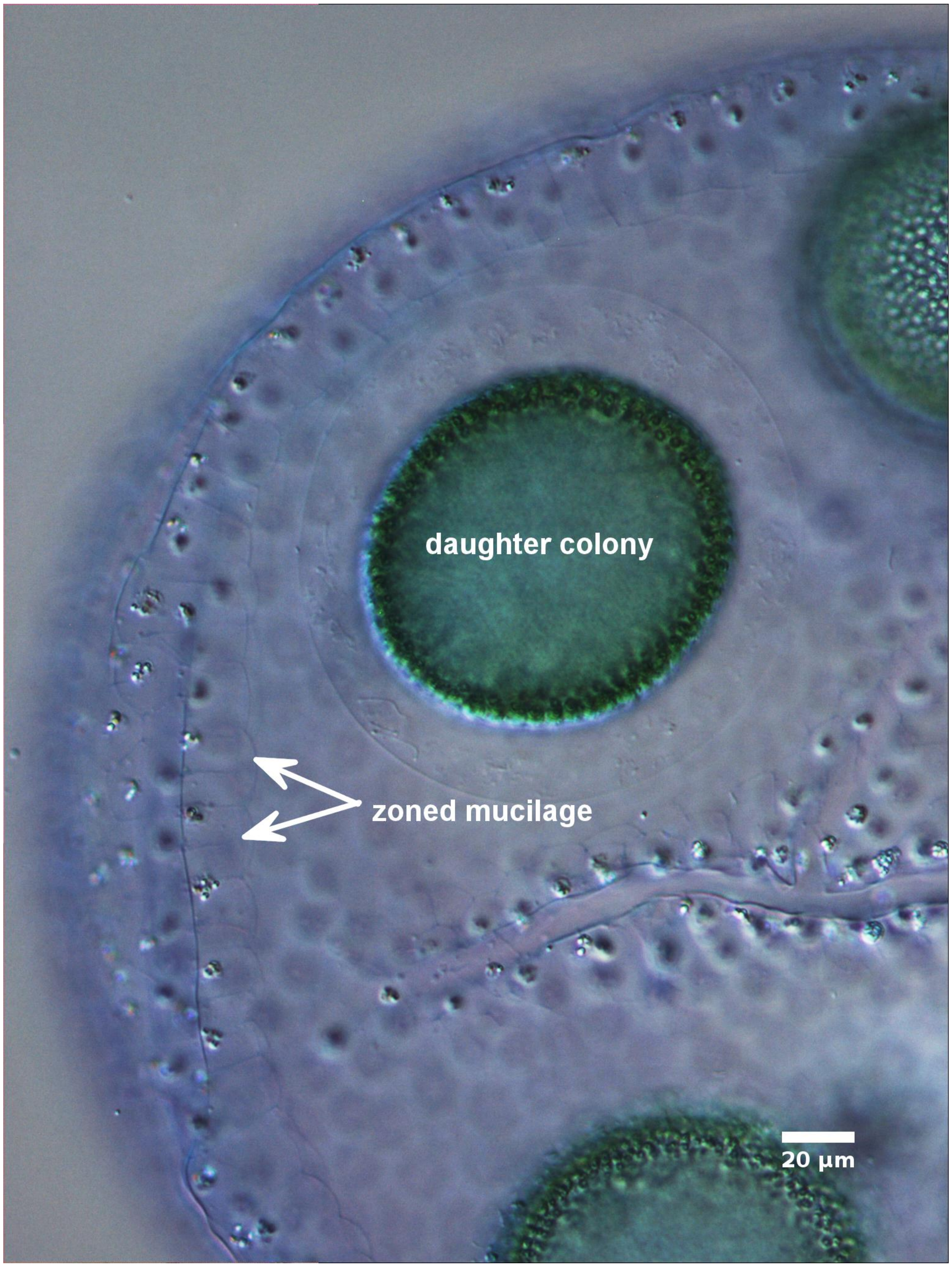


Figure 2.114: *Volvox tertius* stained with methylene blue (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 1, 2009.

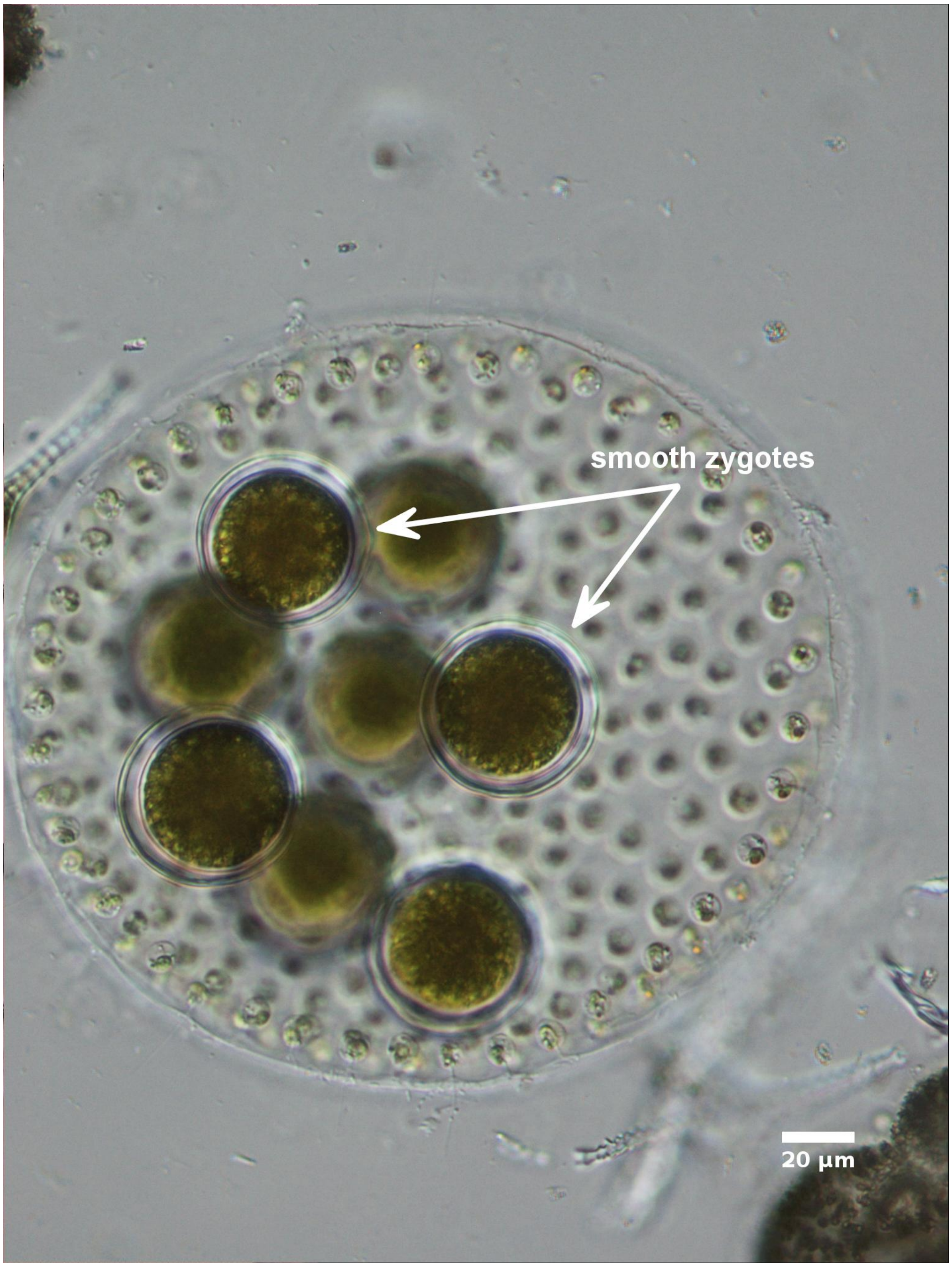


Figure 2.115: *Volvox tertius* zygotes (200x DIC), Lone Lake, IWS water quality sampling site, Island County, October 1, 2009.

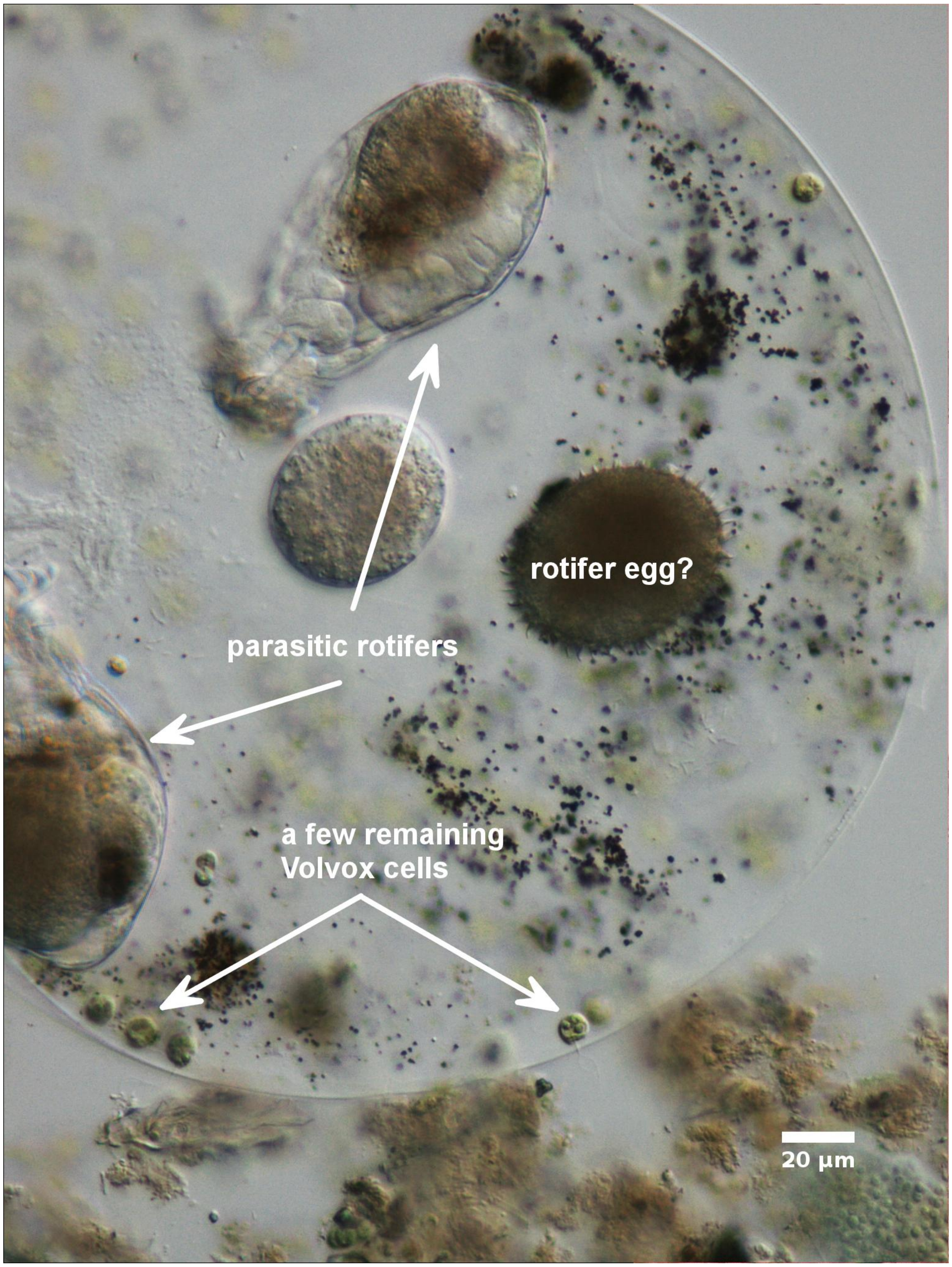


Figure 2.116: *Volvox tertius* with parasitic rotifer (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 13, 2008.

Chapter 3

Solitary and Colonial Chlorophyta

The key on page 161 will help you identify solitary and colonial Chlorophyta. For motile Chlorophyta, go to page 16; for filamentous[12] Chlorophyta, go to page 532; and for filamentous Rhodophyta go to page 755. Remember that many motile taxa have nonmotile resting stages or may be become nonmotile due to stress. The presence of flagella or an eyespot are good indicators of motility, even if the cell or colony is stationary in your sample.

The taxa in this chapter are distinguished, in part, by whether they are solitary or aggregated into colonies. This distinction is not rigid. Solitary cells form small groups when they are reproducing, and cells surrounded by mucilage can stick together, forming temporary aggregations. Try to examine more than one specimen to determine whether the cells are usually solitary or found in colonies.

This chapter does not include solitary or filamentous desmids, which are abundant and diverse in northwest Washington lakes and bogs (Figures 3.1 and 4.1, pages 160 and 531). The desmids have been placed in a separate algal division (Charophyta) that will be described in **Freshwater Algae in Northwest Washington, Volume III. Desmids**. Many older taxonomic guides include desmids in the division Chlorophyta because the cells are bright green and form starch, so they stain dark purple or brown in Lugol's iodine solution.

[12]The filamentous Chlorophyta key includes pseudofilaments (cells not actually joined end-to-end) as long as the filamentous structure is obvious.

Figure 3.1: Examples of local nonfilamentous desmids (see **Freshwater Algae in Northwest Washington, Volume III. Desmids**).

Table 3.1: Key to the Solitary and Colonial Chlorophyta

A	Cells epiphytic; solitary; oval, fusiform, crescent-shaped; often bent	*Characium* and *Stylosphaeridium* (page 274)
B	Cells form net-like or indistinct filaments; (for distinct filaments, see key on page 532)	Go to page 162
Cells solitary		
C	Cells spherical, oval, or broadly elliptical	Go to page 162
D	Cells elliptical, fusiform, club-shaped, or irregular	Go to page 163
Cells not solitary		
E	Cells connected by mucilage strands or with gelatinous, thread-like, pseudocilia	Go to page 164
F	Colonies flattened and rectangular, circular, or ribbon-like	Go to page 165
G	Colonies not as above; cells spherical, oval, or broadly elliptical	Go to page 166
H	Colonies not as above; cells narrowly elliptical, cylindrical, club-shaped, fusiform, crescent-shaped, or irregular	Go to page 168

continued on next page

Table 3.1: Key to Solitary/Colonial Chlorophyta, continued

B Cells form net-like or indistinct filaments; filamentous structure may not be obvious	
B.1 Cells epiphytic	
B.1a Cells form flat, disk-like colonies	*Coleochaete* (page 583)
B.1b Cells spherical; often solitary; usually with hair-like setae	*Chaetosphaeridium* (page 570)
B.1c Cells ±cylindrical or irregular; rarely solitary; usually with hair-like setae	*Aphanochaete* (page 536)
B.2 Cells not epiphytic	
B.2a Cells cylindrical, in open, net-like colony	*Hydrodictyon* (page 624)
B.2b Cells elliptical or fusiform; solitary or small colonies in lens-shaped mucilage	*Elakatothrix* (page 327)
C Cells solitary; spherical, oval, or broadly elliptical	
C.1 Nonmotile cysts of snow algae; cysts bright red, orange, or yellow-green; motile cells rare	See key on page 16
C.2 Cells spiny or with long, hair-like setae	
C.2a Spherical cells with 3 long, stout spines	*Treubaria* (page 522)
C.2b Spherical cells with $\gg$4 long setae	*Golenkinia* (page 352)
C.2c Oval or elliptical cells with 4 short spines or $\gg$4 long setae; solitary or 4–8 cell colonies	*Lagerheimia* (page 370)

continued on next page

Table 3.1: Key to Solitary/Colonial Chlorophyta, continued

C.3 Cells smooth (not spiny); surrounded by a wide, distinct mucilage layer	
C.3a Cells spherical; mucilage unstriated; chloroplast dense (fills cell); solitary or 4–32 cell colonies	*Planktosphaeria* (page 451)
C.3b Cells spherical, oval, or broadly elliptical; mucilage usually striated; chloroplast stellate; solitary or 2–16 cell colonies	*Asterococcus* (page 245)
C.3c Cells spherical or broadly elliptical; mucilage usually striated; chloroplast not stellate; solitary or multi-cellular aggregations	*Gloeocystis* (page 343)
C.4 Cells smooth (not spiny); mucilage absent or thin, diffuse (not clearly visible)	
C.4a Very large spherical cells (>100 μm); mucilage strands radiating from center of cell	*Eremosphaera* (page 338)
C.4b Cells oval, elliptical, or football-shaped; cell walls thick (not mucilaginous); solitary or forming 4-cell subgroups enclosed in mother cell wall	*Oocystis* (page 401)
C.4c Cells spherical; cells walls thin; solitary and multi-cellular aggregations	*Chlorella* (page 282)
D Cells solitary; elliptical, fusiform, club-shaped, or irregular	
D.1 Cells 4-sided (tetrahedral), 5-sided (star-shaped), or irregular	*Tetraedron* (page 498)

continued on next page

Table 3.1: Key to Solitary/Colonial Chlorophyta, continued

	D.2	Cells fusiform or club-shaped, with long apical and posterior spines	
		D.2a Cells broadly fusiform or club-shaped; apical spine intact, posterior spine split or paddle-shaped	*Ankyra* (page 228)
		D.2b Cells narrowly fusiform; apical and posterior spines intact	*Schroederia* (page 470)
	D.3	Cells elliptical or fusiform; no apical or posterior spines	
		D.3a Cells elliptical or fusiform; solitary or small colonies in lens-shaped mucilage	*Elakatothrix* (page 327)
		D.3b Cells narrowly fusiform; straight, curved, or S-shaped; not surrounded by mucilage; cells divide parallel to long axis	*Monoraphidium* (page 383)
		D.3c Cells narrowly or broadly fusiform; straight or slightly curved, not surrounded by mucilage; division perpendicular to long axis	*Koliella* (page 365)
E	Cells not solitary; connected by mucilage strands or with gelatinous, thread-like, pseudocilia		Go to page 164
	E.1	Cells form groups of 2 or 4 at the ends of long, radiating mucilage strands	
		E.1a Cells cylindrical or heart-shaped (both shaped in same colony)	*Dimorphococcus* (page 324)

continued on next page

Table 3.1: Key to Solitary/Colonial Chlorophyta, continued

		E.1b Cells spherical, oval, or broadly elliptical	*Dictyosphaerium* (page 317)
	E.2	Cells attached in groups of 4 by short, mucilaginous cell wall fragments	*Westella* (page 524)
	E.3	Cells with gelatinous, thread-like, non-motile pseudocilia (resemble long flagella)	
		E.3a Cells form 4-cell planktonic colonies suspended in homogeneous mucilage	*Tetraspora* (page 508)
		E.3b Cells form multi-cellular aggregations (4-cell subgroups); cells and subgroups surrounded by striated mucilage	*Paulschulzia* (page 421)
		E.3c Cells form multi-cellular aggregations enclosed in an amorphous sac	*Apiocystis* (page 240)
		E.3d Cells flattened on one end; multi-cellular aggregations (4-cell subgroups); surrounded by fragments of old mother cells	*Schizochlamys* (page 465)
	E.4	Colonies amorphous; cells form dense clumps joined by mucilage strands; individual cells partially or completely embedded in mucilage	*Botryococcus* and *Botryosphaerella* (page 254)
F	Cells not solitary; colonies flattened and rectangular, circular, or ribbon-like		
	F.1	Colonies circular or oval (coin-like); cells rectangular or irregular; outer cells usually with horn-like extensions	*Pediastrum* (page 424)

continued on next page

Table 3.1: Key to Solitary/Colonial Chlorophyta, continued

F.2 Colonies linear and ribbon-like, with cells joined along lateral walls; cells oval, elliptical, fusiform, or crescent-shaped; cell walls spiny or smooth (most colonies contain 4 or 8 cells)	*Acutodesmus*, *Desmodesmus*, *Scenedesmus*, and *Tetradesmus* (page 174)
F.3 Colonies rectangular	
F.3a Colonies with 4 wedge-shaped cells; outer margin of cells deeply incised	*Pediastrum*, in part (page 424)
F3.b Colonies with 4 wedge-shaped cells; outer margin of cells straight or slightly curved, but not incised	*Crucigenia* and *Crucigeniella* (page 303)
F.3c Colonies with >4 cells; cells oval or broadly elliptical, with no horn-like projections	*Crucigenia* and *Crucigeniella* (page 303)
G Cells not solitary; colonies not flattened; cells spherical, oval, or broadly elliptical	
G.1 Cells form single or double row inside tube-shaped mucilage attached to substrate	*Palmodictyon* (page 413)
G.2 Cells joined by angular extensions to form a hollow-centered, spherical colony	*Coelastrum* (page 292)
G.3 Cells spiny or with long, hair-like setae (see page 164 for cells with pseudocilia)	
G.3a Spherical cells with many long, rigid spines; cells in groups of 4	*Micractinium* (page 377)

continued on next page

Table 3.1: Key to Solitary/Colonial Chlorophyta, continued

	G.3b Oval or elliptical cells with 4 short spines or ≫4 long setae; solitary or in 4–8 cell colonies	*Lagerheimia* (page 370)
G.4	Cells smooth (not spiny); surrounded by a wide, distinct mucilage layer	
	G.4a Cells spherical; mucilage unstriated; chloroplast dense (fills cell); solitary or in 4–32 cell colonies	*Planktosphaeria* (page 451)
	G.4b Cells spherical, oval, or broadly elliptical; mucilage usually striated; chloroplast stellate; solitary or in 2–16 cell colonies	*Asterococcus* (page 245)
	G.4c Cells spherical or broadly elliptical; mucilage usually striated; chloroplast not stellate; solitary or multi-cellular aggregations	*Gloeocystis* (page 343)
	G.4d Cells oval or broadly elliptical (may be slightly curved); enclosed in thick, gelatinous mother cell wall	*Nephrocytium* and *Oonephris* (page 390)
G.5	Cells smooth (not spiny); mucilage absent or thin, diffuse (not clearly visible)	
	G.5a Colony surrounded by diffuse mucilage; cells spherical, in multi-generation groups (large and small cells)	*Sphaerocystis* (page 493)
	G.5b Cells oval, elliptical, or football-shaped; cell wall thick (not mucilaginous); solitary or forming 4-cell subgroups enclosed in mother cell wall	*Oocystis* (page 401)

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Table 3.1: Key to Solitary/Colonial Chlorophyta, continued

G.5c Cells spherical; cell walls thin; solitary or multi-cellular aggregations	*Chlorella* (page 282)
H Cells not solitary; colonies not flattened; cells narrowly elliptical, cylindrical, club-shaped, fusiform, crescent-shaped, or irregular	
H.1 Cells cylindrical, fusiform, or club-shaped	
H.1a Cells club-shaped, with long, apical hairs; 2-cell colony joined by interlocking posterior spines	*Paradoxia* (page 416)
H.1b Cells cylindrical or club-shaped; cells form 4-cell or 8-cell tetrahedral colonies	*Actinastrum* (page 169)
H.1c Cells cylindrical or bluntly fusiform; cells in groups of 4, forming parallel bundles enclosed in diffuse mucilage	*Quadrigula* (page 459)
H.1d Cells very narrowly fusiform; acutely pointed; may be curved or twisted	*Ankistrodesmus* (page 220)
H.2 Cells strongly curved, crescent-shaped	
H.2a Cells acute; joined along convex wall	*Selenastrum* (page 477)
H.2b Cells acute or blunt; not joined on convex wall	*Kirchneriella* (page 356)
H.3 Cells irregular, with 2–4 apical, horn-like spines; cells radiate from colony center, forming compact, spherical colonies	*Sorastrum* (page 486)

3.1 *Actinastrum* Lagerheim

Local taxa
Actinastrum spp.

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Actinastrum sp.1‡	min	2.2 μm	10.5 μm	35.7 μm^3
cells (cyl + two $\frac{1}{2}$ spheres)	med	2.5 μm	13.7 μm	41.8 μm^3
	max	3.1 μm	15.1 μm	64.5 μm^3
Actinastrum sp.2§	min	4.2 μm	16.4 μm	85.0 μm^3
cells (cone + $\frac{1}{2}$ sphere)	med	4.3 μm	17.1 μm	85.4 μm^3
	max	4.5 μm	17.8 μm	85.9 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume based on cylinder length (< cell length).
§Biovolume based on cone length (< cell length); biovolume estimate based on <5 cells.

Description
Actinastrum colonies contain small groups of cylindrical, fusiform, or club-shaped cells joined at one end, usually in multiples of four, to form 4-cell or 8-cell tetrahedral colonies (Figures 3.2–3.5). The cells have smooth walls and a single chloroplast containing one pyrenoid. Although the colonies usually contain only 4–8 cells, larger aggregations can occur. The cells are embedded in a diffuse colonial mucilage, which may cause subgroups to stick together.

Two types of *Actinastrum* cells were present in the Lake Fazon sample collected on September 17, 2009 (Figure 3.2). The cells in Figures 3.3–3.4 are cylindrical and considerably smaller than the club-shaped cells in Figure 3.5. The cell dimensions for both types are within the range for *Actinastrum hantzschii* Lagerheim (John, et al., 2011), so these could be varieties of the same species.

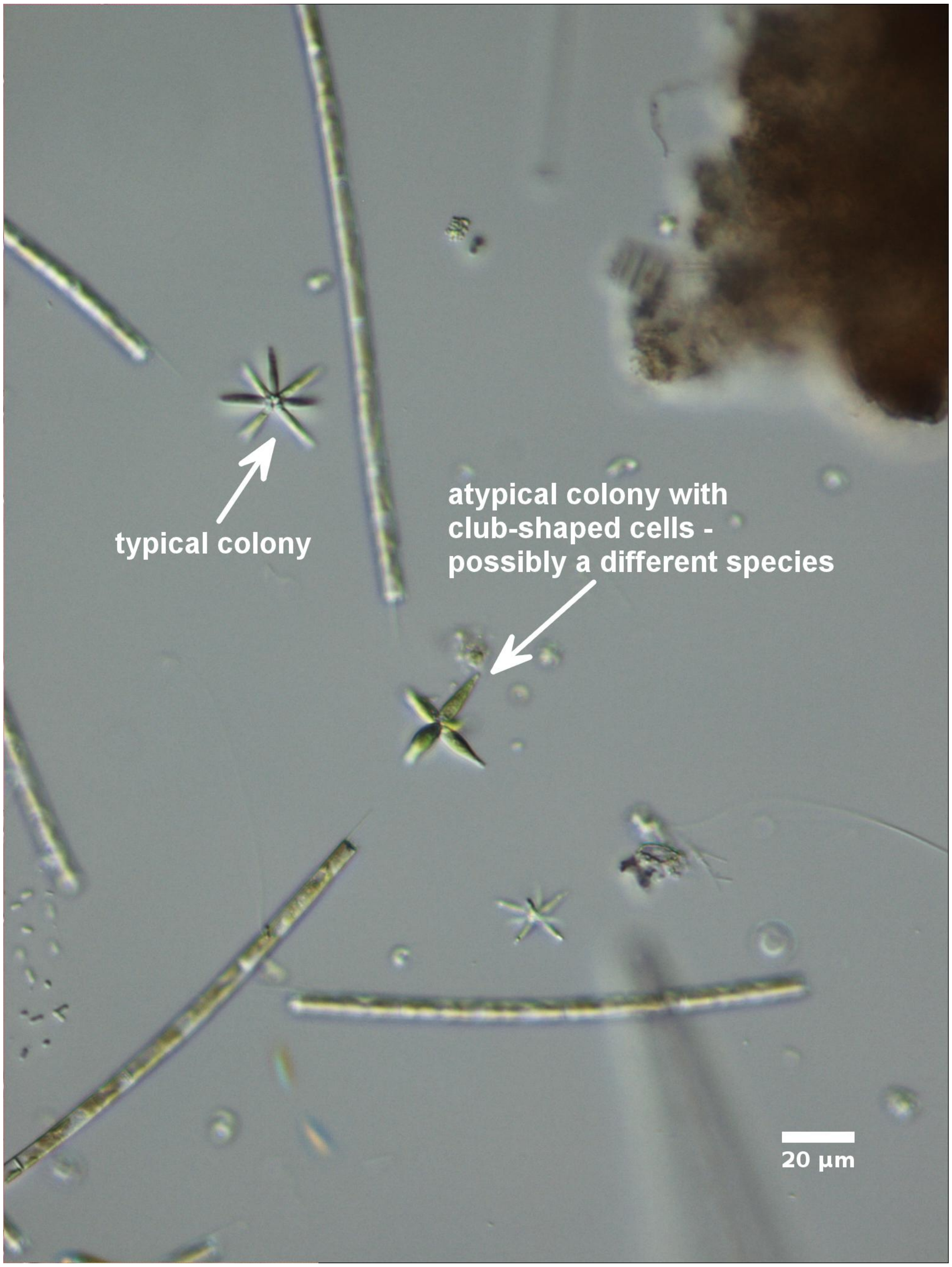

Figure 3.2: *Actinastrum* spp. (200x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, September 17, 2009.

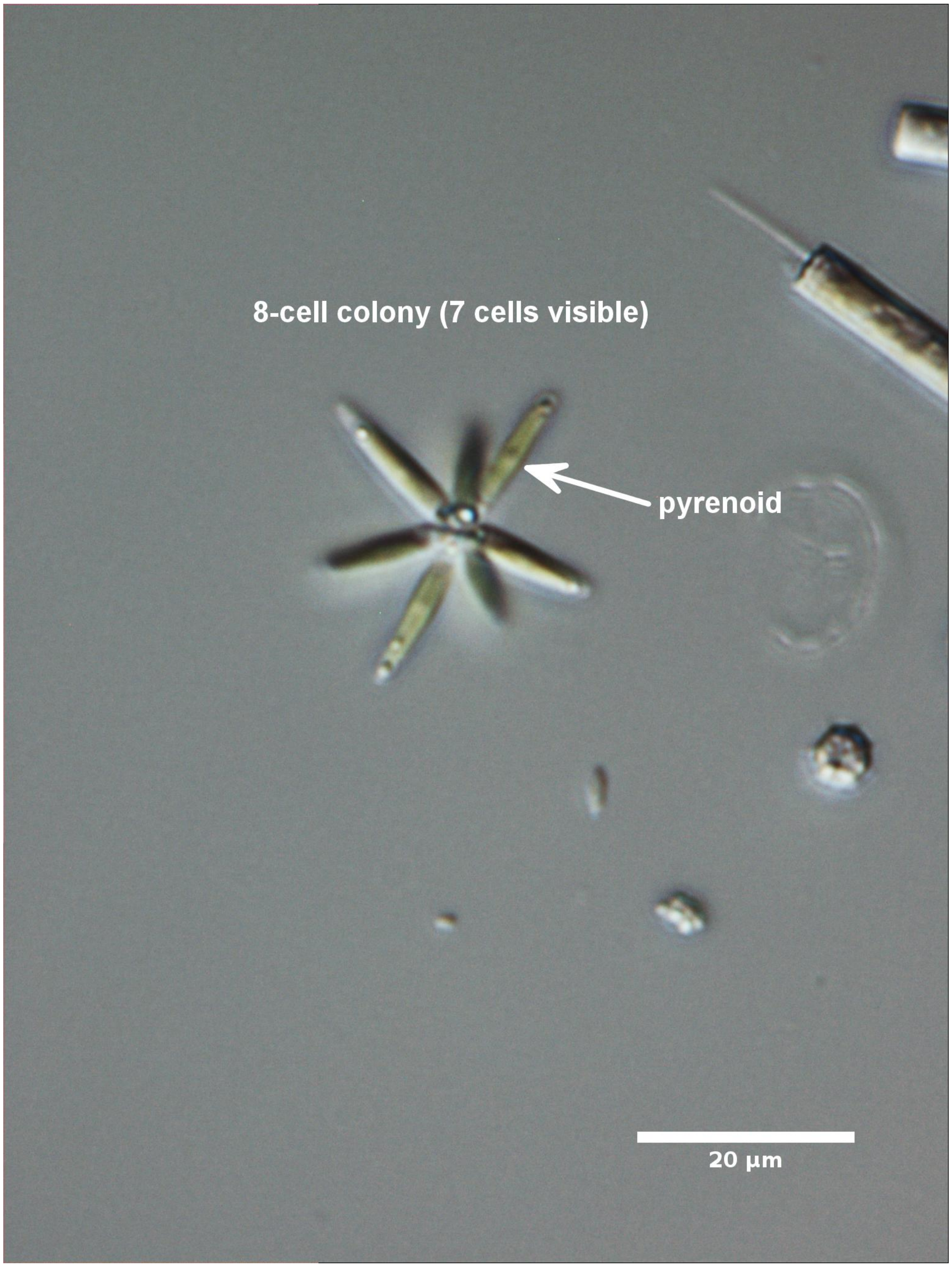

Figure 3.3: *Actinastrum* sp.1 (600x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, September 17, 2009.

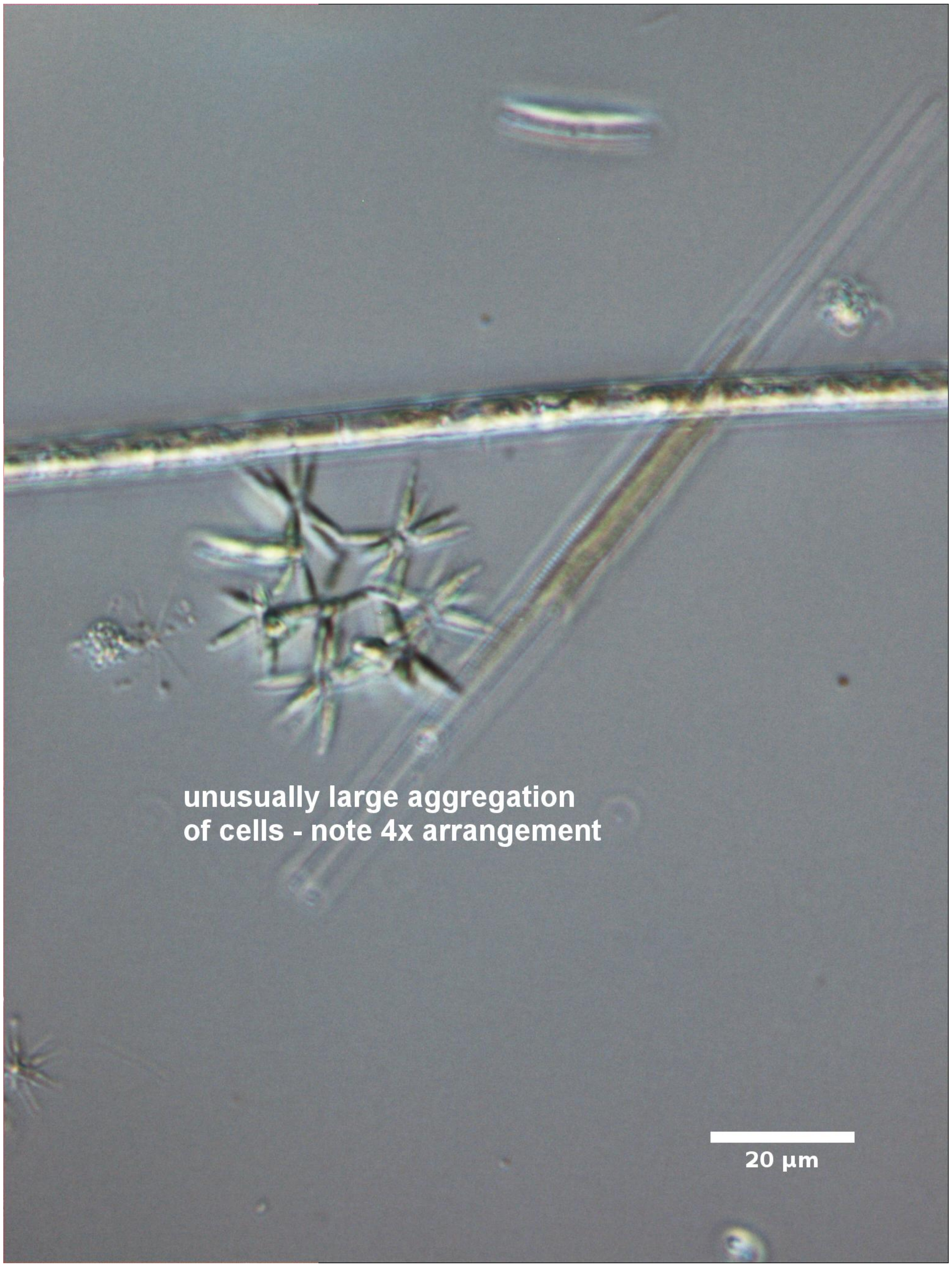

Figure 3.4: *Actinastrum* sp.1 (400x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, September 17, 2009.

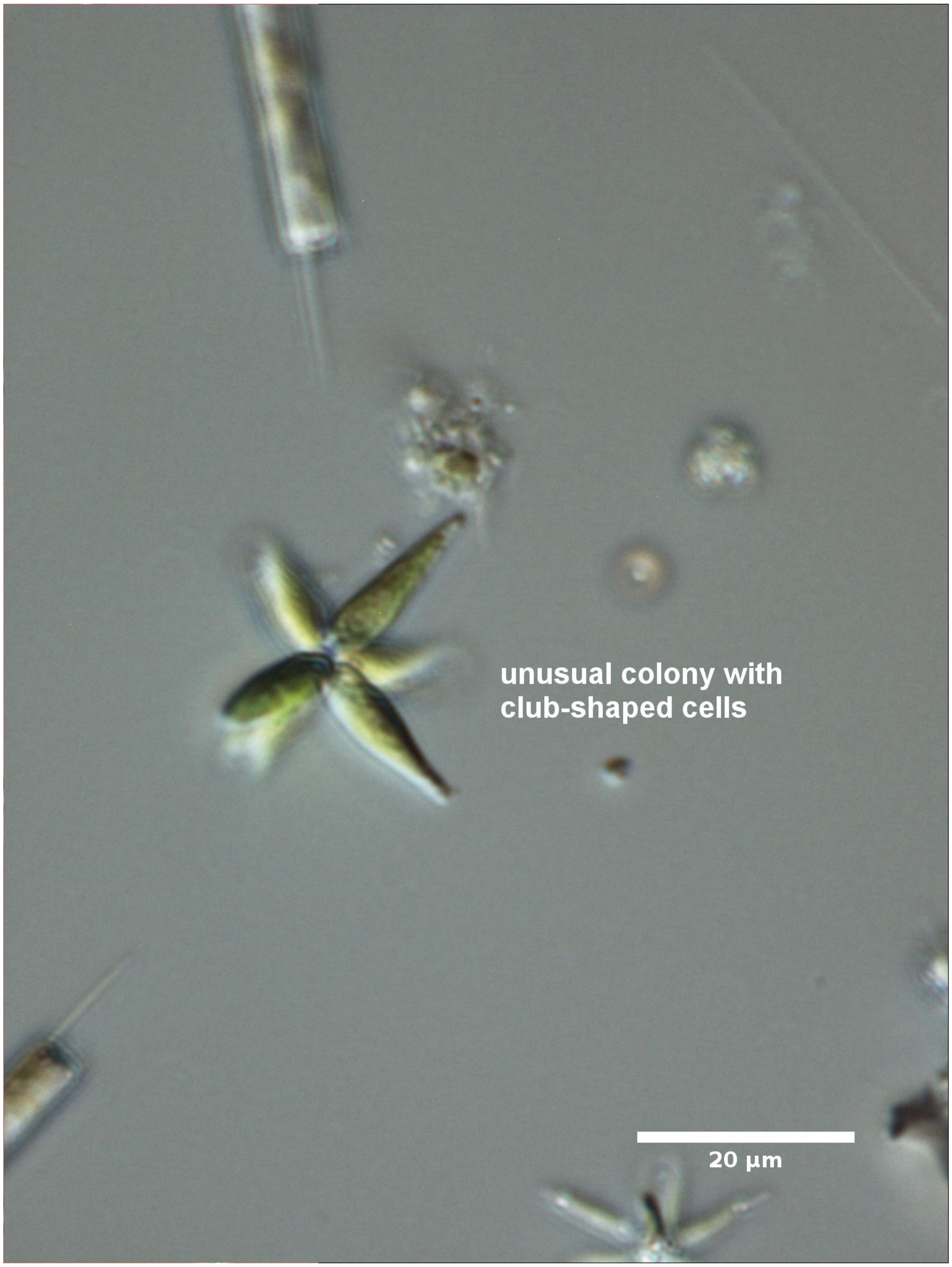

Figure 3.5: *Actinastrum* sp.2 (600x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, September 17, 2009.

3.2 *Acutodesmus* (E. Hegewald) Tsarenko, *Desmodesmus* (Chodat) S. S. An, T. Friedl & E. Hegewald, *Scenedesmus* Meyen, and *Tetradesmus* G. M. Smith

Local taxa

There are many species of *Acutodesmus*, *Desmodesmus*, *Scenedesmus*, and *Tetradesmus* in northwest Washington lakes and ponds, so only the common or distinctive taxa are included in this section. Many of the species are polymorphic and difficult to identify correctly. The genus names have been revised, with most of the spiny taxa moved to *Desmodesmus* and most of the narrow, fusiform taxa moved to *Acutodesmus* or *Tetradesmus*.

Acutodesmus/Tetradesmus **species**
Tetradesmus acuminatus (Lagerheim) Wynne (=*A. acuminatus* [Lagerheim] Tsarenko)
Tetradesmus dimorphus (Turpin) Wynne (=*A. dimorphus* [Turpin] Tsarenko)
Tetradesmus wisconsinensis G. M. Smith (=*A. wisconsinensis* [G. M. Smith] Tsarenko)

Desmodesmus **species**
Desmodesmus abundans (Kirchner) E. Hegewald (=*S. abundans* [Kirchner] Chodat)
Desmodesmus armatus [Chodat] E. Hegewald (=*S. armatus* [Chodat] Chodat)
Desmodesmus brasiliensis (Bohlin) E. Hegewald (=*S. brasiliensis* Bohlin)
Desmodesmus granulatus (West & G. S. West) Tsarenko (=*S. granulatus* West & G. S. West)
Desmodesmus magnus (Meyen) Tsarenko (=*S. magnus* Meyen)
Desmodesmus serratus (Corda) S. S. An, T. Friedl & E. Hegewald (=*S. serratus* [Corda] Bohlin)
Desmodesmus spp.

Scenedesmus **species**
Scenedesmus arcuatus (Lemmermann) Lemmermann
Scenedesmus ellipticus Corda
Scenedesmus quadricauda (Turpin) Brébisson

Local measurements		Width	Length	Biovolume†
Tetradesmus acuminatus	min	3.2 μm	22.0 μm	59.0 μm^3
cells (fusiform)	med	4.2 μm	30.0 μm	169 μm^3
	max	5.8 μm	39.0 μm	303 μm^3
Tetradesmus dimorphus	min	4.0 μm	16.0 μm	154 μm^3
cells (spheroid)	med	6.6 μm	18.1 μm	412 μm^3
	max	7.0 μm	20.7 μm	501 μm^3
Tetradesmus wisconsinensis	min	3.6 μm	11.9 μm	90.9 μm^3
cells (spheroid)	med	5.2 μm	14.7 μm	203 μm^3
	max	6.6 μm	17.9 μm	350 μm^3
Desmodesmus abundans	min	3.8 μm	9.6 μm	72.6 μm^3
type A cells (spheroid)	med	4.5 μm	11.3 μm	127 μm^3
	max	5.5 μm	17.0 μm	232 μm^3
Desmodesmus abundans	min	2.8 μm	9.8 μm	52.5 μm^3
type B cells (spheroid)	med	3.6 μm	13.7 μm	87.5 μm^3
	max	5.1 μm	17.2 μm	223 μm^3
Desmodesmus armatus	min	1.7 μm	7.0 μm	13.5 μm^3
cells (spheroid)	med	2.5 μm	9.1 μm	30.7 μm^3
	max	3.5 μm	12.8 μm	59.0 μm^3
Desmodesmus brasiliensis	min	3.3 μm	9.8 μm	64.8 μm^3
cells (spheroid)	med	3.6 μm	10.6 μm	73.6 μm^3
	max	3.9 μm	12.2 μm	87.5 μm^3
Desmodesmus granulatus‡	min	3.4 μm	10.1 μm	61.1 μm^3
cells (spheroid)	med	3.5 μm	11.1 μm	73.5 μm^3
	max	3.6 μm	11.8 μm	75.7 μm^3
Desmodesmus magnus	min	5.1 μm	17.5 μm	251 μm^3
cells (spheroid)	med	7.0 μm	22.7 μm	521 μm^3
	max	11.2 μm	29.5 μm	1,900 μm^3
Desmodesmus serratus	min	3.2 μm	12.2 μm	65.9 μm^3
cells (spheroid)	med	5.0 μm	13.6 μm	172 μm^3
	max	5.8 μm	17.1 μm	253 μm^3

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Local measurements		Width	Length	Biovolume[†]
Desmodesmus sp.1[‡]	min	13.4 μm	27.9 μm	2,740 μm^3
cells (spheroid)	med	13.6 μm	29.5 μm	2,830 μm^3
	max	13.7 μm	31.1 μm	2,920 μm^3
Desmodesmus sp.2	min	9.1 μm	17.4 μm	811 μm^3
cells (spheroid)	med	10.4 μm	19.1 μm	1,090 μm^3
	max	12.0 μm	20.1 μm	1,510 μm^3
Desmodesmus sp.3	min	4.0 μm	8.1 μm	73.7 μm^3
cells (spheroid)	med	5.0 μm	9.8 μm	129 μm^3
	max	6.1 μm	11.6 μm	220 μm^3
Desmodesmus sp.4	min	6.6 μm	19.6 μm	479 μm^3
cells (spheroid)	med	6.9 μm	20.6 μm	509 μm^3
	max	8.2 μm	23.4 μm	824 μm^3
Desmodesmus sp.5[‡]	min	3.7 μm	11.2 μm	81.7 μm^3
cells (spheroid)	med	4.8 μm	13.3 μm	155 μm^3
	max	7.1 μm	16.1 μm	425 μm^3
Scenedesmus arcuatus	min	4.8 μm	10.9 μm	142 μm^3
cells (spheroid)	med	6.5 μm	13.2 μm	289 μm^3
	max	8.4 μm	17.4 μm	643 μm^3
Scenedesmus	min	5.8 μm	15.2 μm	268 μm^3
ellipticus type A	med	7.7 μm	19.5 μm	584 μm^3
cells (spheroid)	max	9.0 μm	22.2 μm	942 μm^3
Scenedesmus	min	3.0 μm	8.0 μm	37.7 μm^3
ellipticus type B	med	4.2 μm	12.3 μm	131 μm^3
cells (spheroid)	max	5.2 μm	14.6 μm	170 μm^3
Scenedesmus	min	2.9 μm	7.2 μm	33.5 μm^3
ellipticus type C	med	3.8 μm	7.6 μm	55.9 μm^3
cells (spheroid)	max	4.4 μm	7.8 μm	74.0 μm^3
Scenedesmus quadricauda	min	5.1 μm	15.8 μm	223 μm^3
cells (spheroid)	med	6.5 μm	19.2 μm	411 μm^3
	max	7.5 μm	22.5 μm	622 μm^3

[†]Calculated using original measurements, not summary values.
[‡]Biovolume estimate based on <5 cells.

Description
All of the taxa in this section form small colonies of oval, elliptical, or fusiform cells joined along their long axis. Most of the colonies contain 4 or 8 cells. All cells have a parietal chloroplast containing a single pyrenoid. The outer cells (marginal cells) may have long spines; additional spines and teeth may be present on marginal and interior cells, and the cell wall may have ridges, short teeth, or granulations. Some cells lack any form of wall ornamentation.

In older taxonomic guides (e.g., Prescott, 1962), nearly all of the taxa in this section were placed in the genus *Scenedesmus*. Currently, the taxa have been moved into four genera: *Acutodesmus*, *Desmodesmus*, *Scenedesmus*, and *Tetradesmus*. The separation is based on genetic data, but it aligns fairly well with differences in cell shape and presence or absence of spines and teeth.

Desmodesmus includes most of the former *Scenedesmus* species that have oval or elliptical cells with spines or teeth. *Desmodesmus* colonies usually contain 4–8 cells in a single row. At least some of the cells, usually marginal cells, should have apical teeth or spines. The cells may also be solitary, especially during division and under certain water quality conditions[13], but careful examination of the sample will usually reveal multi-cellular colonies along with the single-cell specimens.

Desmodesmus abundans forms 2-cell or 4-cell colonies with linear or alternating cells. The individual cells are small, oval or elliptical, with short apical and lateral spines or teeth on the marginal cells. The interior cells may also have short apical spines or teeth. The colony in Figure 3.6 has oval cells and relatively short spines; the colonies in Figures 3.7–3.8 have narrower cells and longer apical spines. These specimens were tentatively identified as types of *Desmodesmus abundans* based on the lateral spines on the marginal cells.

Desmodesmus armatus colonies contain two or four cylindrical cells in a linear series (Figures 3.9–3.11). The individual cells are relatively small and ridged; the interior cells are usually slightly longer than the marginal cells. The marginal cells each have a single short spine on alternate poles; the spine is usually angled at 90°.

[13]Dr. Elliot Shubert, British Museum of Natural History, pers. comm., June 2013.

Desmodesmus brasiliensis colonies usually contain four small cylindrical cells with a distinct median ridge and 1–4 short apical teeth (Figure 3.12). The specimen in Figure 3.13 was tentatively identified as *Desmodesmus brasiliensis* because the cells appear to have longitudinal ridges and apical teeth, but they are slightly different than the specimen in Figure 3.12 and may represent a variety or a different species.

Desmodesmus granulatus colonies contain 4 small oval or elliptical cells covered with fine granules (Figure 3.14). The individual cells are often yellowish, and the marginal cells are usually slightly convex. All cells lack spines, teeth, or ridges.

Desmodesmus magnus cells are elliptical or cylindrical, with thick walls, forming 4-cell or 8-cell colonies (Figures 3.15–3.16). The marginal cells have long straight or curved spines on both ends. The interior cells often have one spine; the interior spines may be on a single side of the colony. Some varieties also have ridges or apical teeth. The specimen collected in Vogler Lake (Figure 3.17) was tentatively identified as *Desmodesmus magnus*, but looks slightly different than the specimens in Figures 3.15–3.16.

Desmodesmus serratus colonies contain four elliptical cells with apical teeth and distinctive serrated ridges running the length of the cell (Figures 3.18–3.19).

Desmodesmus sp.1 is characterized by a 2-cell colony of elliptical cells with smooth walls and 0–2 long curved spines on each pole (Figure 3.20). The cells are joined along 2/3 of the lateral wall and may be slightly off-set.

Desmodesmus sp.2 forms 4-cell colonies of oval cells with smooth walls and 0–3 short apical teeth on each pole (Figure 3.20). The cells are joined along 3/4 of the lateral wall to form a linear colony.

Desmodesmus sp.3 forms 4-cell or 8-cell colonies of oval cells with smooth walls and one slightly off-set apical spine on each pole of the marginal cells (Figures 3.22–3.23). The interior cells may have one apical tooth. The cells are joined along 1/2 of the lateral wall and may be slightly offset. This description fits the characteristics for *Desmodesmus kissii* (Hortobágyi) E. Hegewald listed by John, et al. (2011), who state that the species is found in European ornamental ponds and water tanks. The local specimen was collected in a freshwater aquarium.

Desmodesmus sp.4 forms 4-cell colonies of cylindrical cells with thick walls and 0–4 short, stout apical teeth (Figures 3.24–3.25). The cells are joined along 3/4 of the lateral wall, forming linear colonies. These specimens were collected at the same time and location as the specimen tentatively identified as *Desmodesmus magnus* in Figure 3.17. The cells lack the long apical spines on marginal cells that characterize *Desmodesmus magnus*, but are otherwise similar to *Desmodesmus magnus* specimens from Vogler Lake and other sites.

Desmodesmus sp.5 forms 4-cell colonies of broadly fusiform or crescent-shaped cells that are joined along most of the lateral wall (Figure 3.26). Fusiform and crescent-shaped cells are usually associated with the genus *Acutodesmus*, but in this specimen the cells have apical and lateral teeth, which is a characteristic of the genus *Desmodesmus*.

Scenedesmus has been revised to contain mostly species with rounded cells (oval, elliptical, or cylindrical, but not acutely pointed) that lack spines or teeth. The cell walls may be smooth, granular, or warty. There are some interesting exceptions, including *Scenedesmus quadricauda* (see below), which has long, stout spines on the marginal cells.

Scenedesmus arcuatus cells are small, curved, oval, elliptical, or cylindrical, and smooth walled (Figures 3.27–3.30). The cells are often arranged in a double series surrounded by a mucilage layer. The inner cells are joined along most of their lateral walls; outer cell walls are slightly convex.

Scenedesmus ellipticus cells are oval, elliptical, or cylindrical, and smooth walled (Figures 3.31–3.34). The cells are joined along most of their lateral edge to form colonies containing 2–16 cells. This genus has been revised to include a number of morphological types that were formerly listed as separate species. In the local samples there are three distinct types of *Scenedesmus ellipticus*. *Scenedesmus ellipticus* type A is distinguished by thick walled, cylindrical or angular cells, and forms long, linear colonies of up to 16 cells (Figures 3.31–3.32). The interior cells are often larger than the marginal cells. *Scenedesmus ellipticus* type B forms 4-cell colonies of cylindrical cells (Figure 3.33). The cell walls are not noticeably thickened, the marginal cells are convex and smaller than the interior cells. *Scenedesmus ellipticus* type C forms 4-cell colonies of small, oval cells (Figure 3.34). The marginal cells are convex and slightly smaller than the interior cells.

Scenedesmus quadricauda is characterized by 4-cell colonies of elliptical cells that are joined along most of their length (Figures 3.35–3.36). The marginal cells have long, stout, apical spines; the interior cells lack spines, and all cells have smooth walls that lack ridges or teeth. The cells are similar in size to *Desmodesmus magnus*, but lack the long interior spines. According to AlgaeBase (www.algaebase.org, downloaded March 14, 2016), this species is still in the genus *Scenedesmus*, despite the obvious spiny nature of the cells.

Acutodesmus and **Tetradesmus** cells are acutely pointed (fusiform), and lack spines or teeth, but may have apical knobs. The cell walls may be smooth, slightly ridged, or wrinkled. According to AlgaeBase (www.algaebase.org, downloaded March 14, 2016), all of the local species have been moved into the genus *Tetradesmus*. But recently published taxonomic keys (e.g., John, et al., 2011) still list most of the taxa as species of *Acutodesmus*.

Tetradesmus acuminatus cells are acutely pointed (Figures 3.37–3.38). The interior cells are narrowly fusiform, while the marginal cells are strongly curved into crescents. The colonies usually contain four cells, and the cells are twisted so that the colony does not lie flat.

Tetradesmus dimorphus cells are broadly fusiform (Figures 3.39–3.41). The interior cells are usually straight, and the marginal cells are curved, but only near the apex. The cells may be attached in a straight line or alternating (off-set) and may form 1 row (4-cell colony) or 2 rows (8-cell colony).

Tetradesmus wisconsinensis cells are crescent-shaped, with most of the curvature occurring near the apex (Figures 3.42–3.44). The cells often have apical knobs. The cells are joined laterally, and strongly curved (360°), forming a cubical colony.

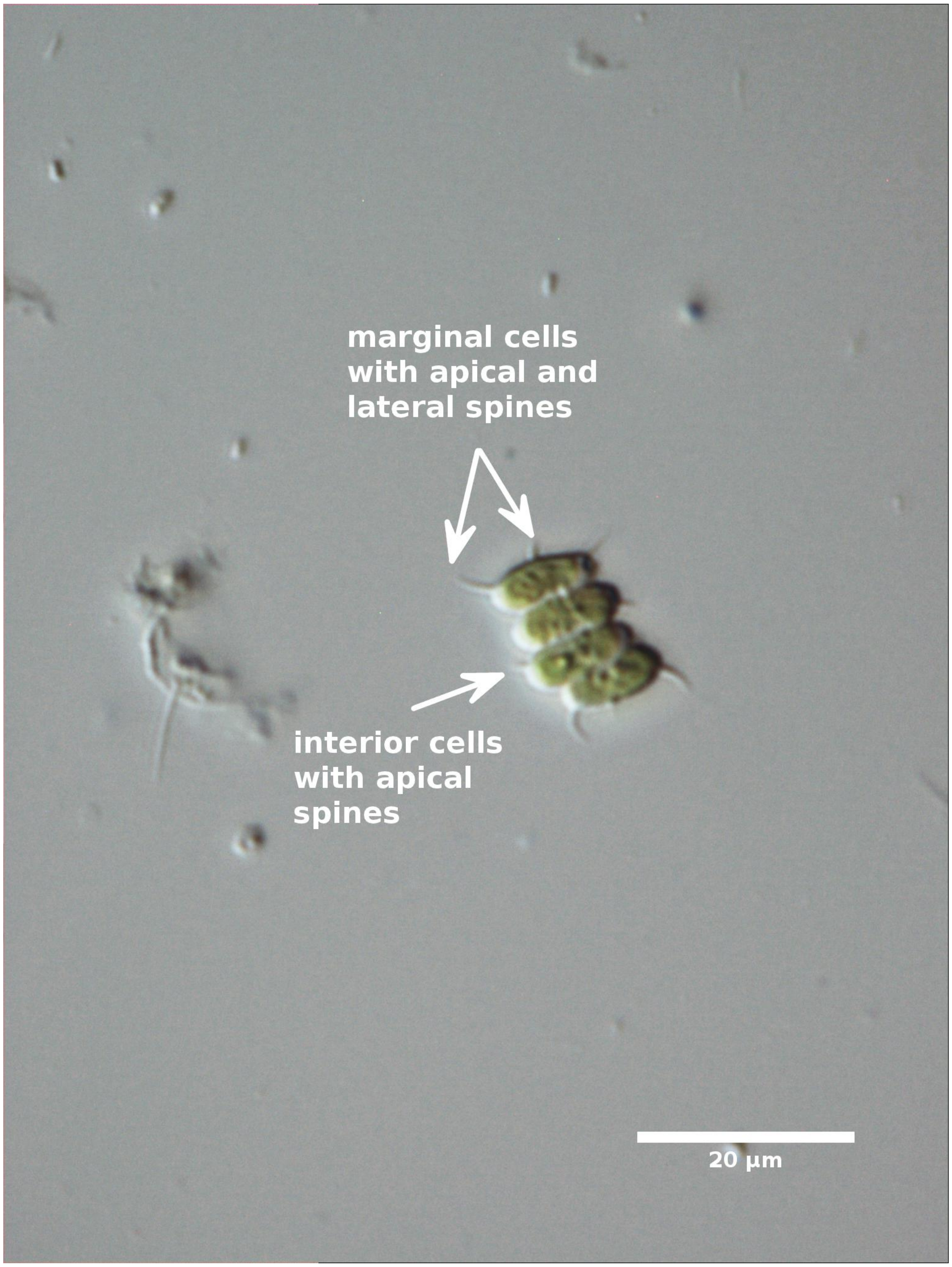

Figure 3.6: *Desmodesmus abundans* type A (600x DIC), pond near Lake Samish, Whatcom County, August 18, 2011.

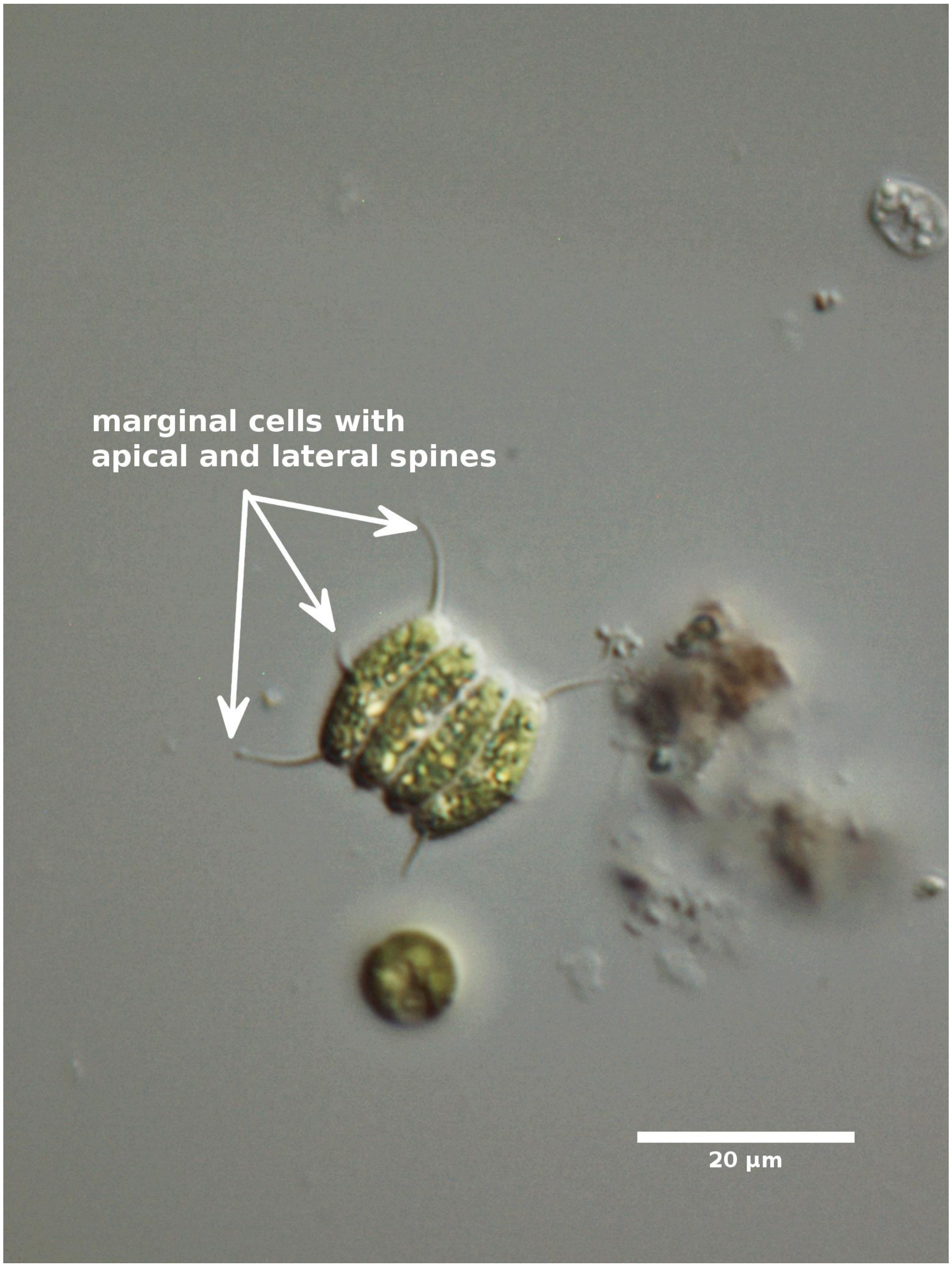

Figure 3.7: *Desmodesmus abundans* type B (600x DIC), Lake Evan, IWS water quality sampling site, Snohomish County, August 2, 2012.

Figure 3.8: *Desmodesmus abundans* type B (600x DIC), Lake Evan, IWS water quality sampling site, Snohomish County, August 2, 2012.

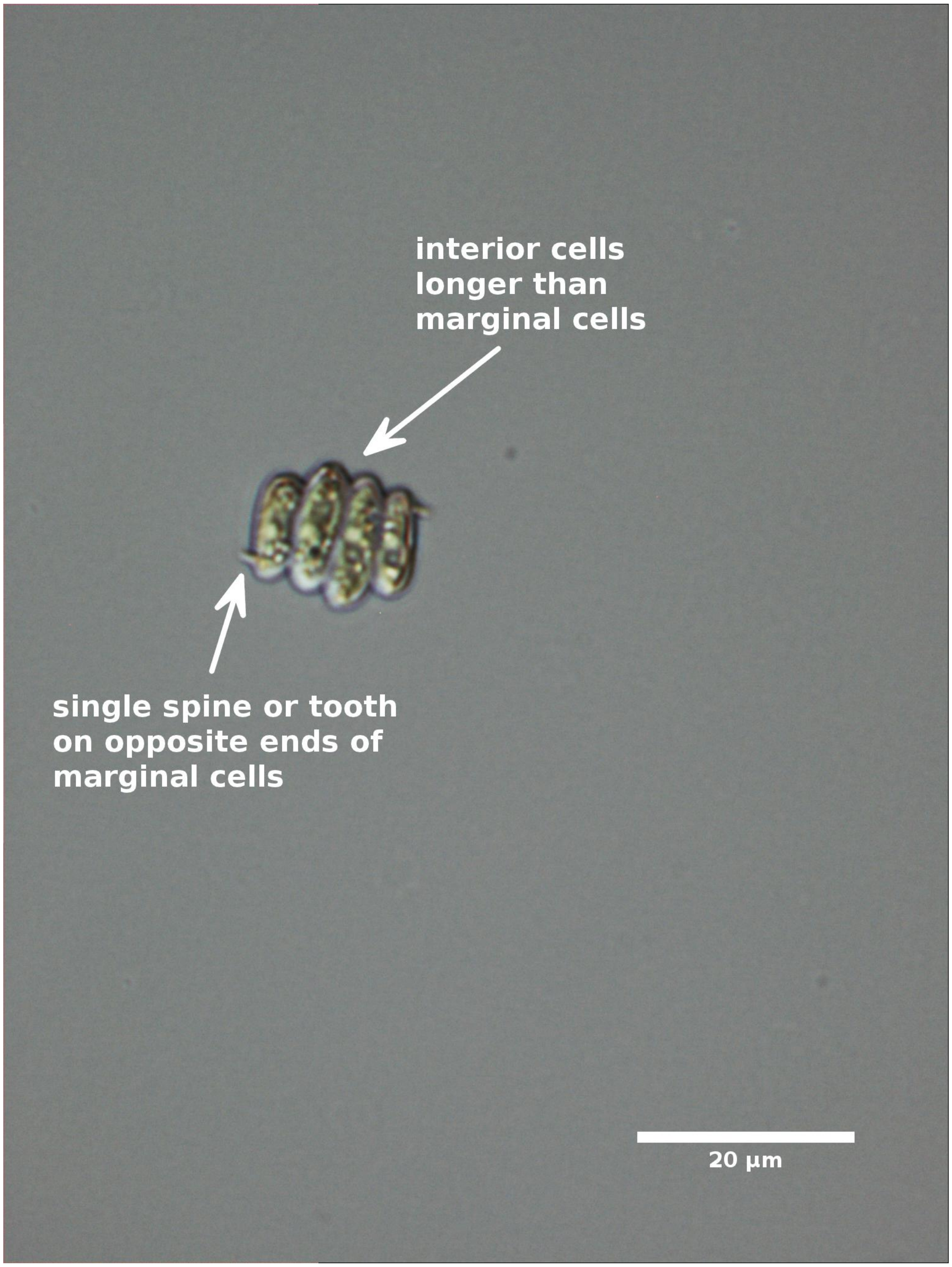

Figure 3.9: *Desmodesmus armatus* (600x DIC), Lake Erie, IWS water quality sampling site, Skagit County, August 28, 2008.

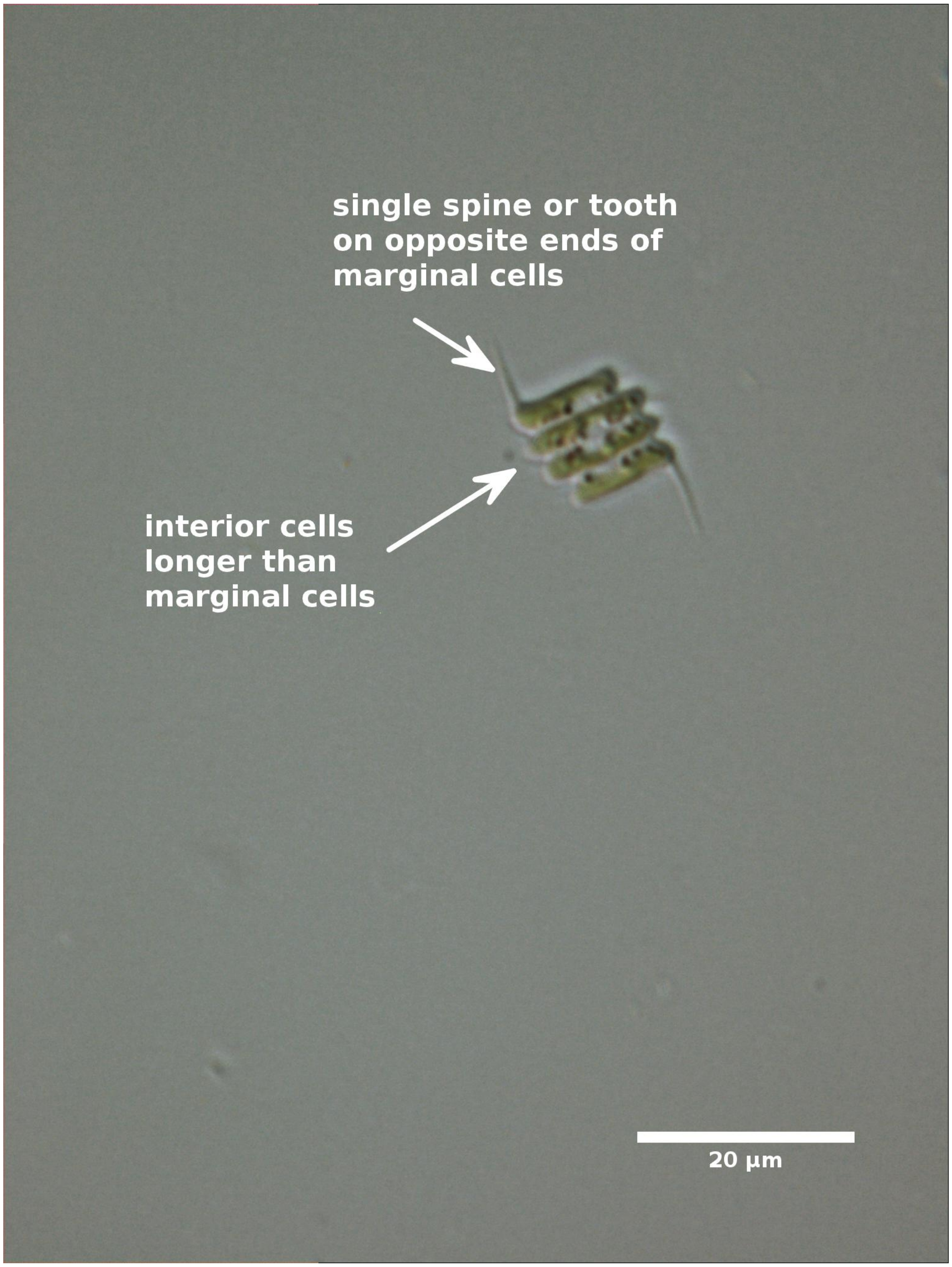

Figure 3.10: *Desmodesmus armatus* (600x DIC), Squalicum Lake, IWS water quality sampling site, Whatcom County, June 30, 2010.

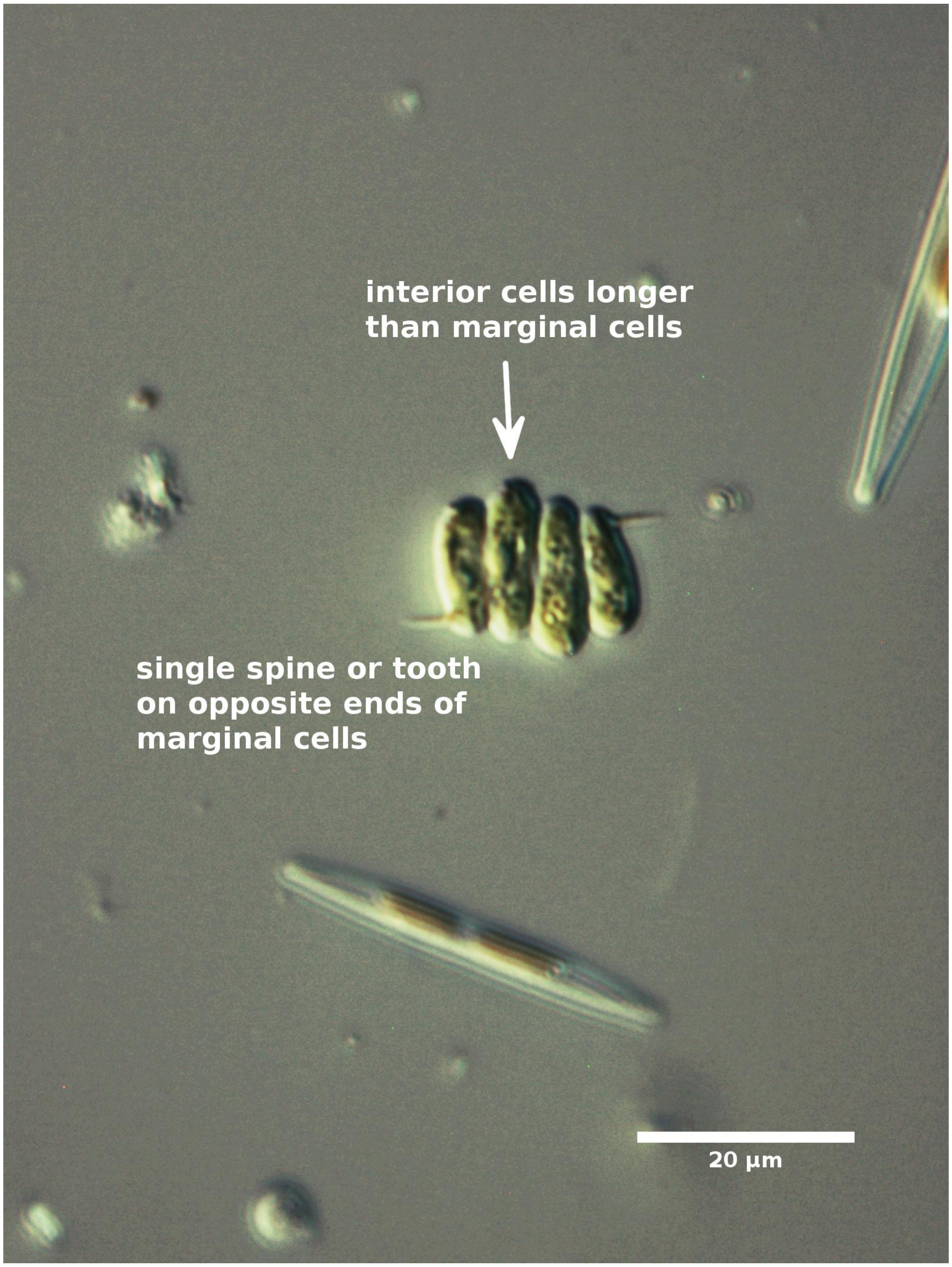

Figure 3.11: *Desmodesmus armatus* (600x DIC), Heart Lake, IWS water quality sampling site, Skagit County, October 8, 2013.

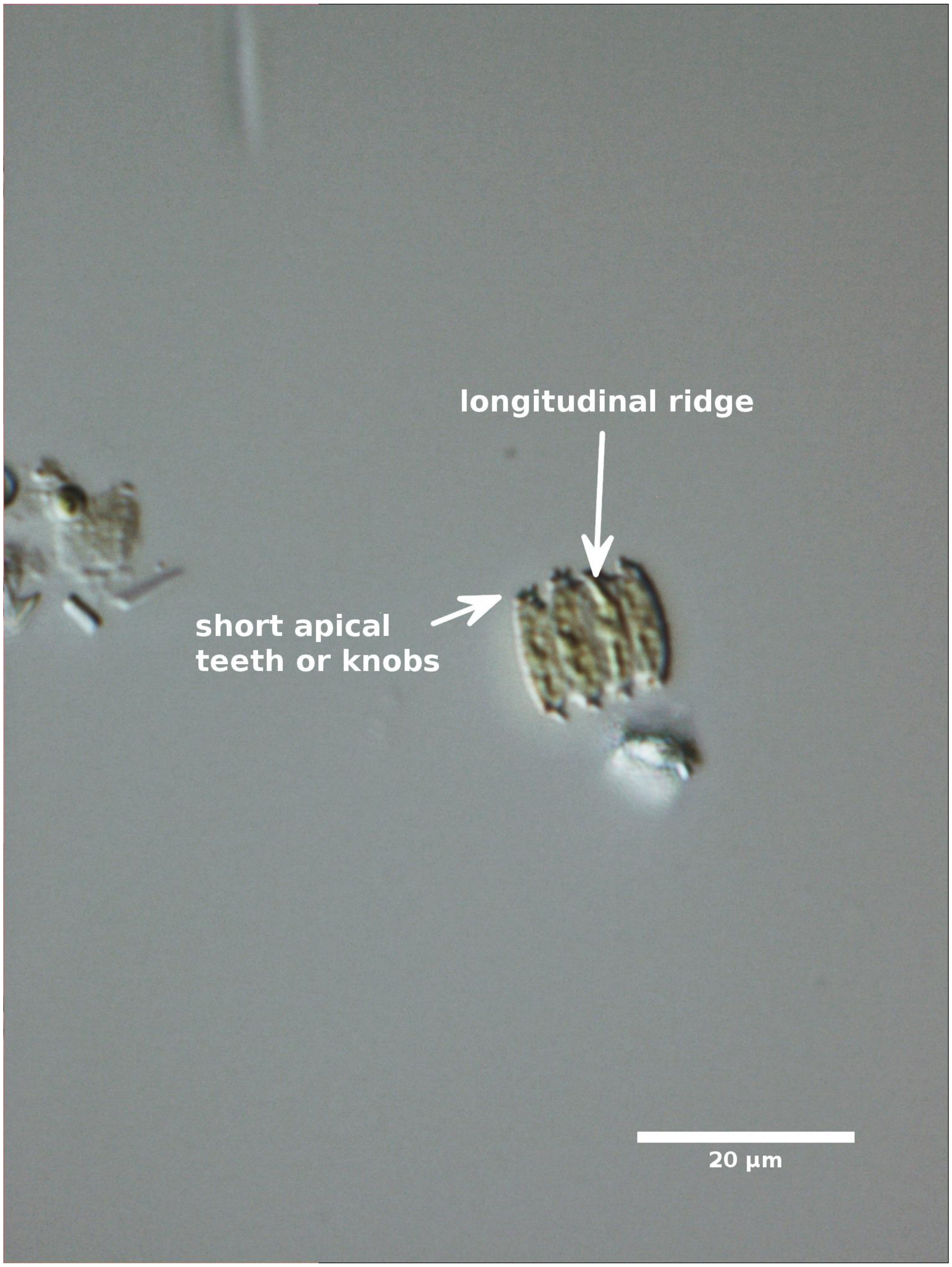

Figure 3.12: *Desmodesmus brasiliensis* (600x DIC), Cedar Lake, IWS water quality sampling site, Whatcom County, August 14, 2008.

Figure 3.13: *Desmodesmus brasiliensis*? (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 12, 2010.

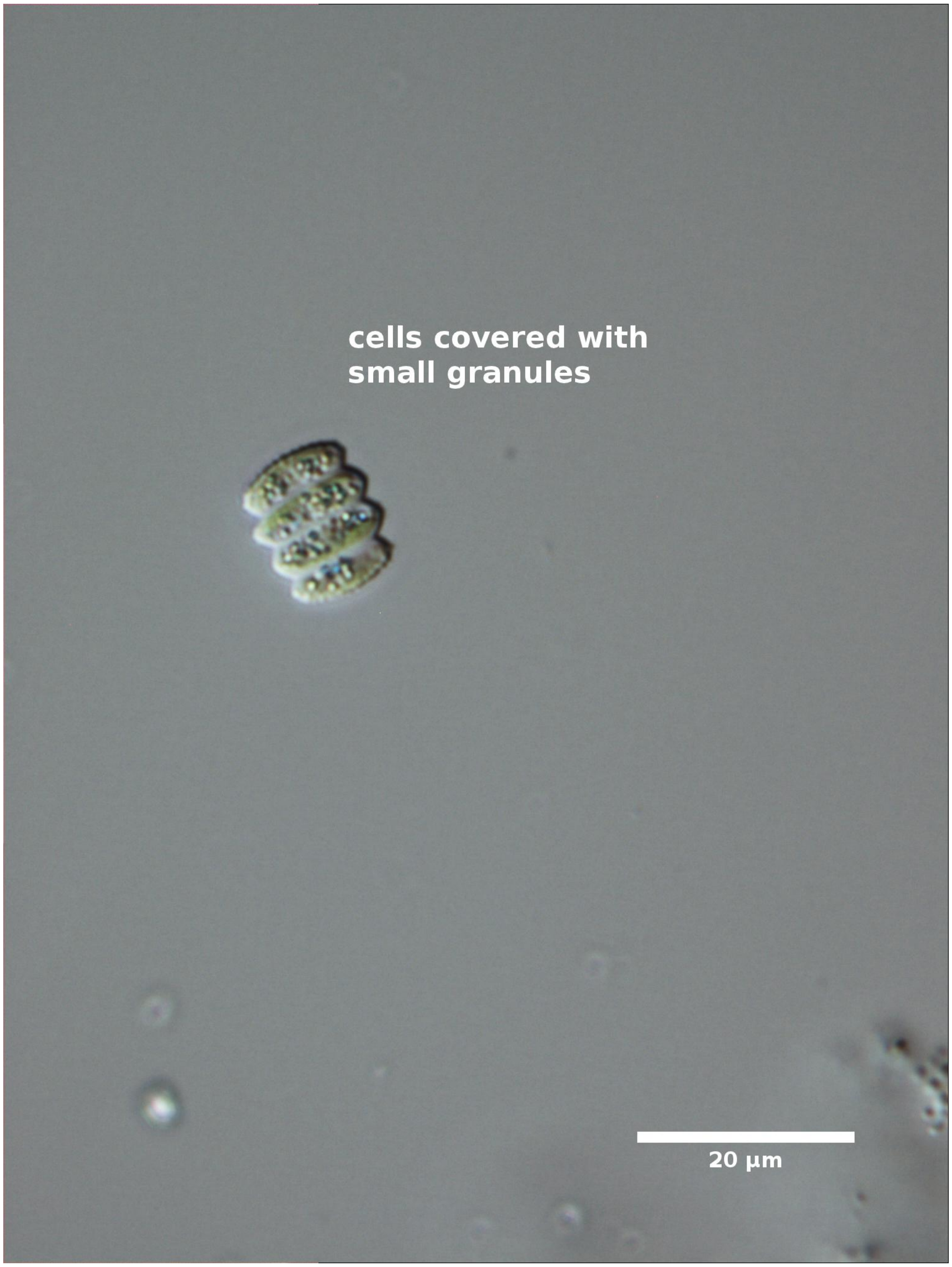

Figure 3.14: *Desmodesmus granulatus* (600x DIC), Lake Erie, IWS water quality sampling site, Skagit County, September 1, 2008.

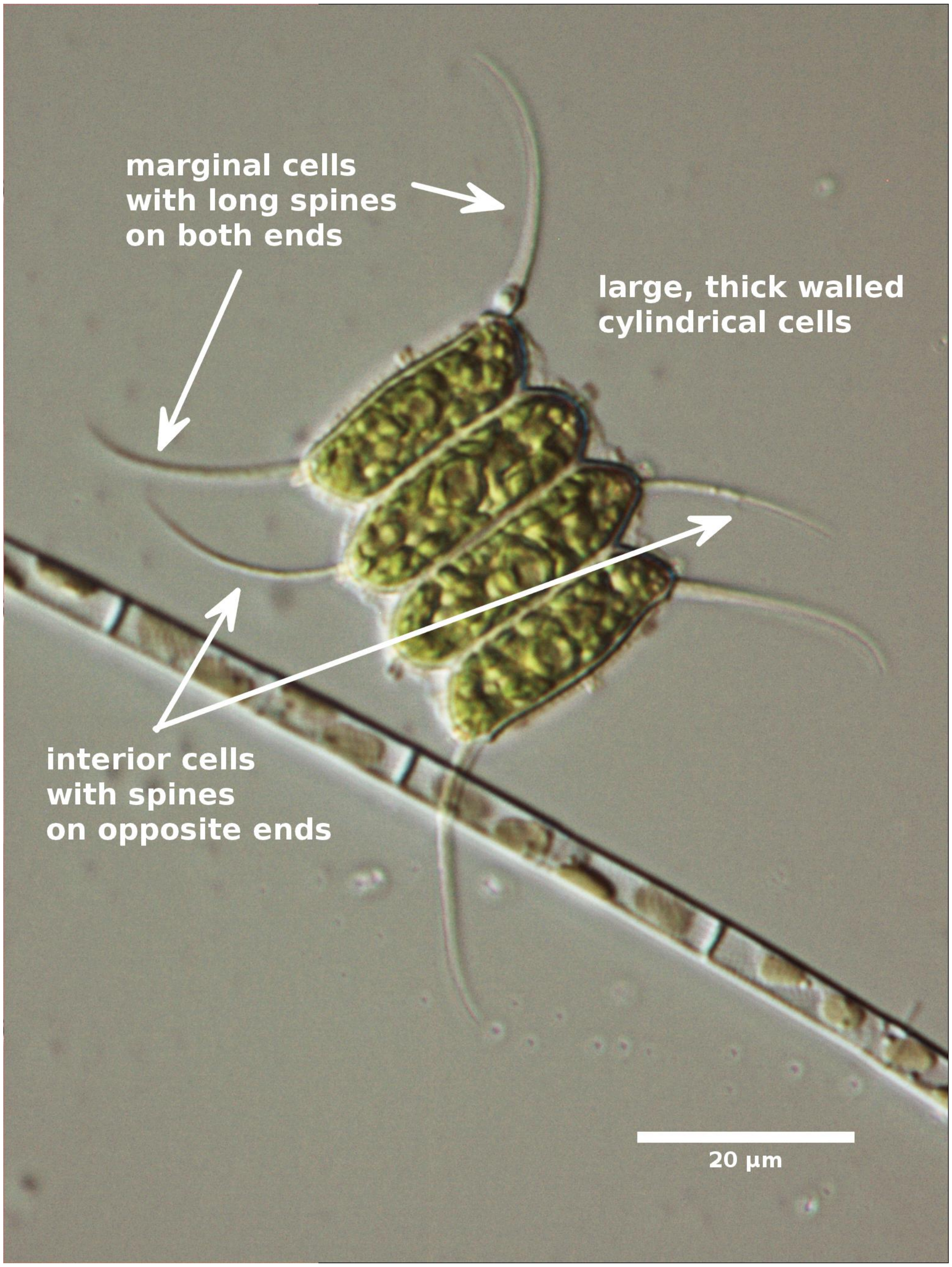

Figure 3.15: *Desmodesmus magnus* (600x DIC), Lake Campbell, IWS water quality sampling site, Skagit County, July 21, 2011.

Figure 3.16: *Desmodesmus magnus* (400x DIC), Lake Campbell, IWS water quality sampling site, Skagit County, August 28, 2008.

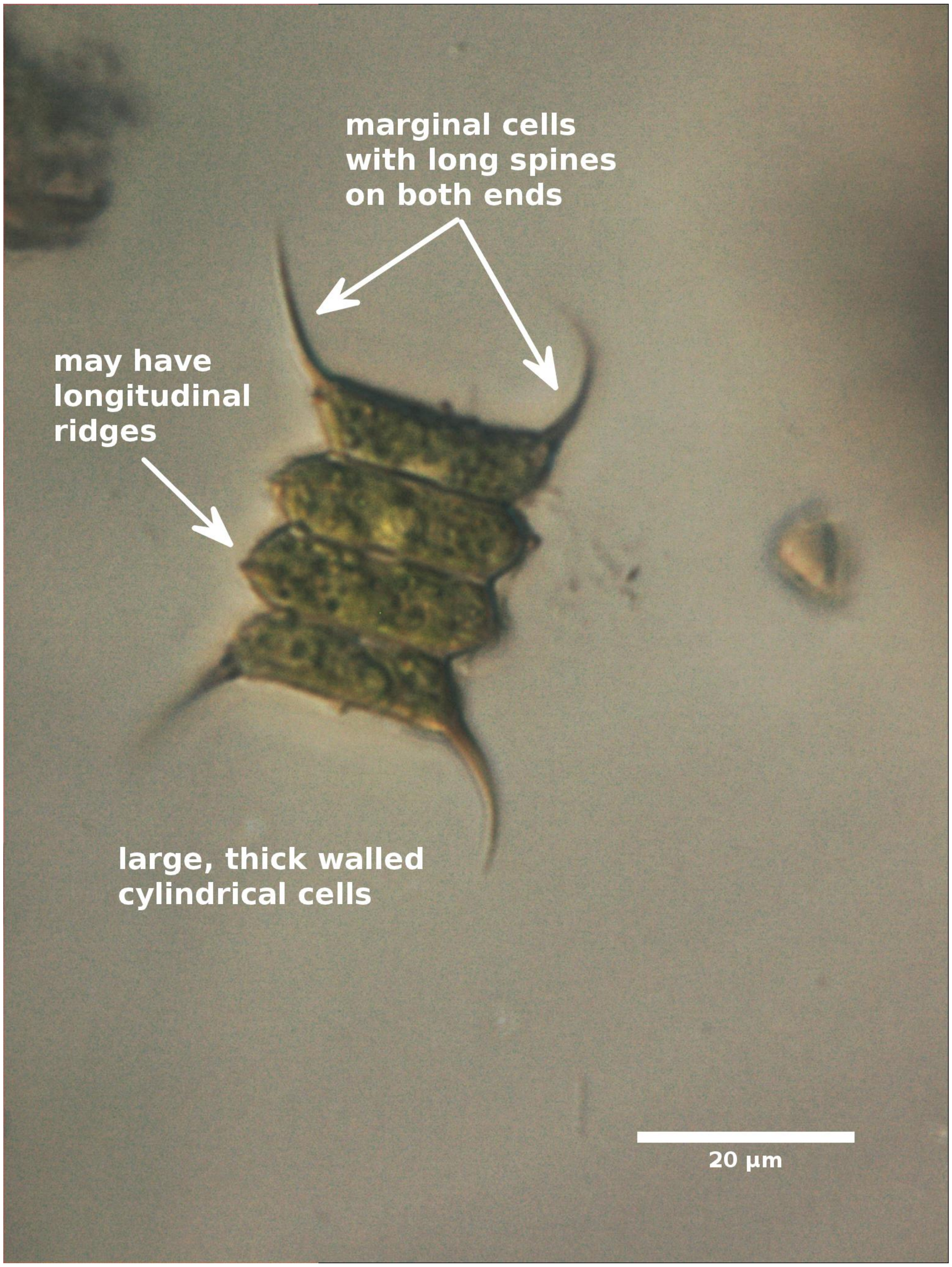

Figure 3.17: *Desmodesmus magnus*? (600x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, September 15, 2010.

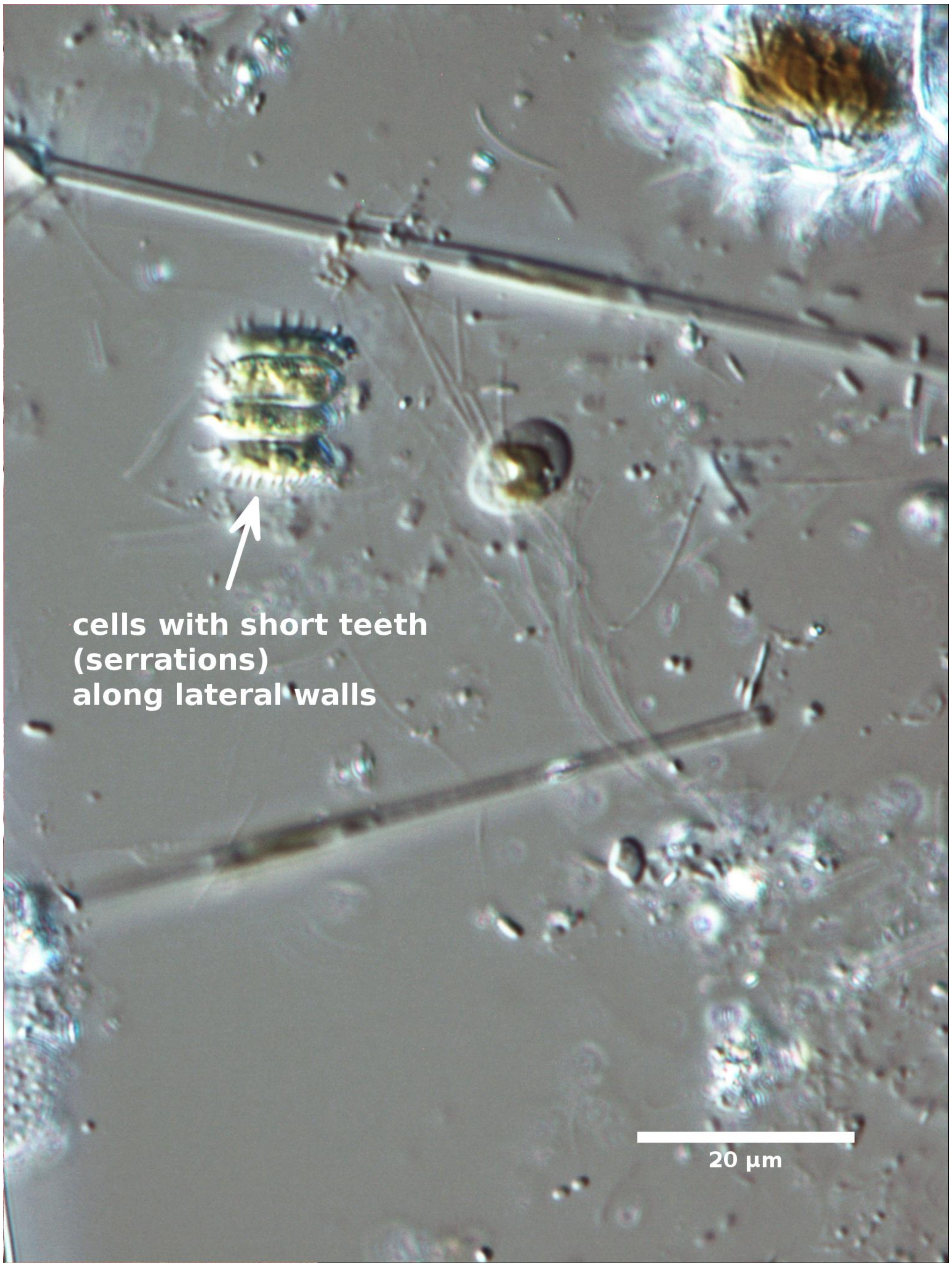

Figure 3.18: *Desmodesmus serratus* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, September 8, 2011.

Figure 3.19: *Desmodesmus serratus* (600x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, September 15, 2010.

Figure 3.20: *Desmodesmus* sp.1 (400x DIC), freshwater pond uphill from Mud Bay, Whatcom County, May 7, 2009.

Figure 3.21: *Desmodesmus* sp.2 (400x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, September 15, 2010.

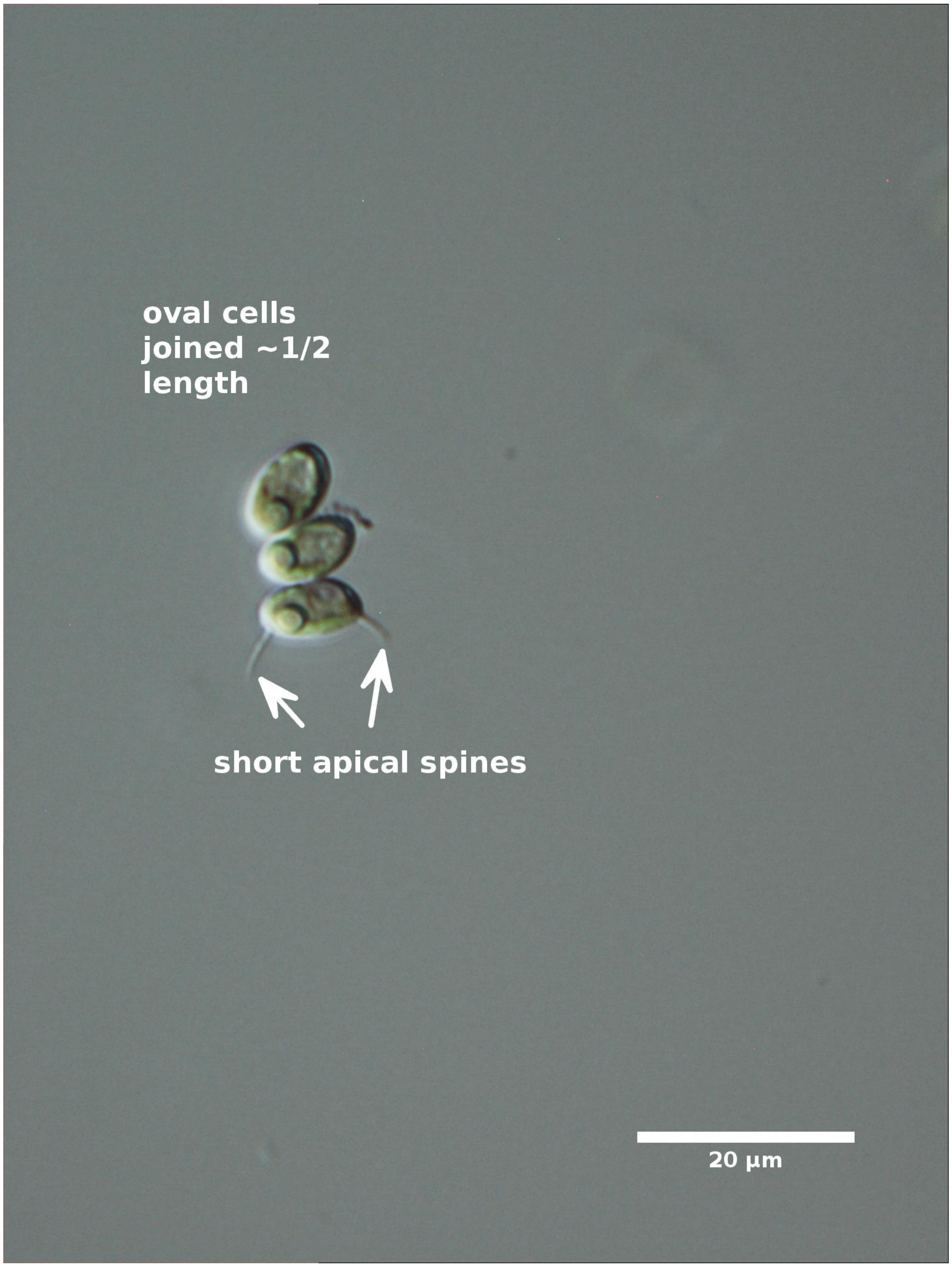

Figure 3.22: *Desmodesmus* sp.3 (600x DIC), freshwater aquarium, May 25, 2011.

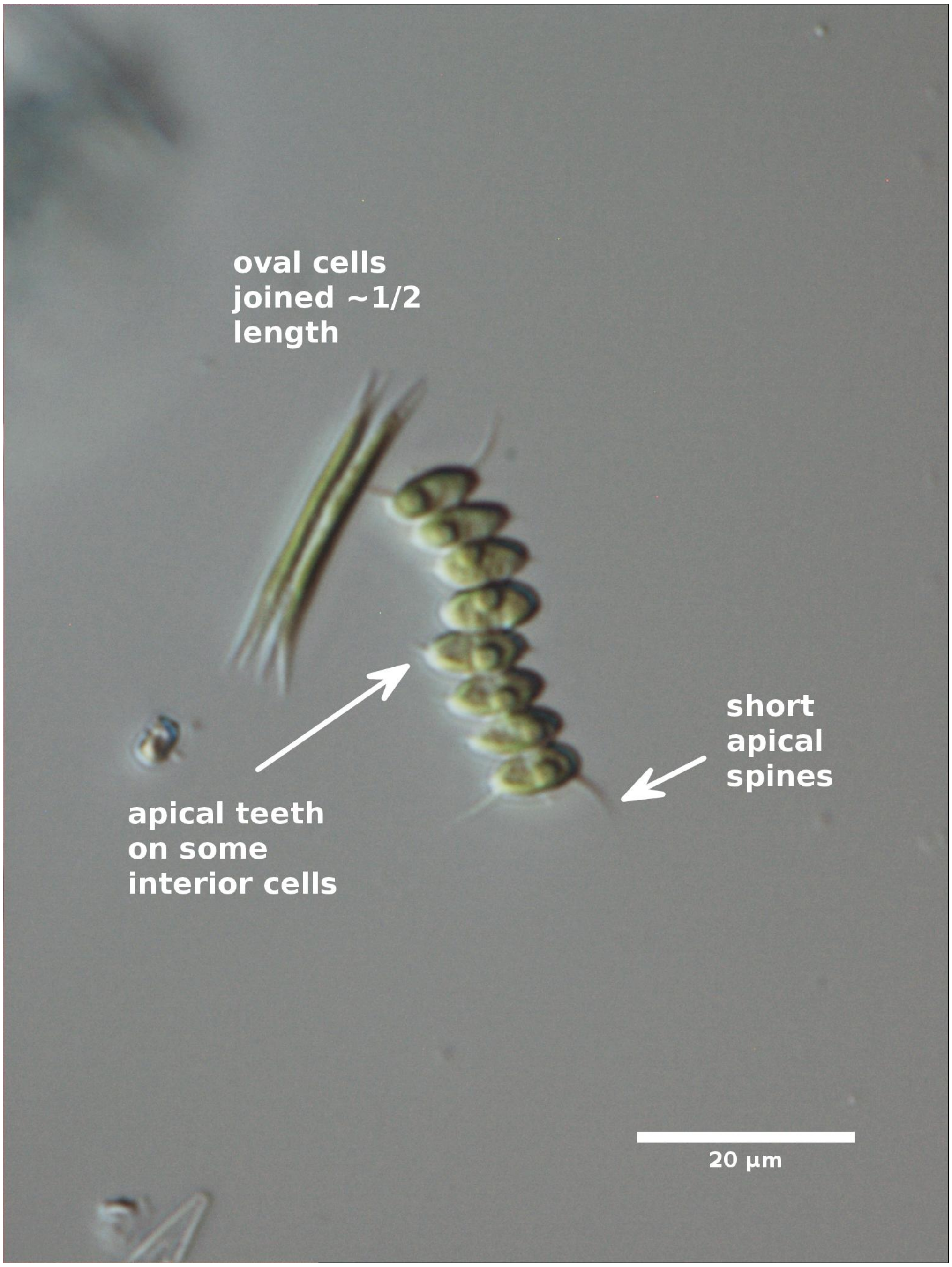

Figure 3.23: *Desmodesmus* sp.3 (600x DIC), freshwater aquarium, May 25, 2011.

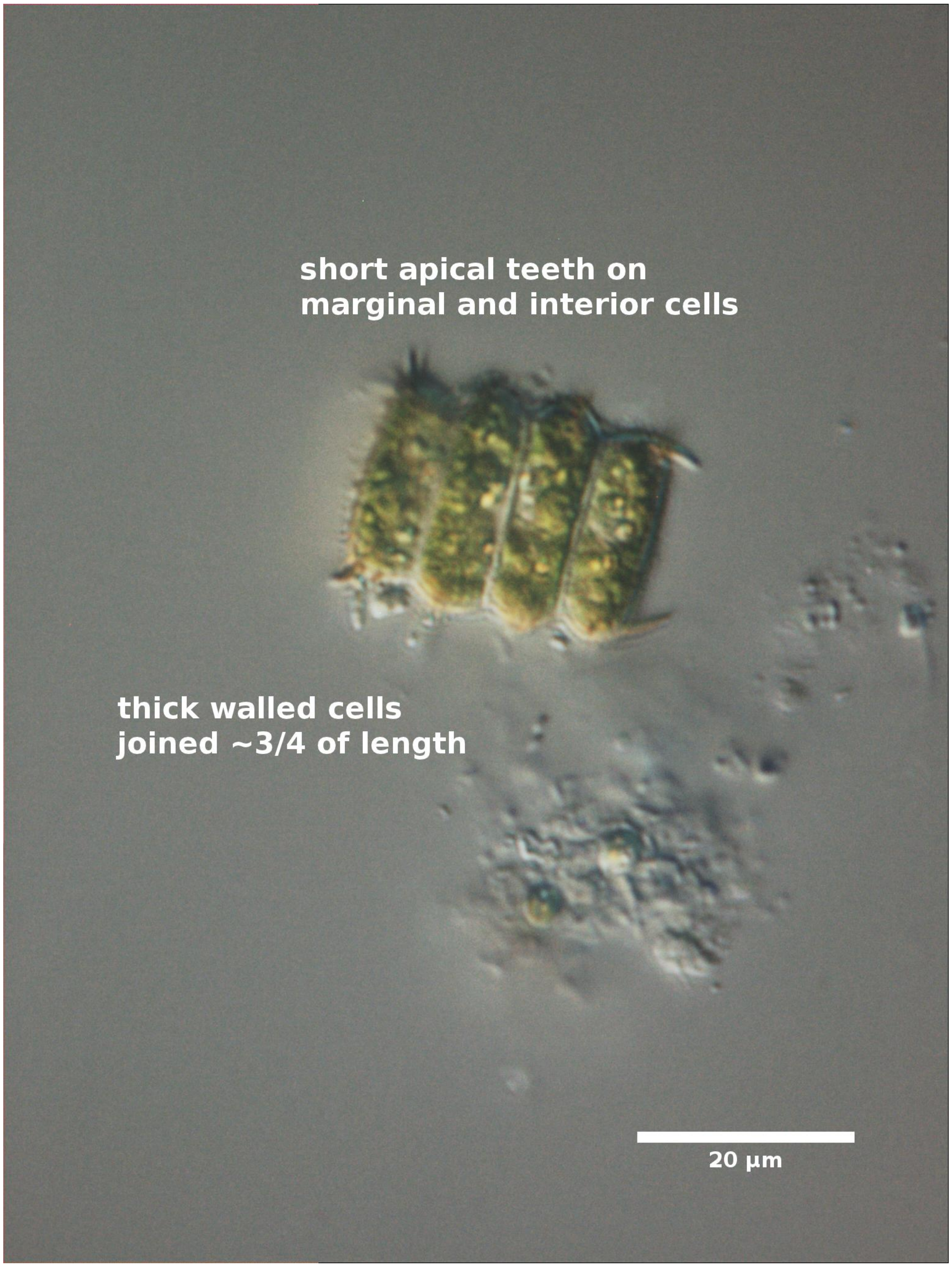

Figure 3.24: *Desmodesmus* sp.4 (600x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, September 14, 2010.

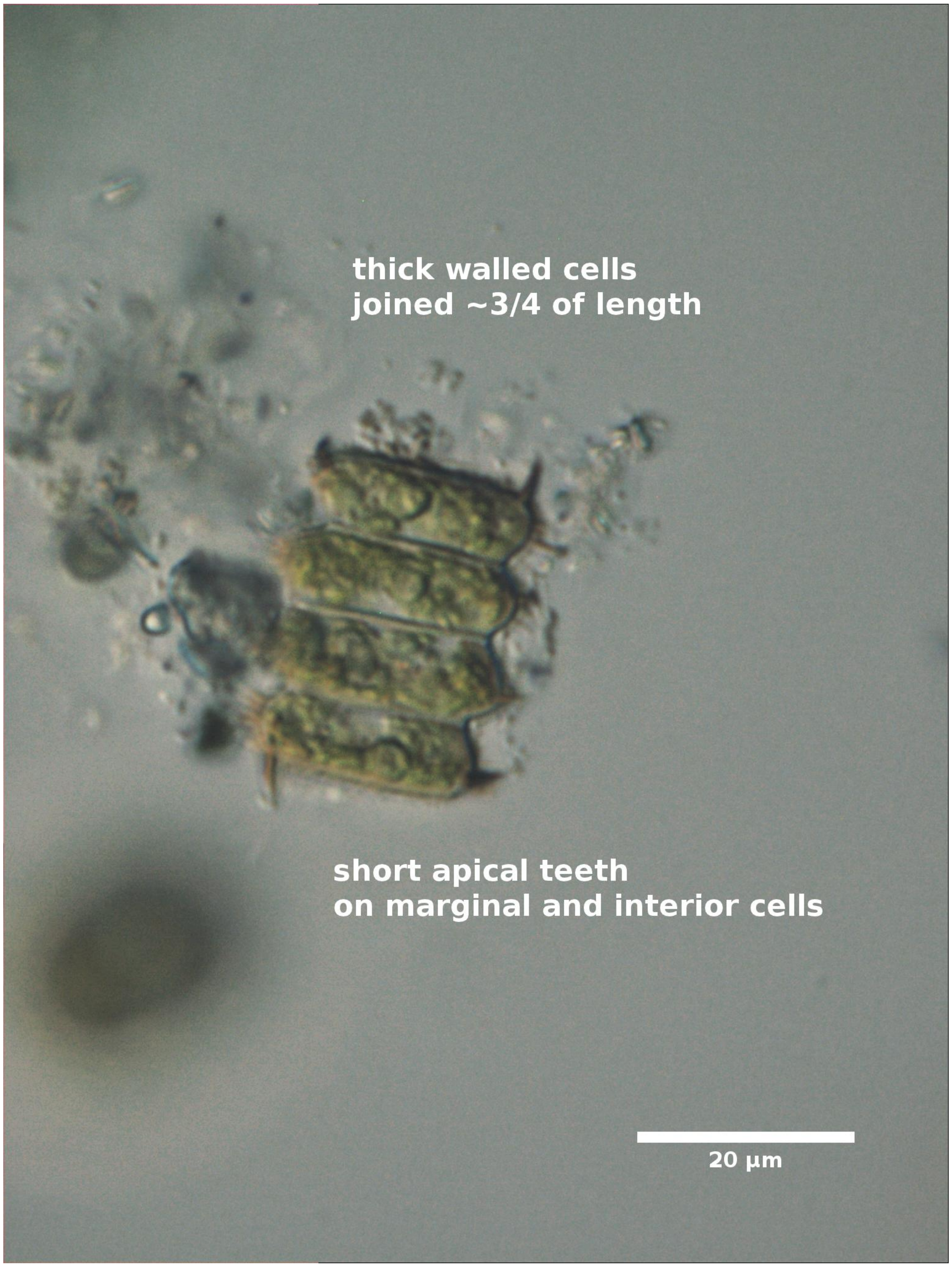

Figure 3.25: *Desmodesmus* sp.4 (600x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, September 15, 2010.

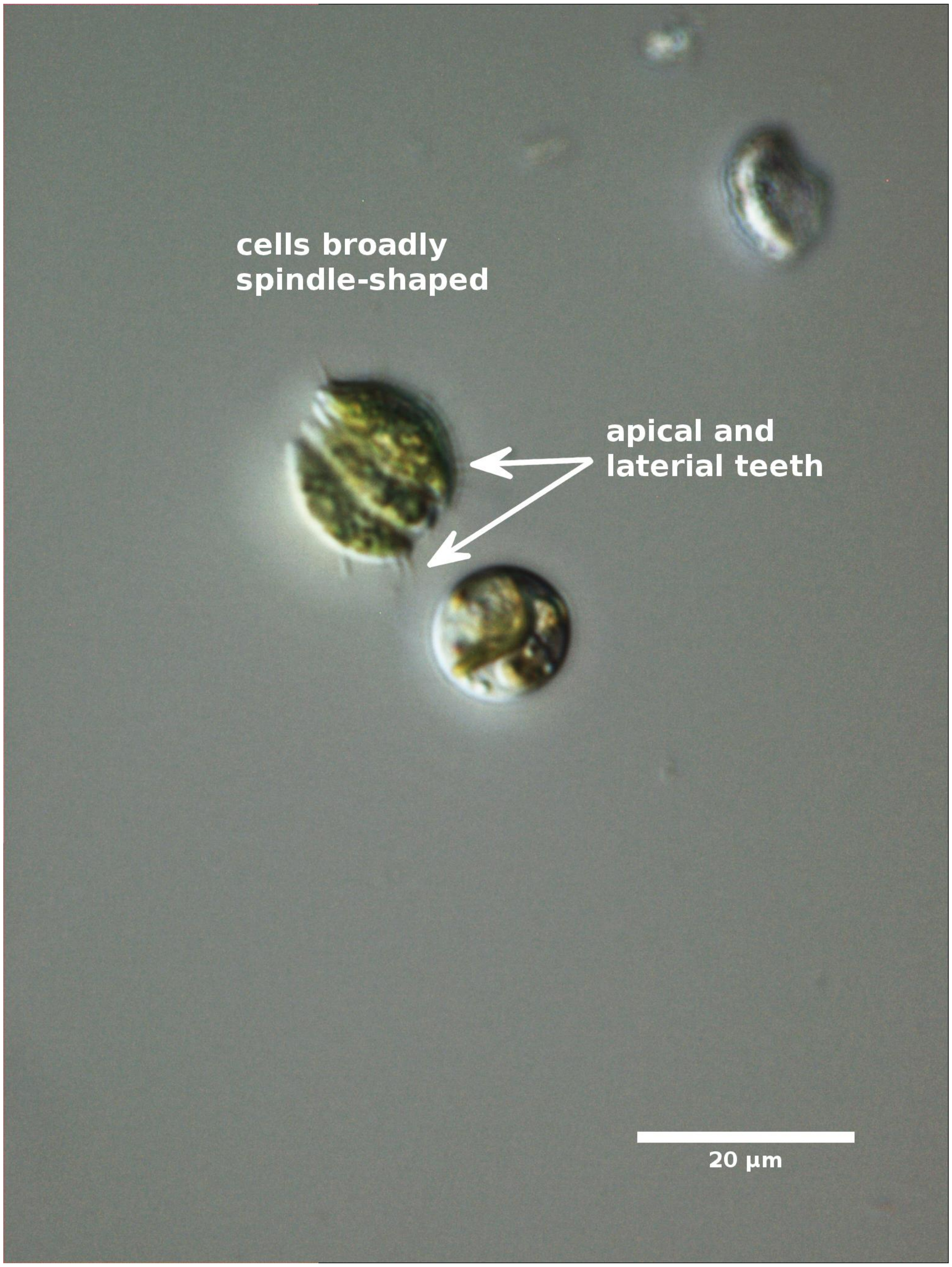

Figure 3.26: *Desmodesmus* sp.5 (600x DIC), snow melt pond on Railroad Grade trail (Park Butte), North Cascades near Mt. Baker area, September 6, 2011.

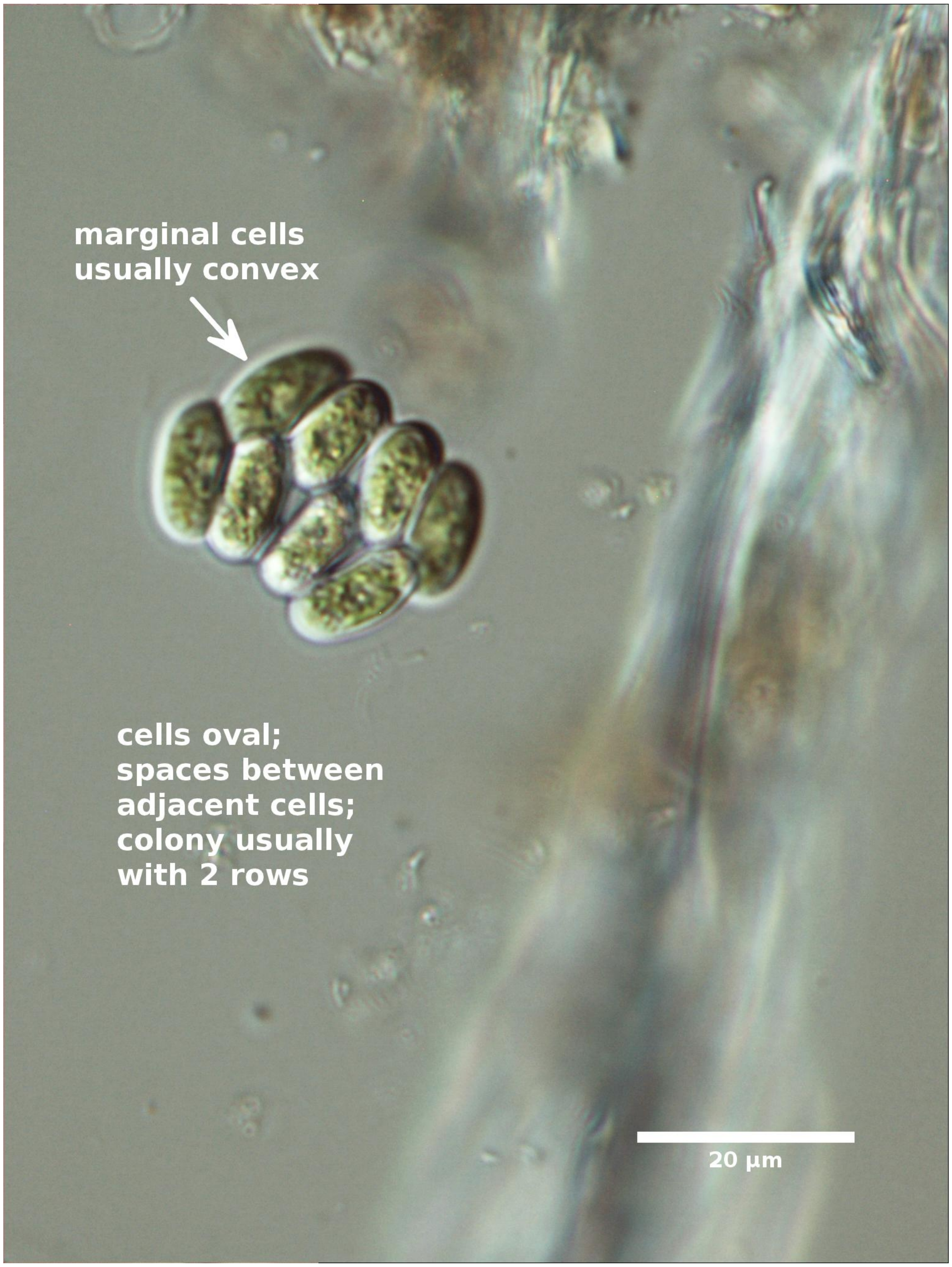

Figure 3.27: *Scenedesmus arcuatus* (600x DIC), Summer Lake, IWS water quality sampling site, Skagit County, July 29, 2011.

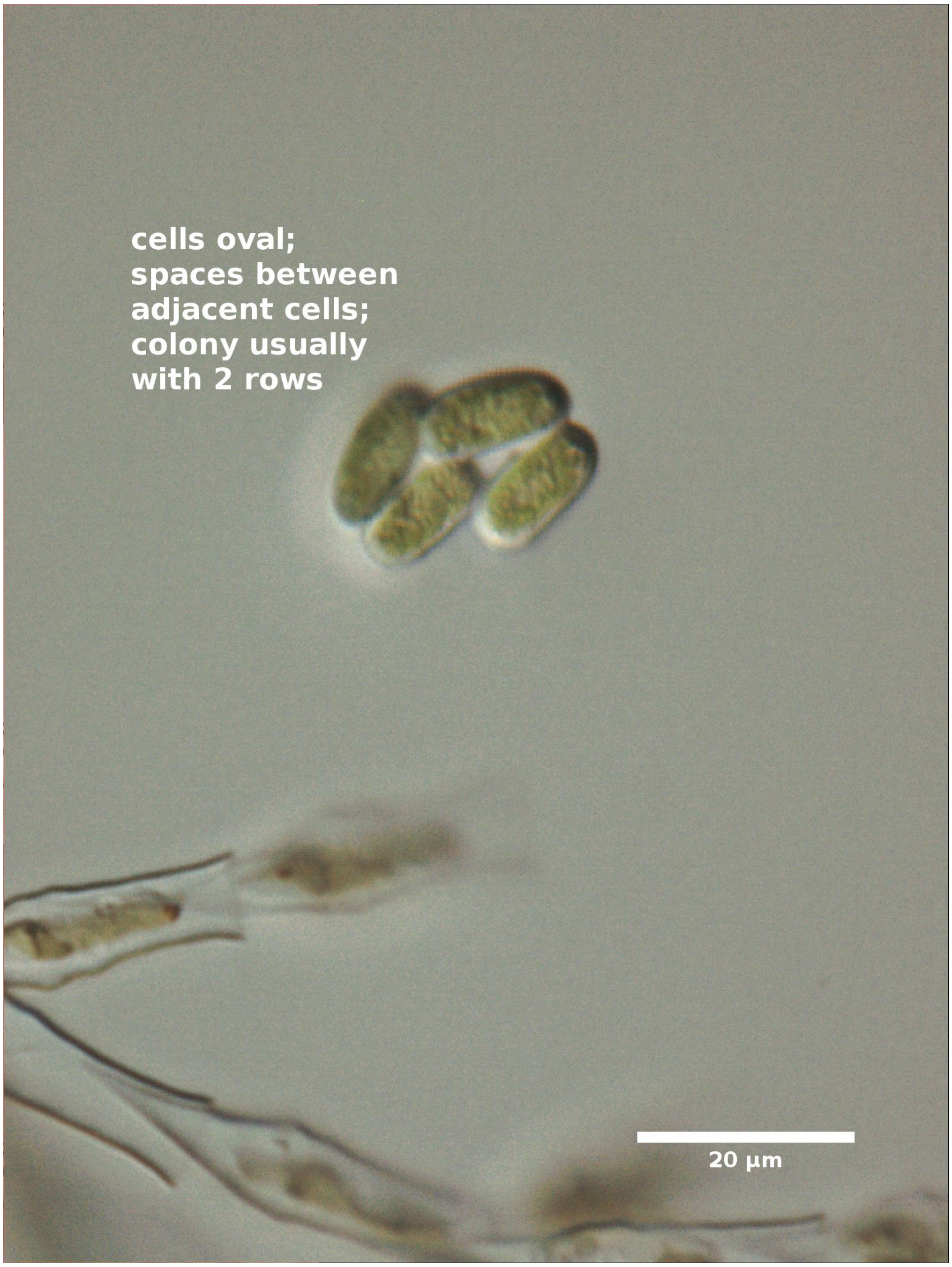

Figure 3.28: *Scenedesmus arcuatus* (600x DIC), Summer Lake, IWS water quality sampling site, Skagit County, July 12, 2010.

Figure 3.29: *Scenedesmus arcuatus* (400x DIC), Cranberry Lake, IWS water quality sampling site, Island County, July 21, 2011.

Figure 3.30: *Scenedesmus arcuatus* (600x DIC), Cranberry Lake, IWS water quality sampling site, Island County, July 21, 2011.

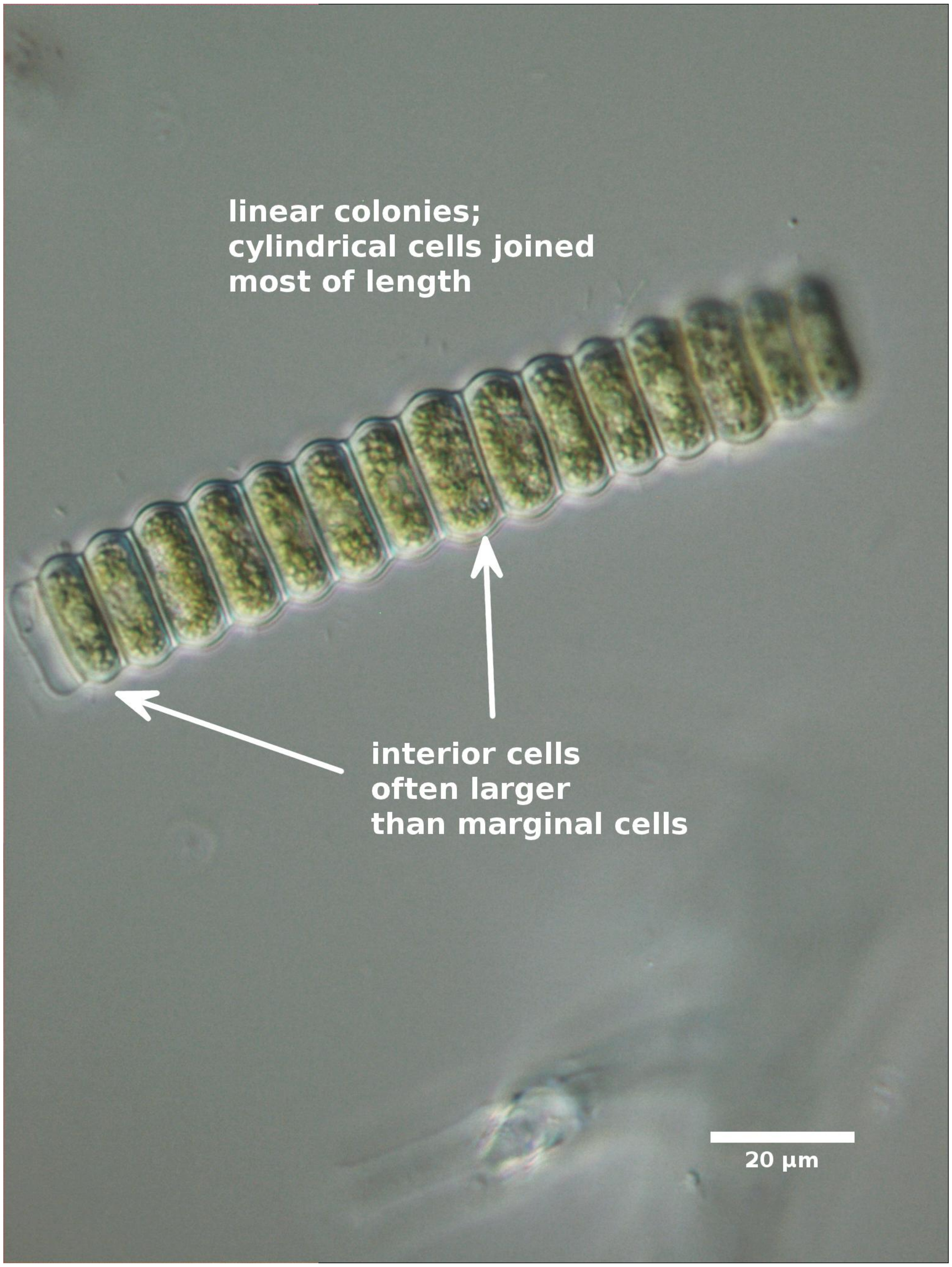

Figure 3.31: *Scenedesmus ellipticus* type A (400x DIC), Lake Campbell, IWS water quality sampling site, Skagit County, July 13, 2010.

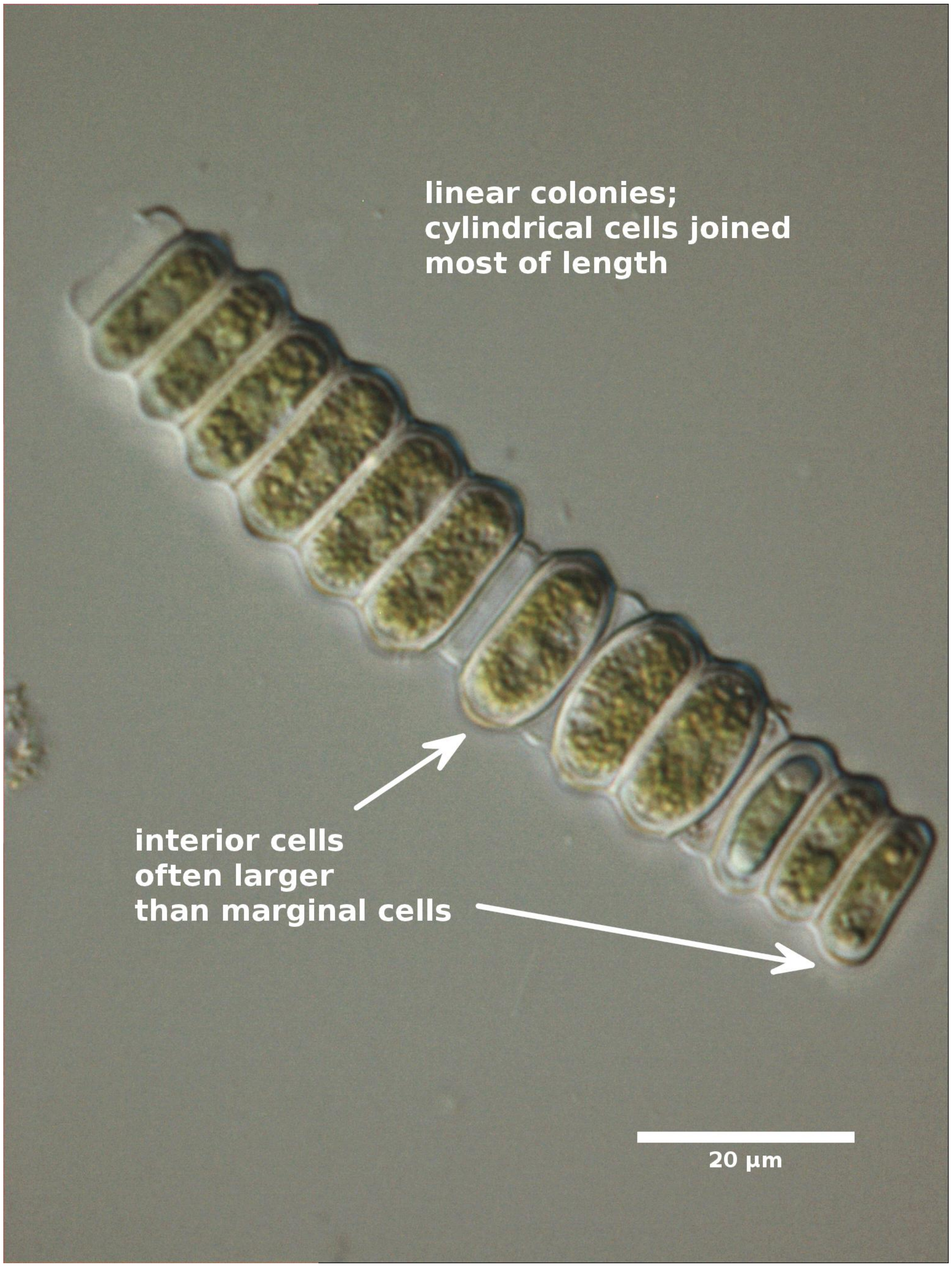

Figure 3.32: *Scenedesmus ellipticus* type A (600x DIC), Lake Campbell, IWS water quality sampling site, Skagit County, July 13, 2010.

Figure 3.33: *Scenedesmus ellipticus* type B (600x DIC), Lake Erie, IWS water quality sampling site, Skagit County, August 28, 2008.

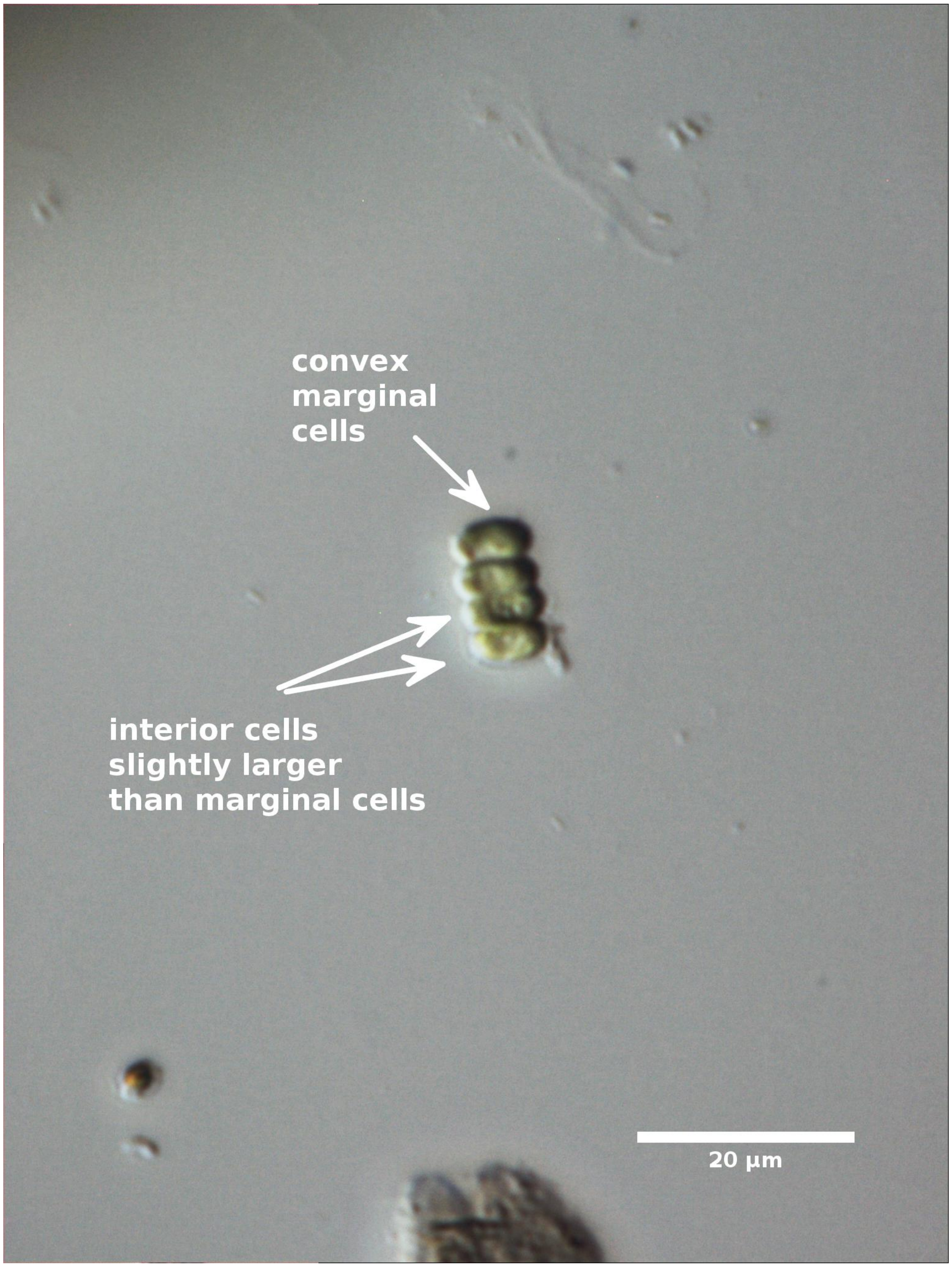

Figure 3.34: *Scenedesmus ellipticus* type C (600x DIC), pond near Lake Samish, Whatcom County, August 18, 2011.

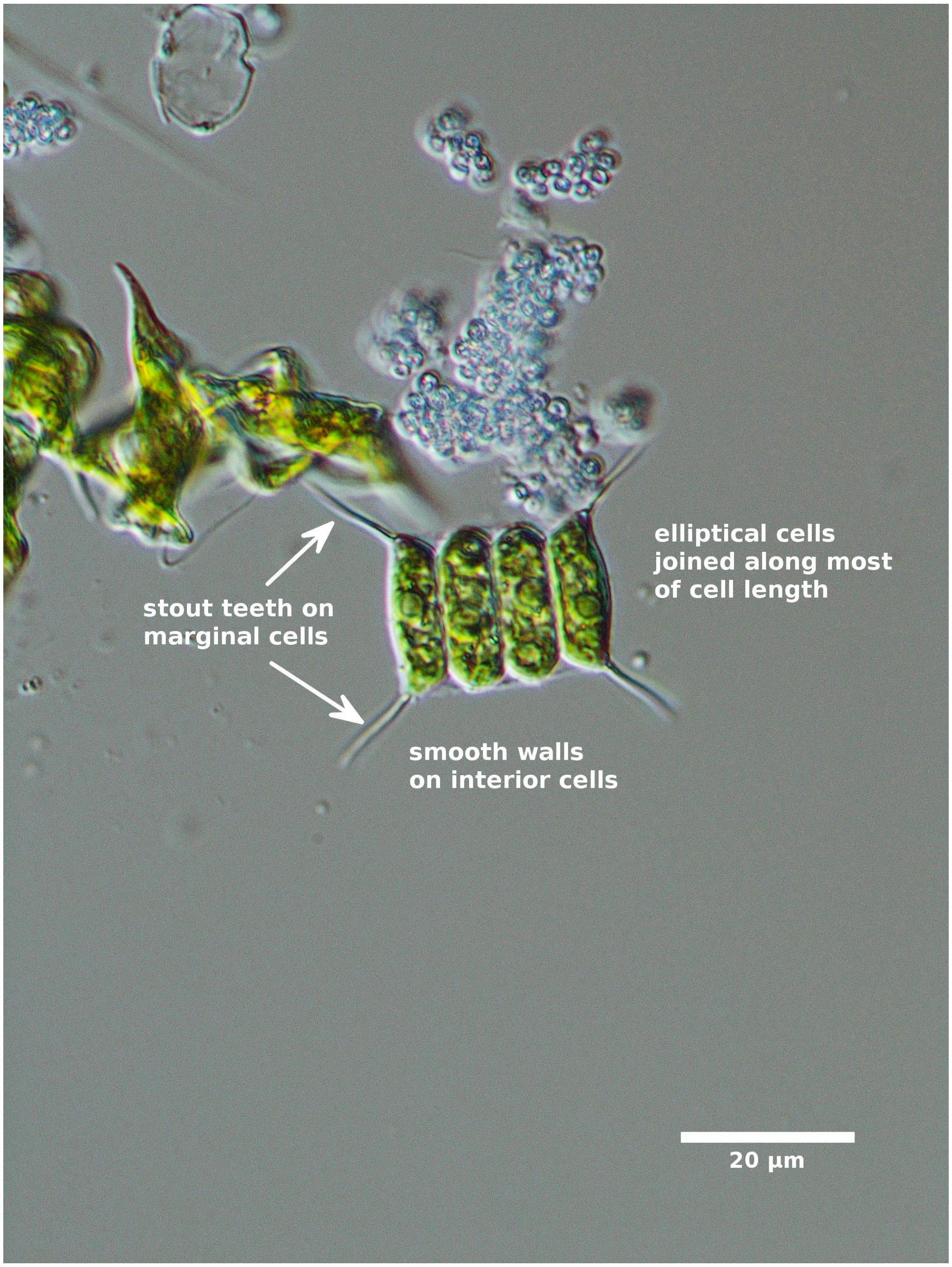

Figure 3.35: *Scenedesmus quadricauda* (600x DIC), small eutrophic farm pond, Whatcom County, June 3, 2014.

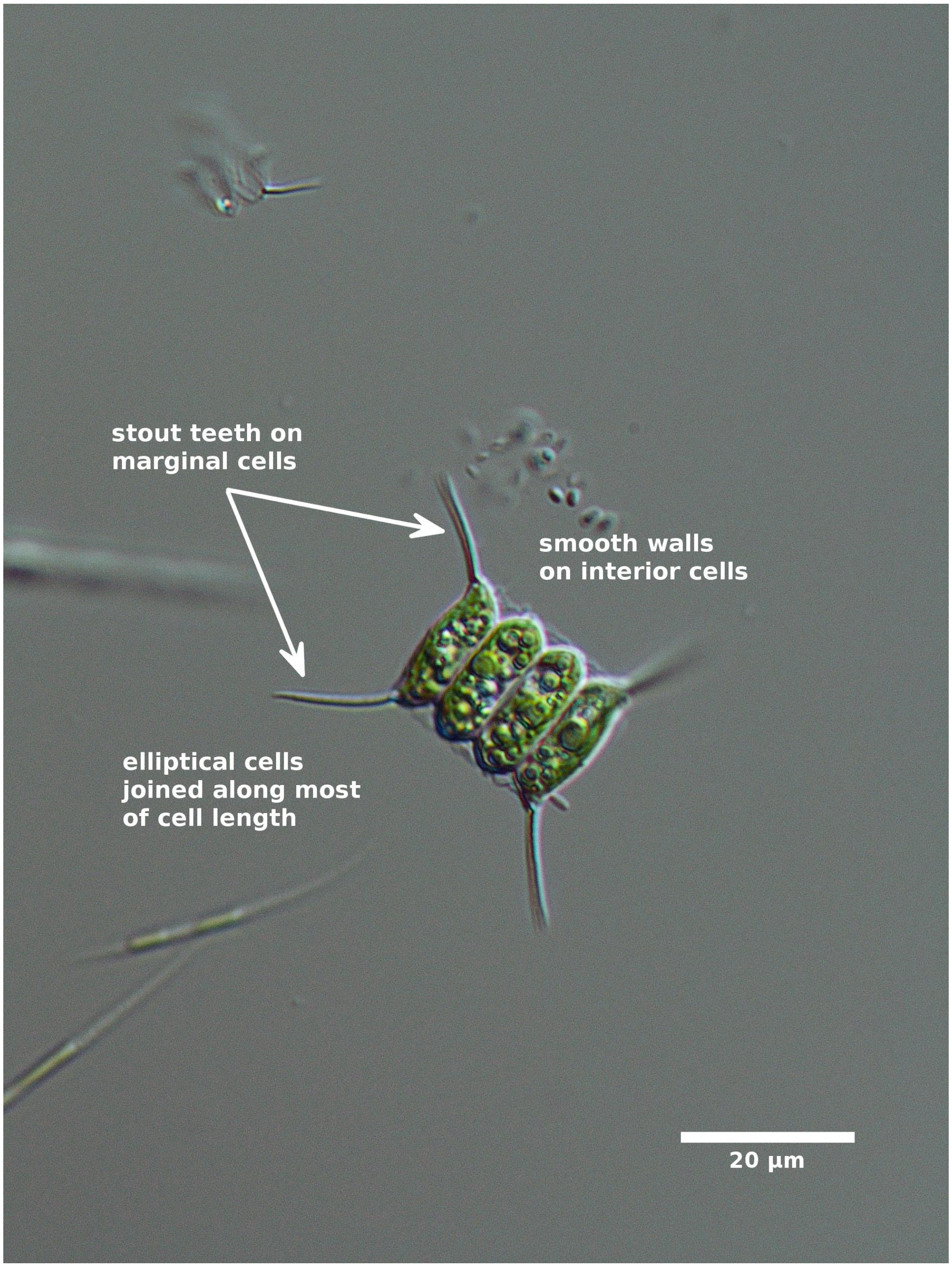

Figure 3.36: *Scenedesmus quadricauda* (600x DIC), small eutrophic farm pond, Whatcom County, June 3, 2014.

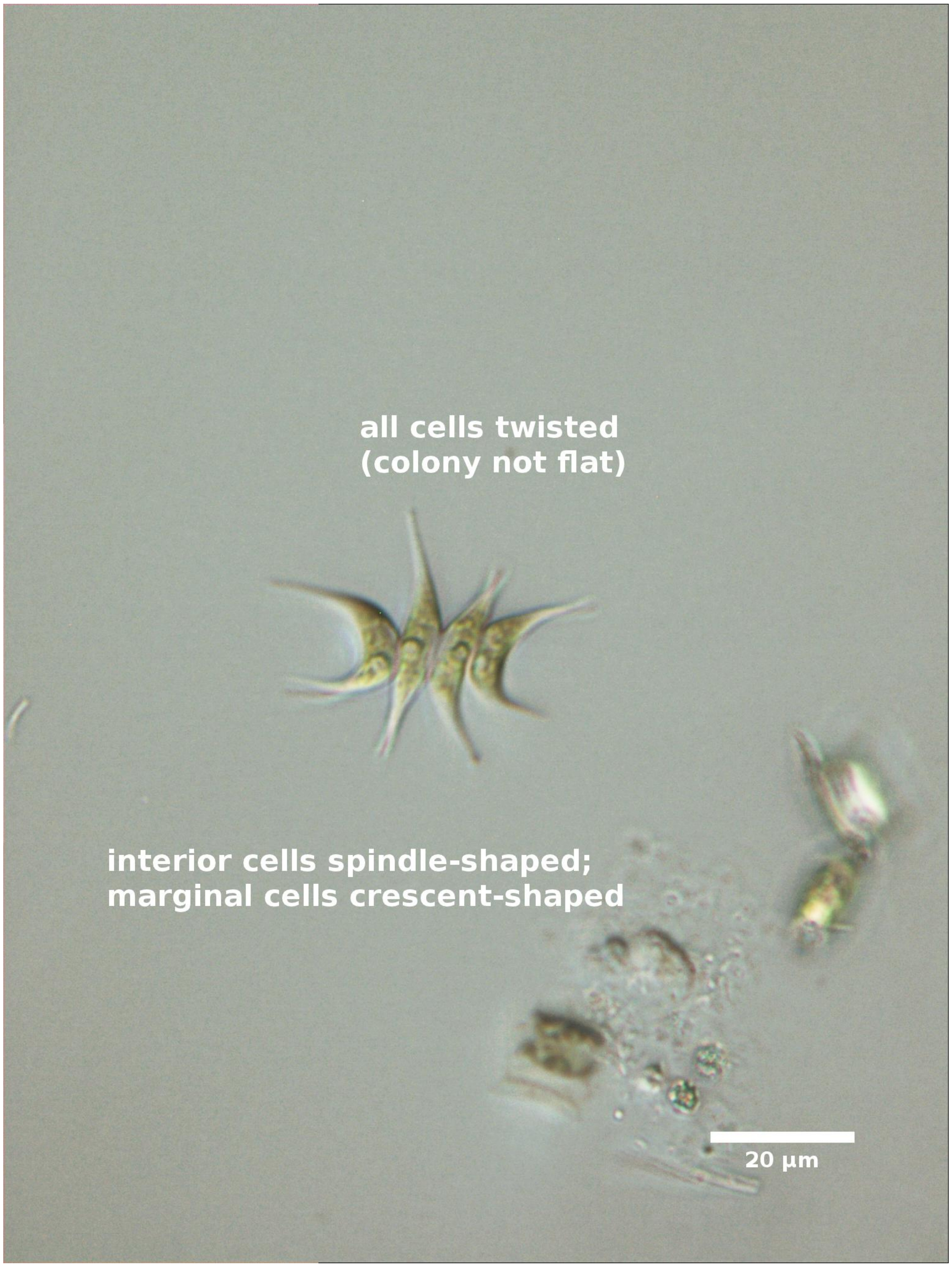

Figure 3.37: *Tetradesmus acuminatus* (400x DIC), Manito Park duck pond (Spokane area), eastern Washington, May 27, 2009.

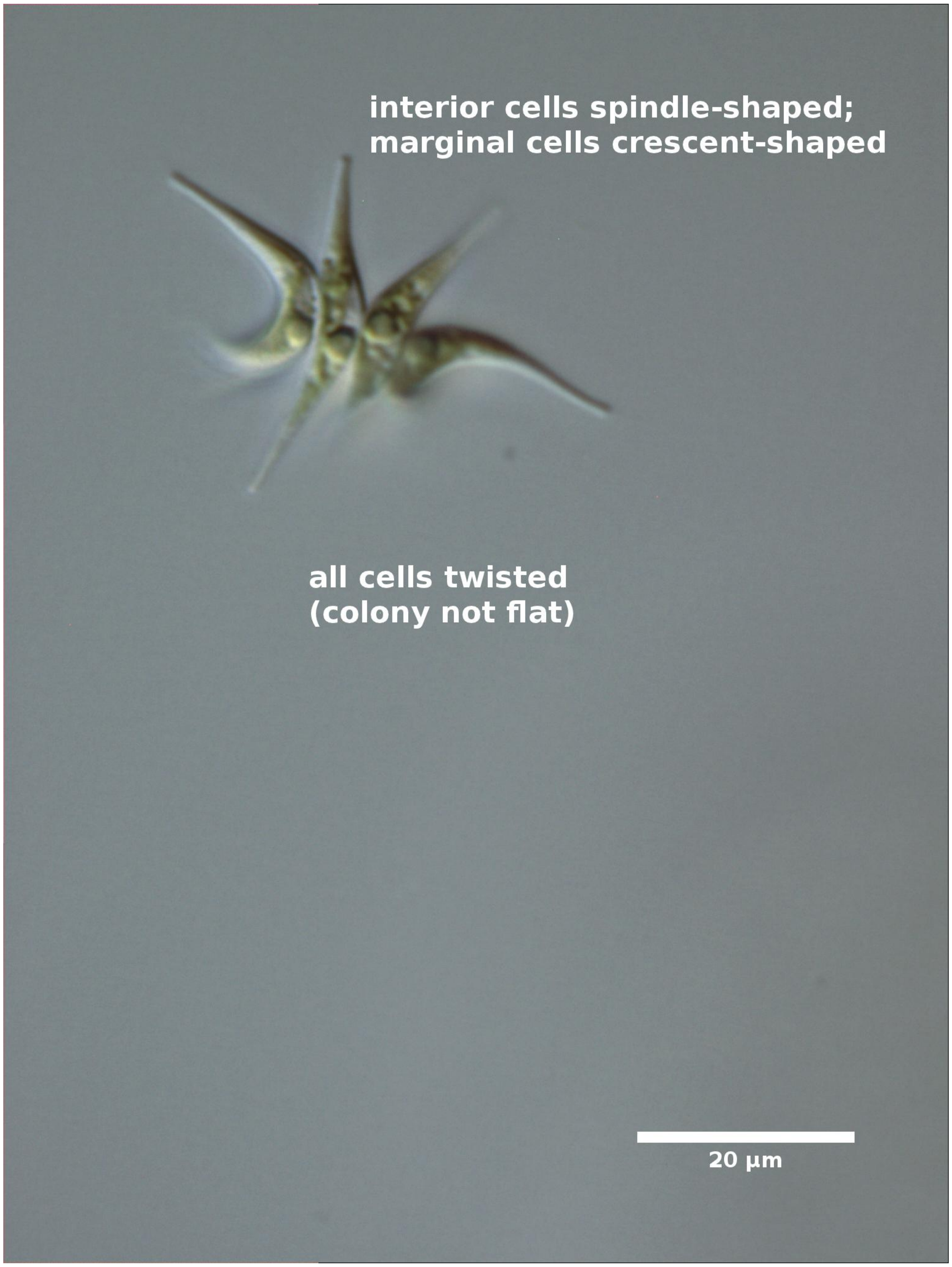

Figure 3.38: *Tetradesmus acuminatus* (600x DIC), Manito Park duck pond (Spokane area), eastern Washington, May 27, 2009.

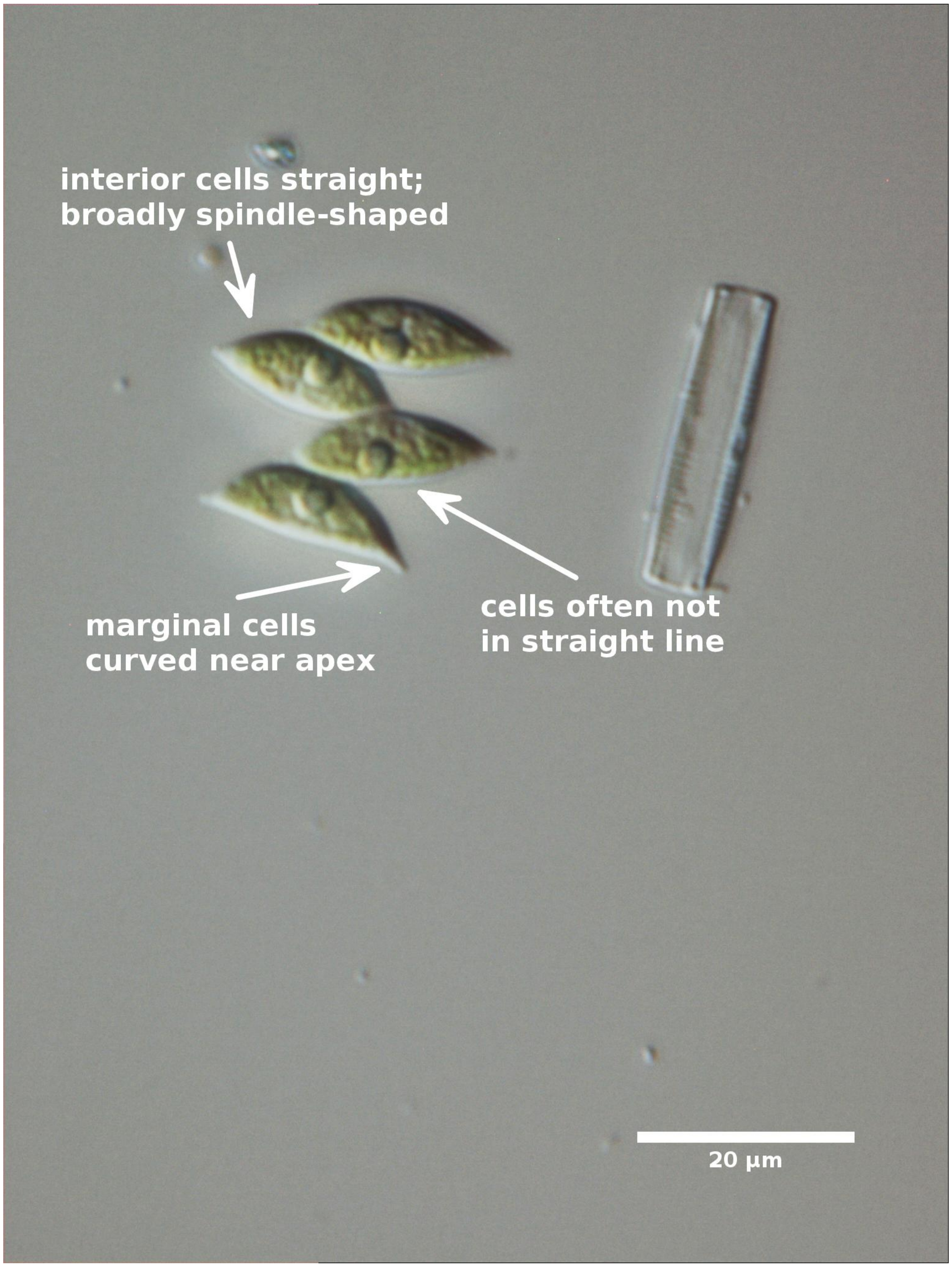

Figure 3.39: *Tetradesmus dimorphus* (600x DIC), freshwater aquarium, May 25, 2011.

Figure 3.40: *Tetradesmus dimorphus* (600x DIC), freshwater aquarium, May 25, 2011.

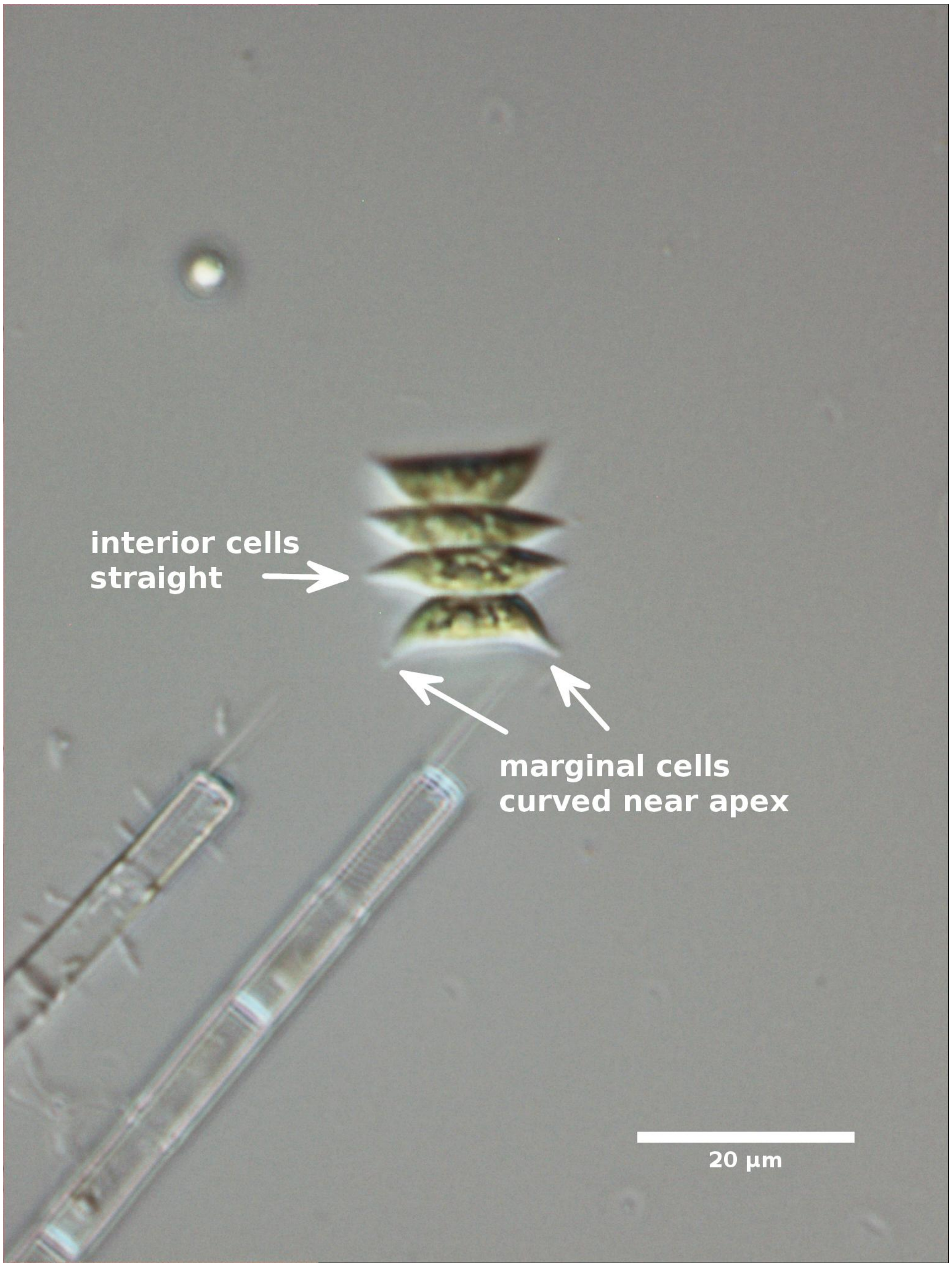

Figure 3.41: *Tetradesmus dimorphus* (600x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, September 17, 2009.

Figure 3.42: *Tetradesmus wisconsinensis* (600x DIC), small lake north of Sultan, Snohomish County, April 27, 2015.

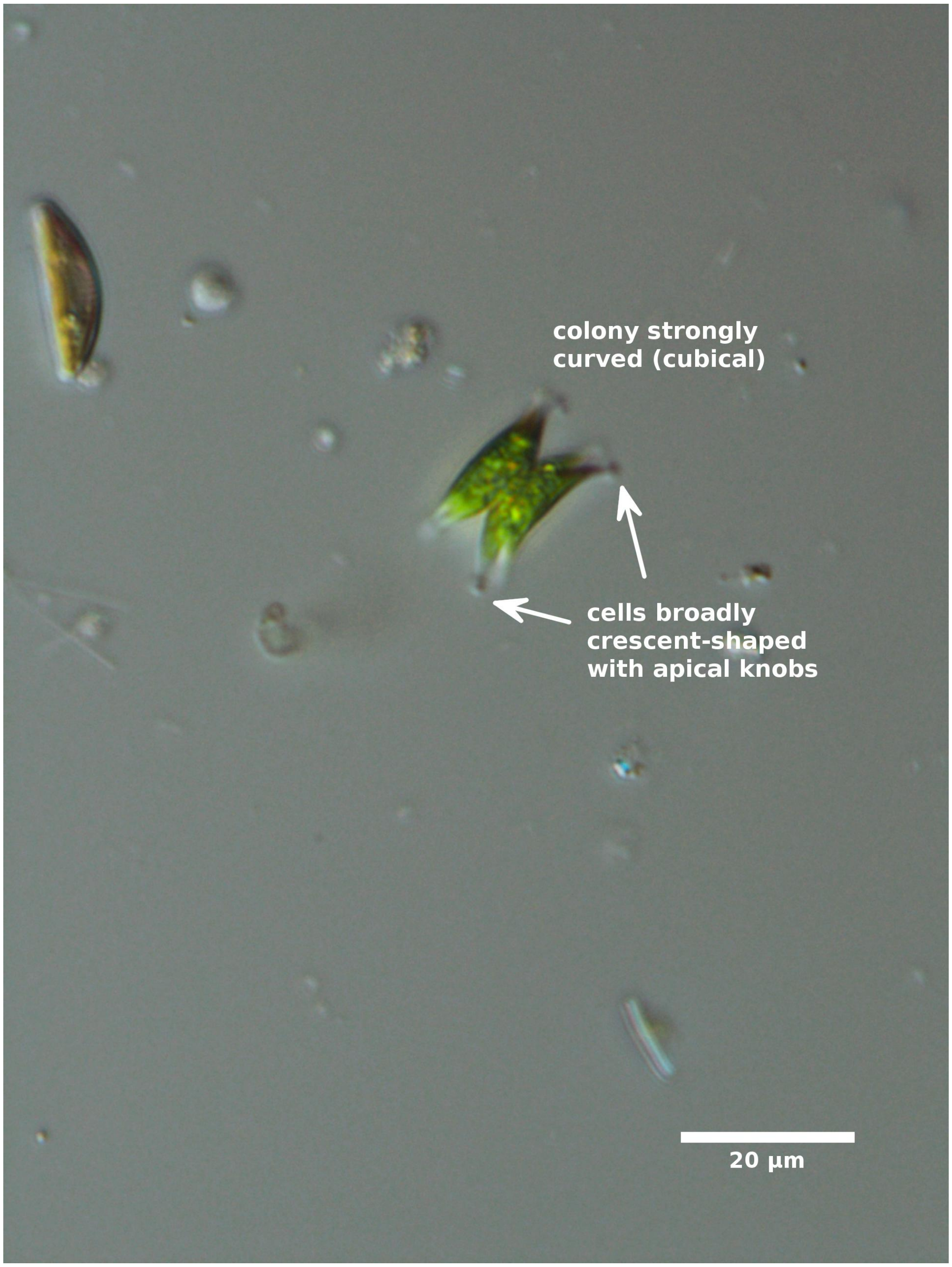

Figure 3.43: *Tetradesmus wisconsinensis* (600x DIC), small lake north of Sultan, Snohomish County, April 27, 2015.

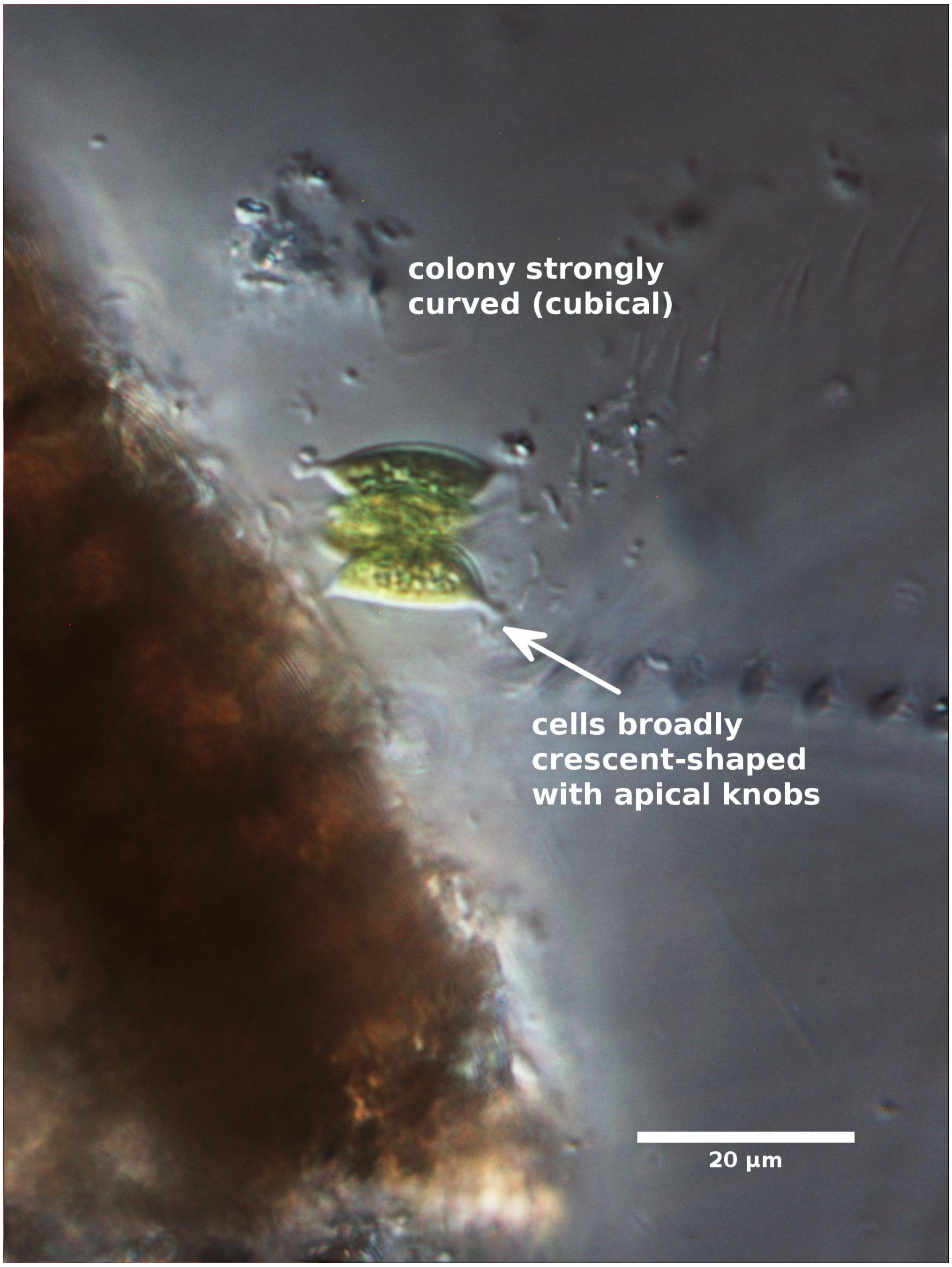

Figure 3.44: *Acutodesmus wisconsinensis* (600x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, September 11, 2009.

3.3 *Ankistrodesmus* Corda

Local taxa

Ankistrodesmus falcatus (Corda) Ralfs;
Ankistrodesmus fusiformis Corda;
Ankistrodesmus spiralis (W. B. Turner) Lemmermann

Abundance

Moderately common; may be present in large numbers but rarely forms blooms.

Local measurements		Width	Length	Biovolume†
Ankistrodesmus falcatus‡	min	1.1 μm	35.2 μm	12.4 μm^3
cells (fusiform)	med	1.2 μm	38.0 μm	14.9 μm^3
	max	1.5 μm	39.1 μm	22.6 μm^3
Ankistrodesmus fusiformis	min	1.8 μm	25.2 μm	21.4 μm^3
cells (fusiform)	med	2.4 μm	51.2 μm	97.7 μm^3
	max	3.5 μm	91.7 μm	199 μm^3
Ankistrodesmus spiralis	min	2.1 μm	48.1 μm	79.9 μm^3
cells (fusiform)	med	3.1 μm	58.2 μm	140 μm^3
	max	3.5 μm	69.6 μm	211 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume estimate based on <5 cells.

Description

Ankistrodesmus cells are narrowly fusiform or crescent-shaped, with acutely pointed ends (Figures 3.45–3.50). The colonies contain bundles of 2–16 cells (or more), with the cells closely aligned or twisted together into bundles. The cells contain a single parietal, band-like chloroplast that lacks visible pyrenoids.[14], The colonies are surrounded by a diffuse mucilaginous matrix that may be difficult to see unless stained or viewed using phase contrast illumination.

[14]The absence of pyrenoids is not a particularly good taxonomic feature. Recent improvements in microscopy have revealed the presence of pyrenoids in species that were initially described as lacking this feature.

The genus *Ankistrodesmus* has been revised and most of the species that are usually solitary have been moved to the genus *Monoraphidium* (Section 3.22, page 383). Also compare solitary cells to *Schroederia* (Section 3.32, page 470), which has visible pyrenoids.

Ankistrodesmus falcatus cells are needle-shaped, slightly curved, and in small colonies of 2–8 cells. The cells are joined along their concave side, forming parallel bundles (Figures 3.45–3.46).

Ankistrodesmus fusiformis cells are narrowly fusiform, straight or slightly curved, and in bundles of 4–16 cells. The cells lie cross-wise to each other in the colony, not parallel (Figures 3.47–3.48).

Ankistrodesmus spiralis cells are also narrowly fusiform, but instead of being parallel or at angles, the cells are strongly twisted together at the center of the colony (Figures 3.49–3.50). Most colonies contain 4–16 cells (Figure 3.49). The cells are so tightly twisted in Figure 3.50 that it is difficult to tell how many cells are in the colony.

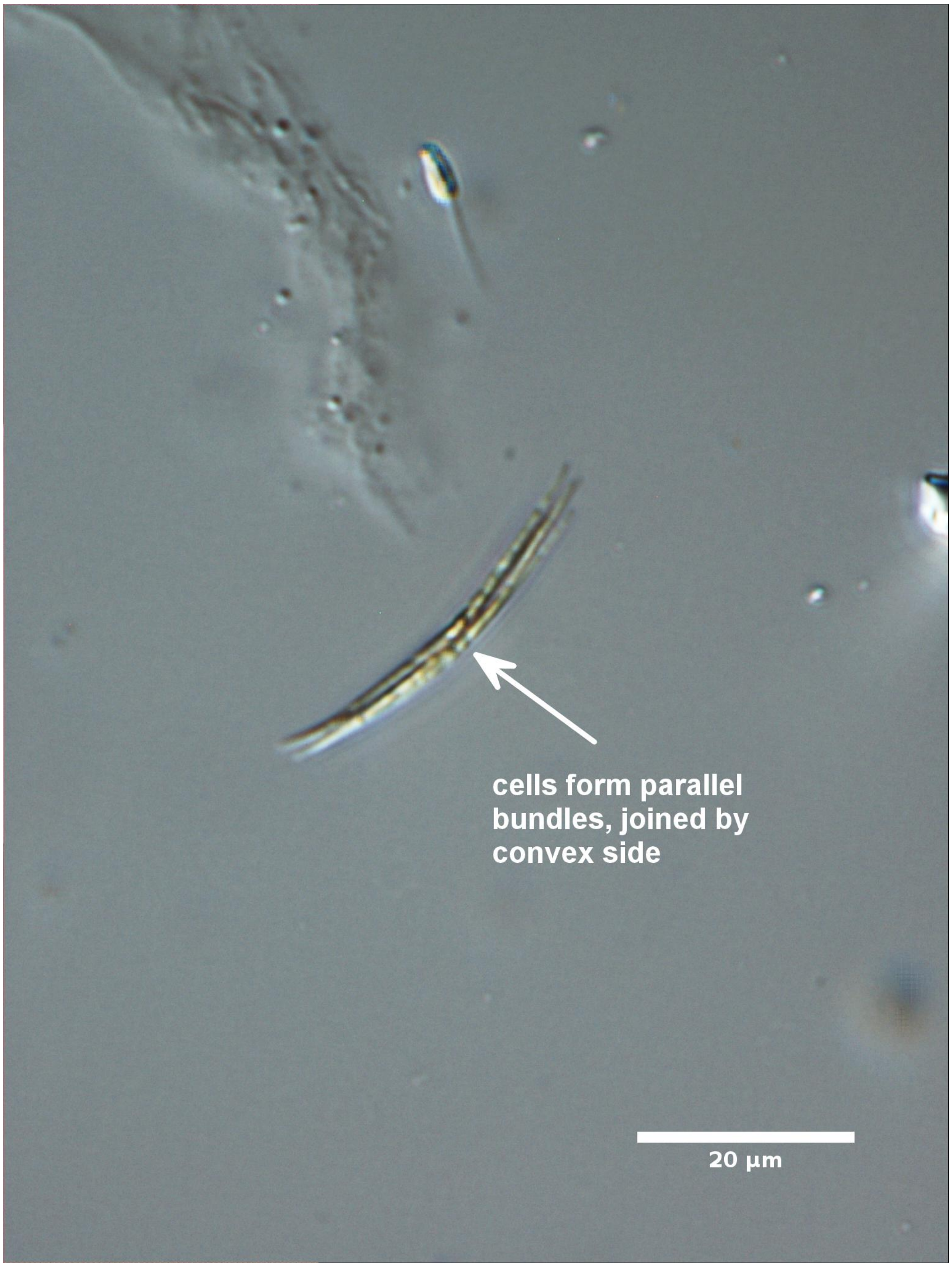

Figure 3.45: *Ankistrodesmus falcatus* in Lugol's iodine solution (600x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, September 28, 2009.

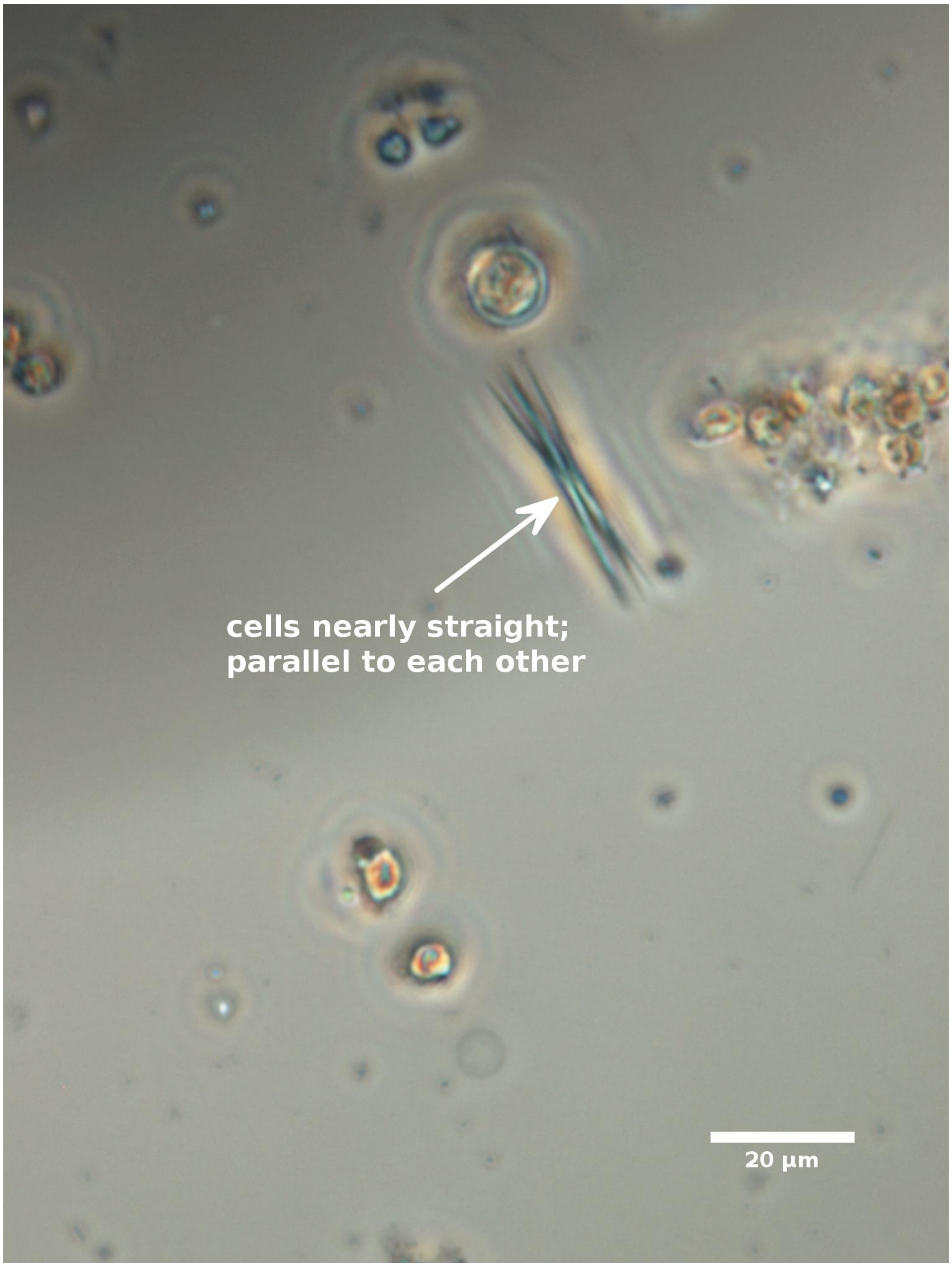

Figure 3.46: *Ankistrodesmus falcatus* in Lugol's iodine solution (400x phase contrast), Lake Padden, IWS water quality sampling site, Whatcom County, June 26, 2012.

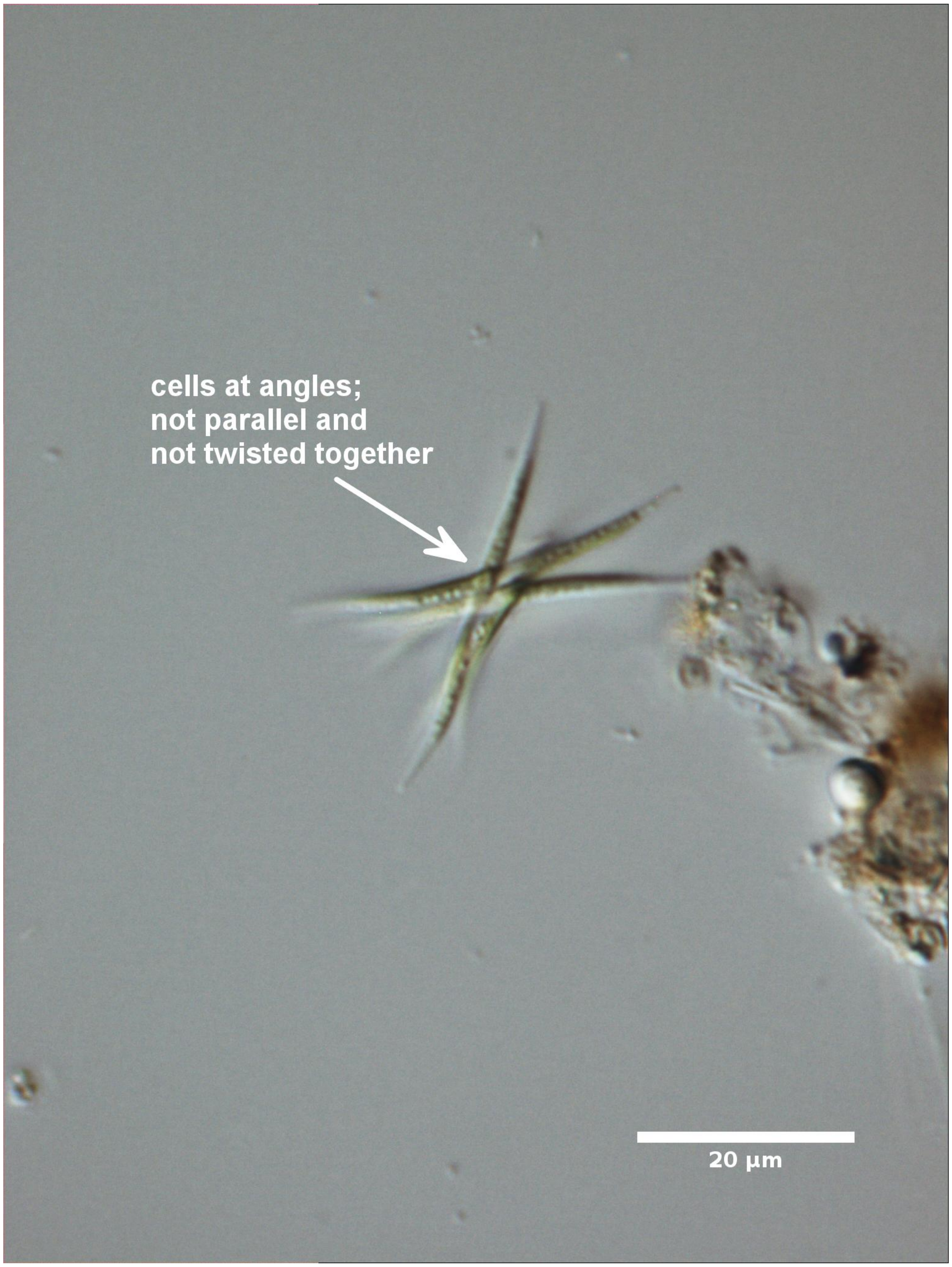

Figure 3.47: *Ankistrodesmus fusiformis* (600x DIC), Cranberry Lake, IWS water quality sampling site, Island County, September 1, 2008.

Figure 3.48: *Ankistrodesmus fusiformis* in Lugol's iodine solution (400x DIC), Toad Lake, IWS water quality sampling site, Whatcom County, April 24, 2009.

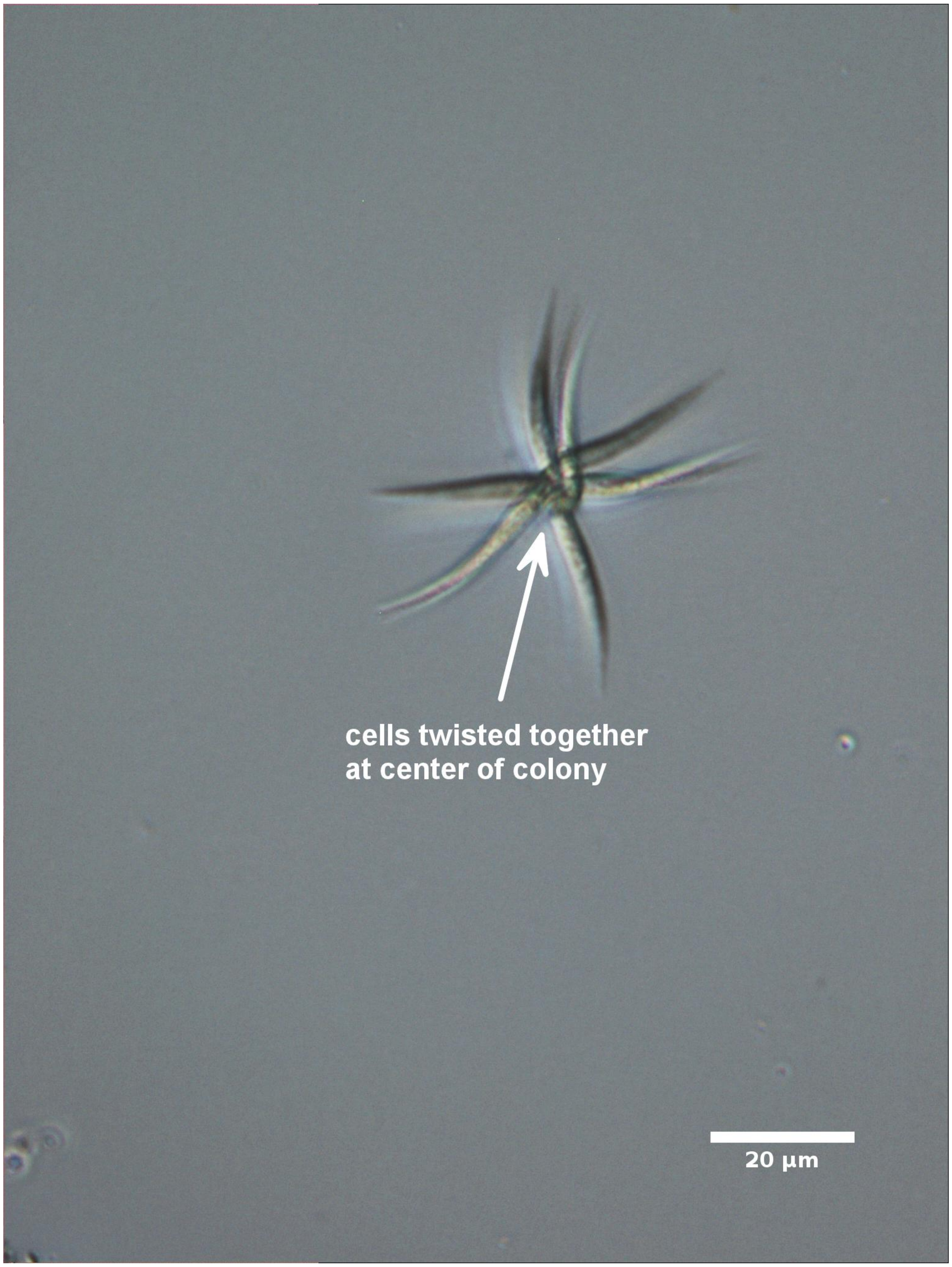

Figure 3.49: *Ankistrodesmus spiralis* (400x DIC), Cutthroat Lake, North Cascades along Hwy 20, October 12, 2009.

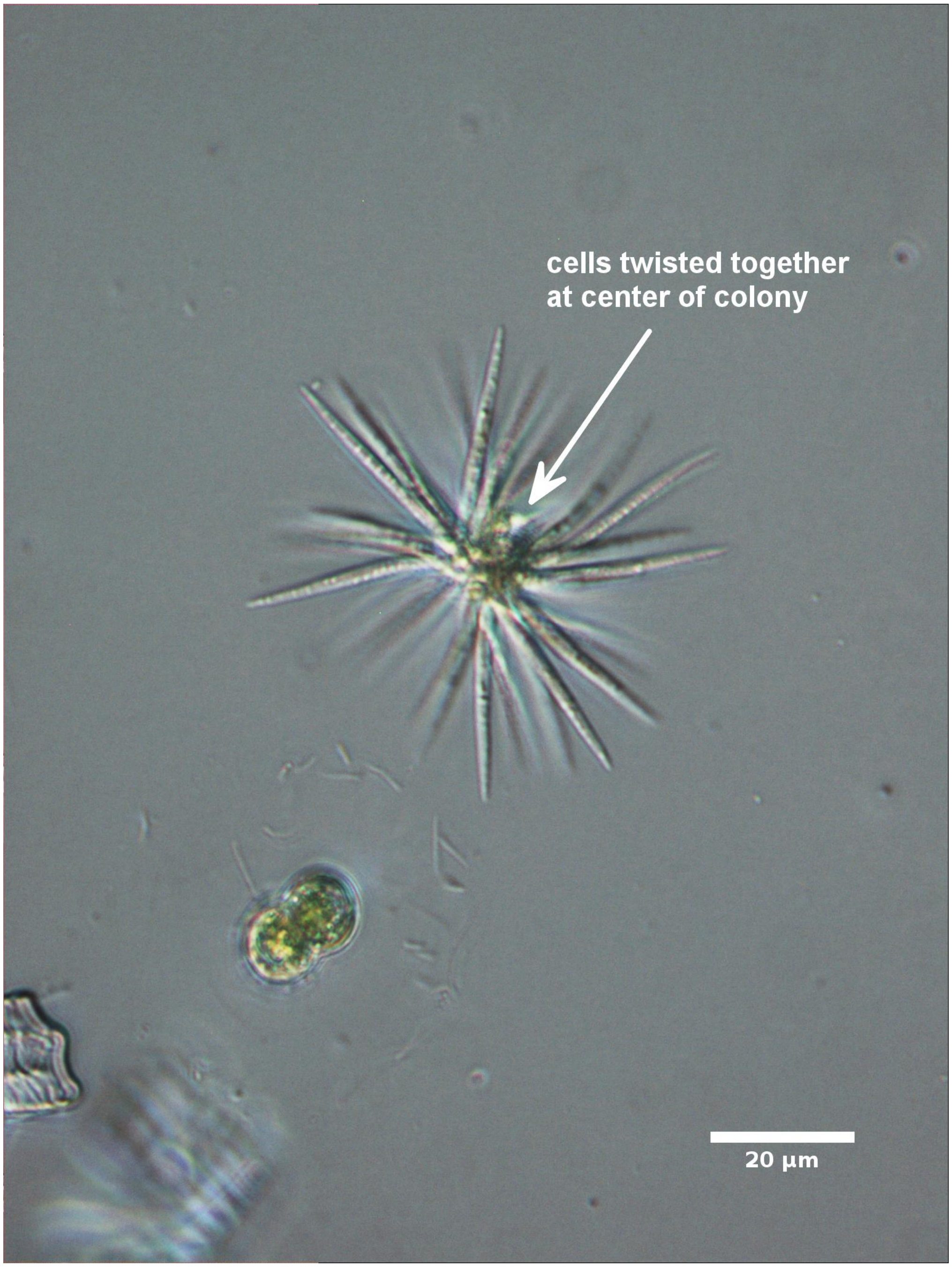

Figure 3.50: *Ankistrodesmus spiralis* (400x DIC), Cutthroat Lake, North Cascades along Hwy 20, October 12, 2009.

3.4 *Ankyra* Fott

Local taxa
Ankyra ancora (G. M. Smith) Fott;
Ankyra judayi (G. M. Smith) Fott;
Ankyra lanceolata (Korshikov) Fott (=*Lanceola spatulifera* [Korshikov] Hindák);
Ankyra sp.

Abundance
Infrequently collected; easily overlooked.

Local measurements		Width	Length	Biovolume†
Ankyra ancora	min	5.5 μm	69.9 μm	–
cells with apical spine‡	med	9.8 μm	89.6 μm	–
	max	11.1 μm	105.5 μm	–
Ankyra ancora	min	5.5 μm	42.7 μm	382 μm^3
cells without spine‡	med	9.8 μm	59.8 μm	1,880 μm^3
(cone $+\frac{1}{2}$ sphere)	max	11.1 μm	80.0 μm	2,670 μm^3
Ankyra judayi	min	4.3 μm	44.6 μm	221 μm^3
cells with apical spine	med	5.3 μm	70.8 μm	634 μm^3
(fusiform)	max	6.6 μm	85.1 μm	970 μm^3
Ankyra lanceolata	min	1.6 μm	49.3 μm	33.0 μm^3
cells with apical spine	med	3.6 μm	86.1 μm	285 μm^3
(fusiform)	max	5.6 μm	117.7 μm	966 μm^3

†Calculated using original measurements, not summary values.
‡*Ankyra ancora* biovolume was calculated without the apical spine (cone length $<$ cell length); other species taper gradually, so the spine was included in the calculations.

Description
Ankyra cells are solitary, elliptical, club-shaped, or fusiform, with long spines on both poles (Figures 3.51–3.60). The spines can be straight or curved; the posterior spine is usually bifurcate (split).

Ankyra ancora cells are robust and club-shaped, with a long straight apical spine and a short bifurcate posterior spine (Figures 3.51–3.52). The apical portion of the cell narrows abruptly; the posterior portion of the cell tapers more gradually. The chloroplasts are distinctively H-shaped and have a prominent central pyrenoid. Compare *Ankyra ancora* cells to *Paradoxia multiseta* (Section 3.26, page 416), a closely related species that is rare in most regions of the United States but fairly common in several northwest Washington lakes.

The specimen in Figure 3.53 was tentatively identified as *Ankyra ancora* because it was collected in Heart Lake, a good collecting site for this species. The cell appear to be dividing, with the chloroplast forming 2–4 smaller H-shaped segments. It is also possible that these cells are *Korshikoviella michailovskoensis* (Elenkin) P. C. Silva, a closely related rare species that has segmented chloroplast in the vegetative cells. The specimen in Figure 3.54 was also tentatively identified as *Ankyra ancora*, and it appears to have formed zoospores.

Ankyra judayi cells are long and narrow, tapering gradually to a long apical spine and shorter bifurcate posterior spine (Figures 3.55–3.57). The chloroplast is large, plate-like, and fills most of the cell body. The cell may be straight, but more often curves to form a crescent. The tiny *Ankyra* in Figure 3.58 is moderately common in settled, whole-water plankton samples but rarely found in plankton tows collected using a 20 μm net. The cells are straight or very slightly curved, with a plate-like chloroplast, a long, straight apical spine, and a clearly bifurcate posterior spine. These specimens may be small *Ankyra judayi* cells.

Ankyra lanceolata is very common in local lakes, but the cells are easy to miss (Figures 3.59–3.60). The cells are very narrow and fusiform, with a plate-like chloroplast. The cells are usually straight or very slightly curved. The apical spine is long and straight; the posterior spine ends in a leaf-like extension that does not appear to be split when examined using phase contrast or DIC. Scanning electron microscopy (SEM) revealed that the extensions are split, but not widely separated (R. Gravon, WWU graduate student, pers. comm., 2010).

According to AlgaeBase (`www.algaebase.org`, downloaded March 11, 2016), *Ankyra lanceolata* is a synonym for *Lanceola spatulifera*. The revision, including the separation of the *Lanceola* from *Ankyra*, is based on the structure of the posterior bristle, which appears "lanceolate" (lance-shaped or leaf-shaped), and not clearly divided. Several researchers report that the bristle is indeed split, but the split is not widely separated, so the basis for separation is questionable.

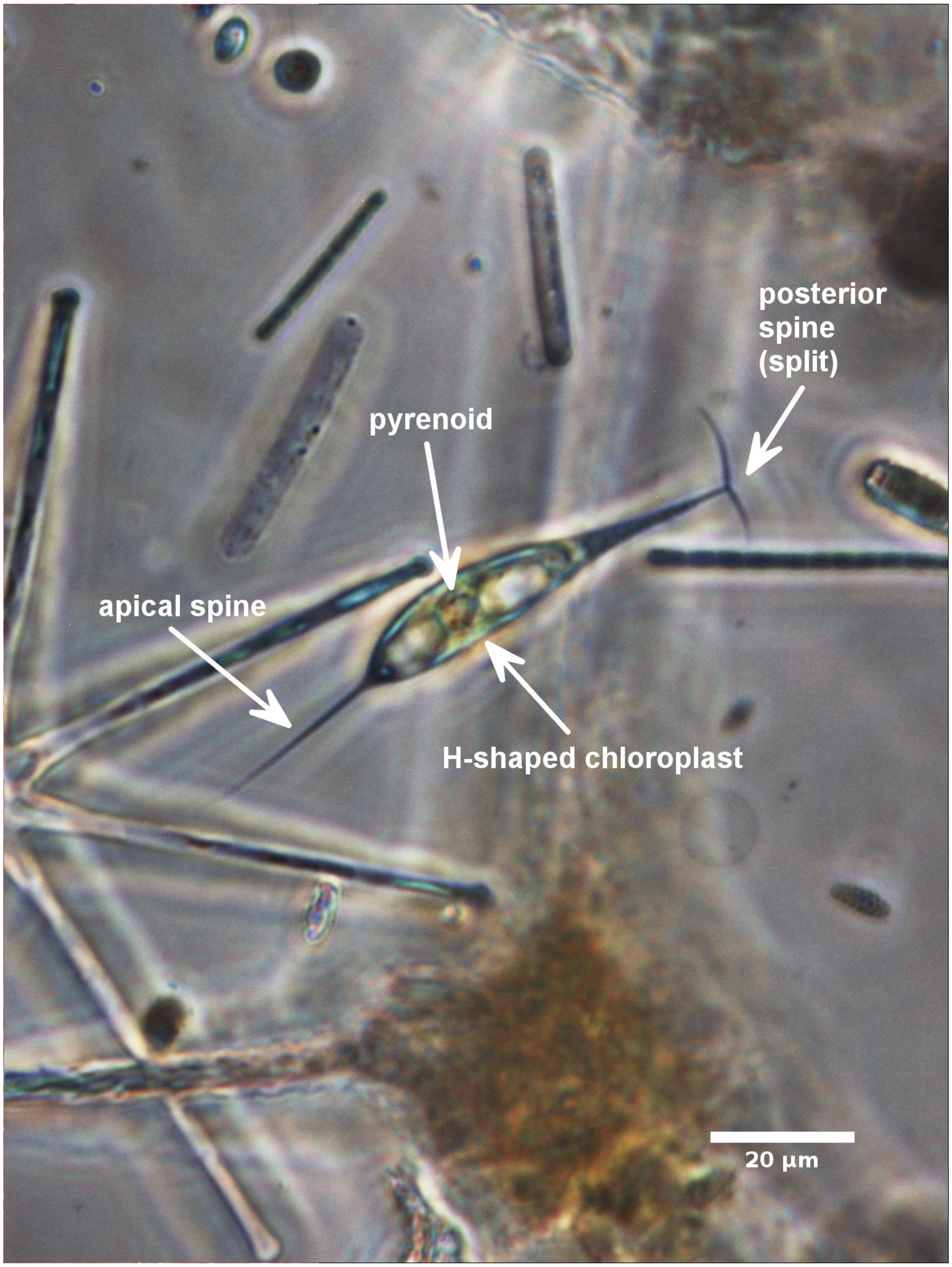

Figure 3.51: *Ankyra ancora* (400x phase contrast), Cranberry Lake, IWS water quality sampling site, Island County, August 25, 2009.

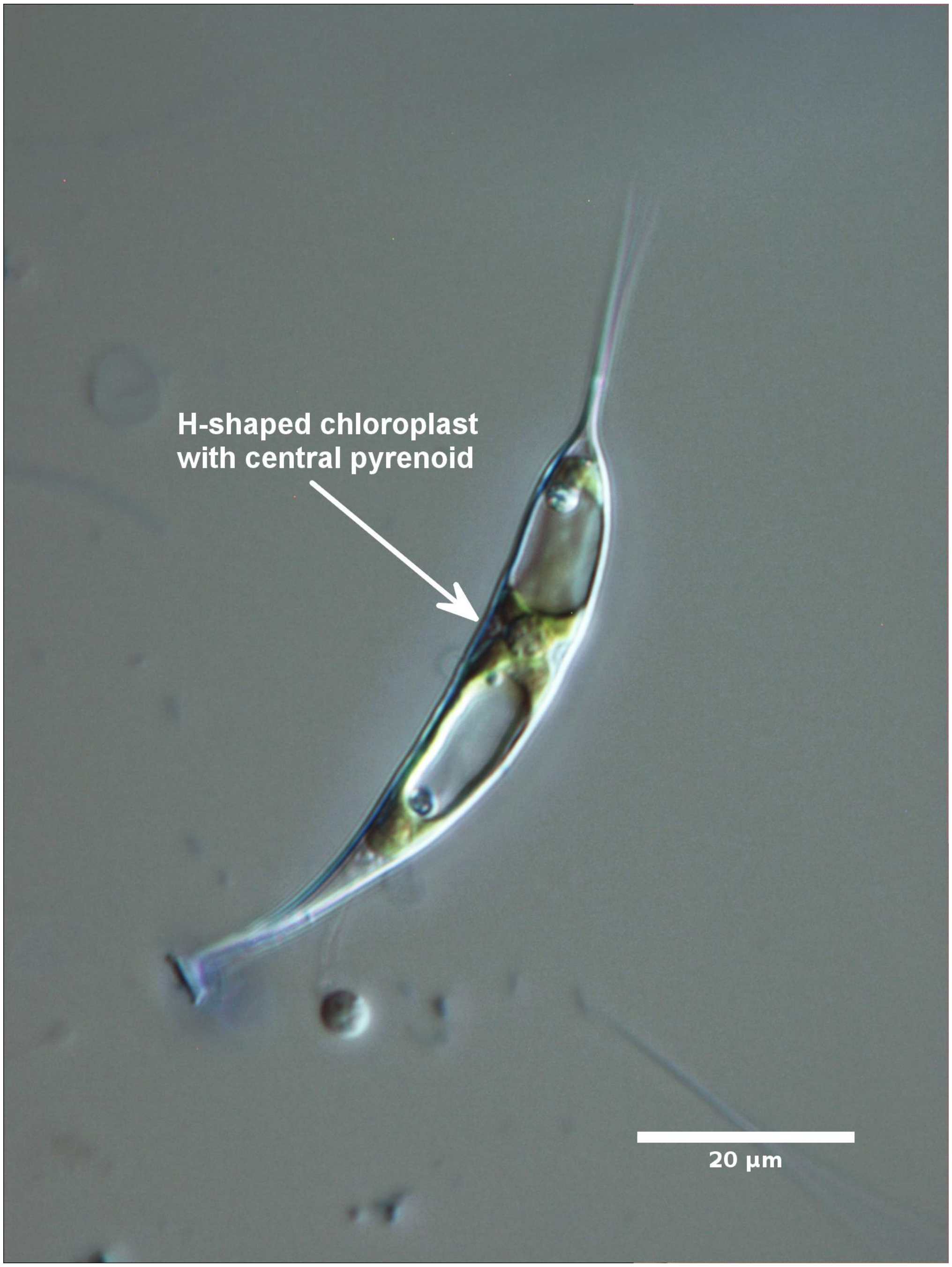

Figure 3.52: *Ankyra ancora* stained with methylene blue (600x DIC), Cranberry Lake, IWS water quality sampling site, Island County, July 21, 2011.

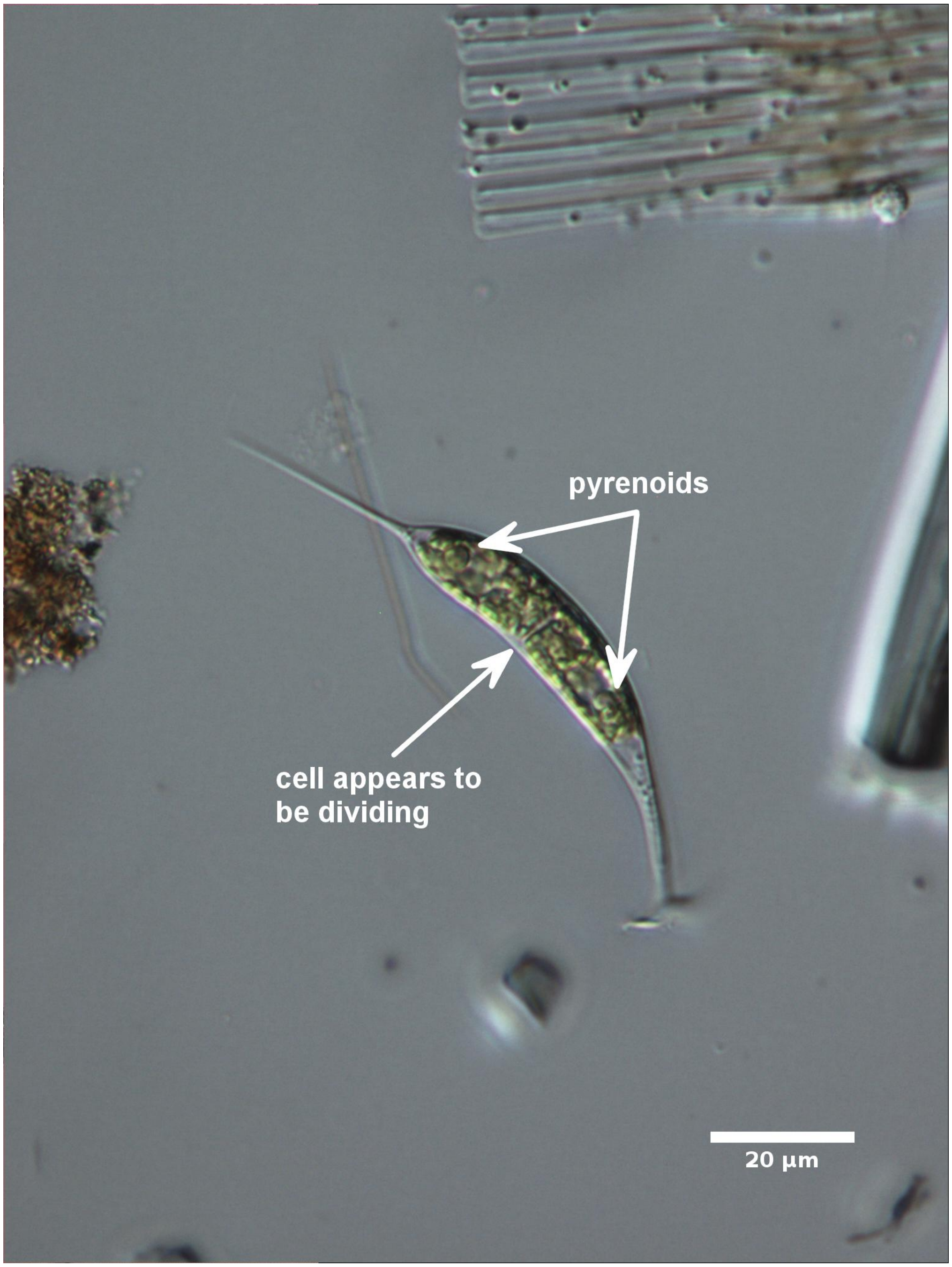

Figure 3.53: *Ankyra ancora*? dividing (400x DIC), Heart Lake, IWS water quality sampling site, Skagit County, August 28, 2008.

Figure 3.54: *Ankyra ancora* zoospores? (600x DIC), Lake Campbell, IWS water quality sampling site, Skagit County, July 21, 2011.

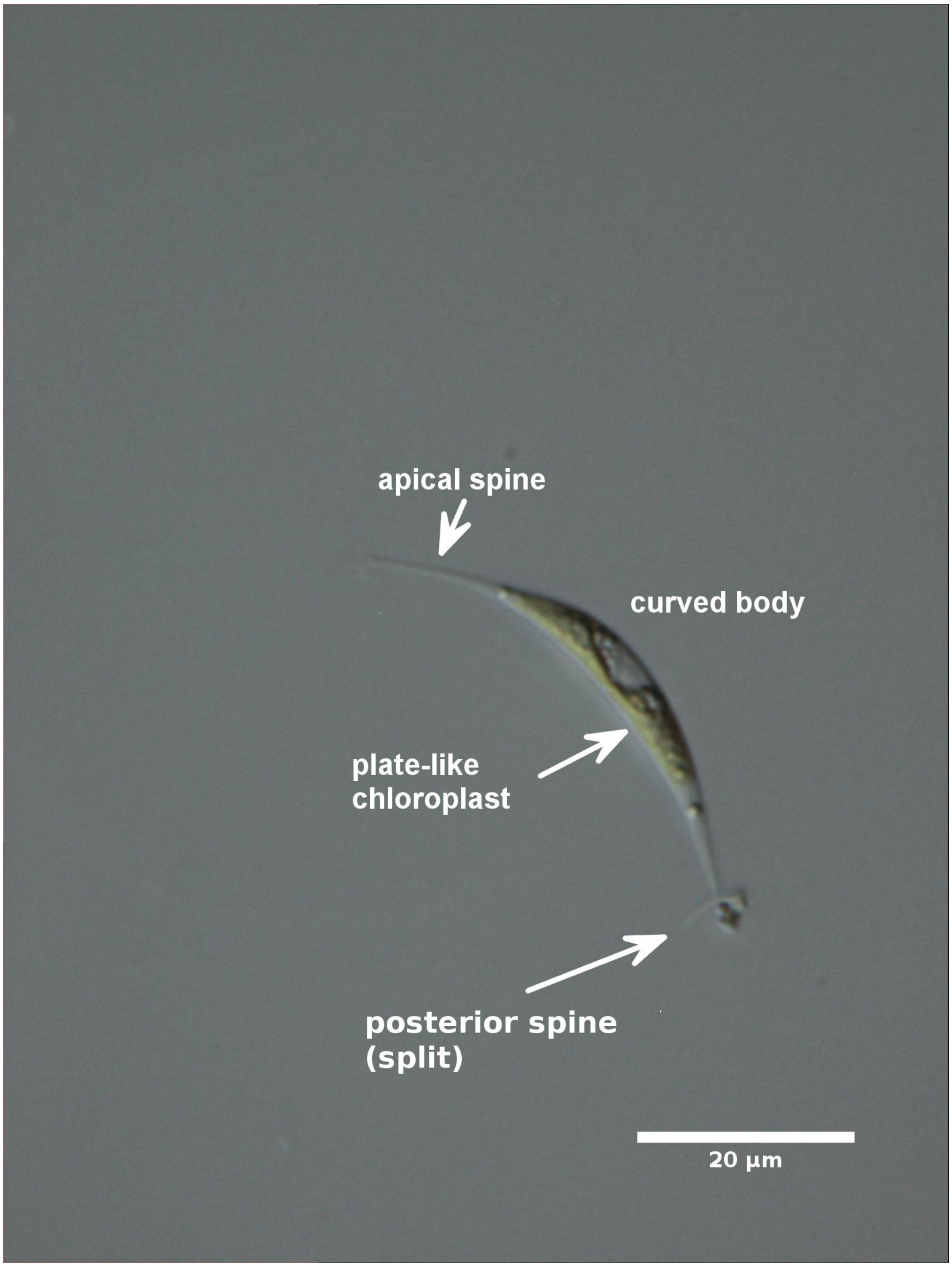

Figure 3.55: *Ankyra judayi* (600x DIC), Goss Lake, IWS water quality sampling site, Island County, August 28, 2008.

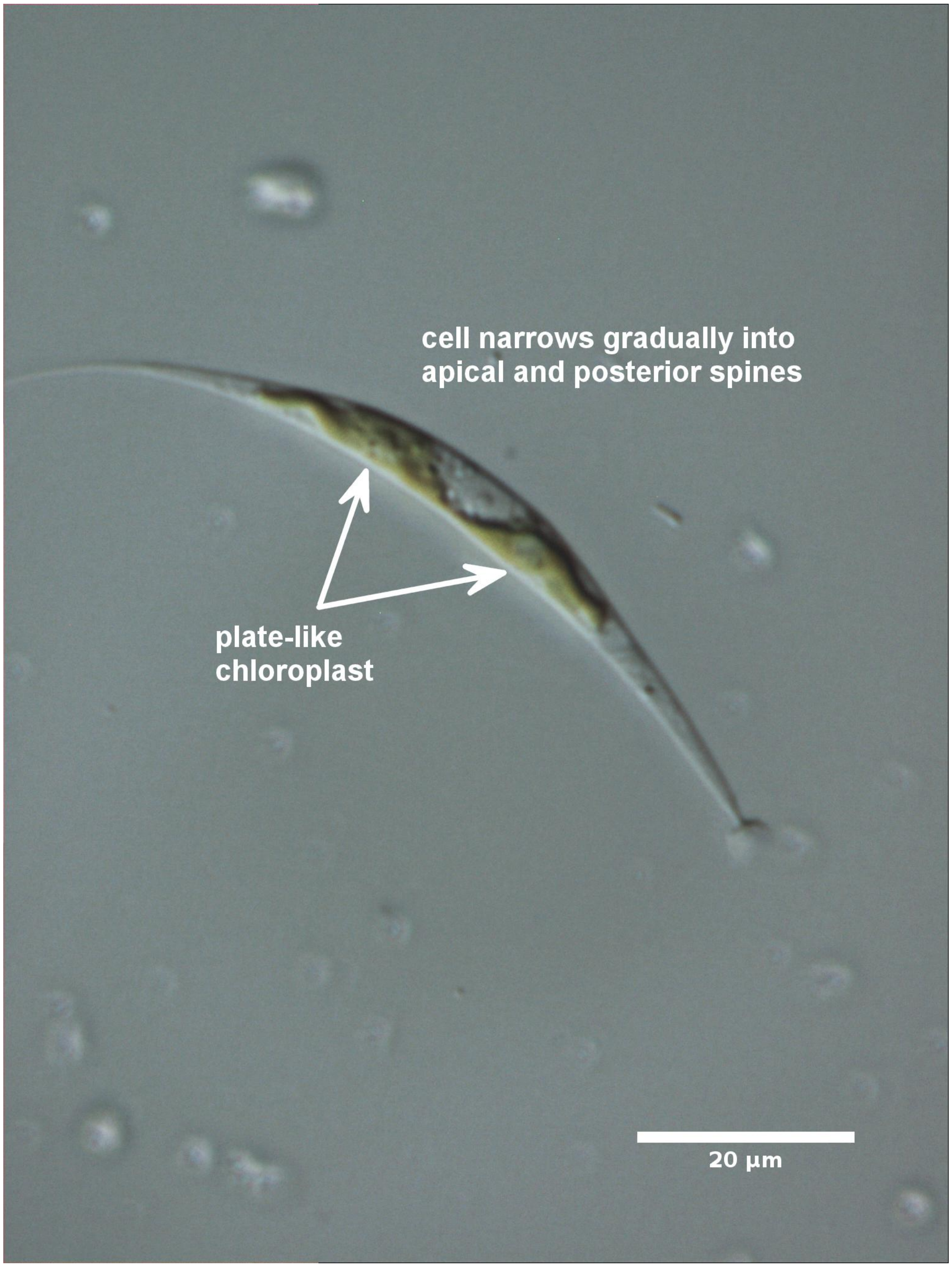

Figure 3.56: *Ankyra judayi* (600x DIC), Cranberry Lake, IWS water quality sampling site, Island County, July 18, 2010.

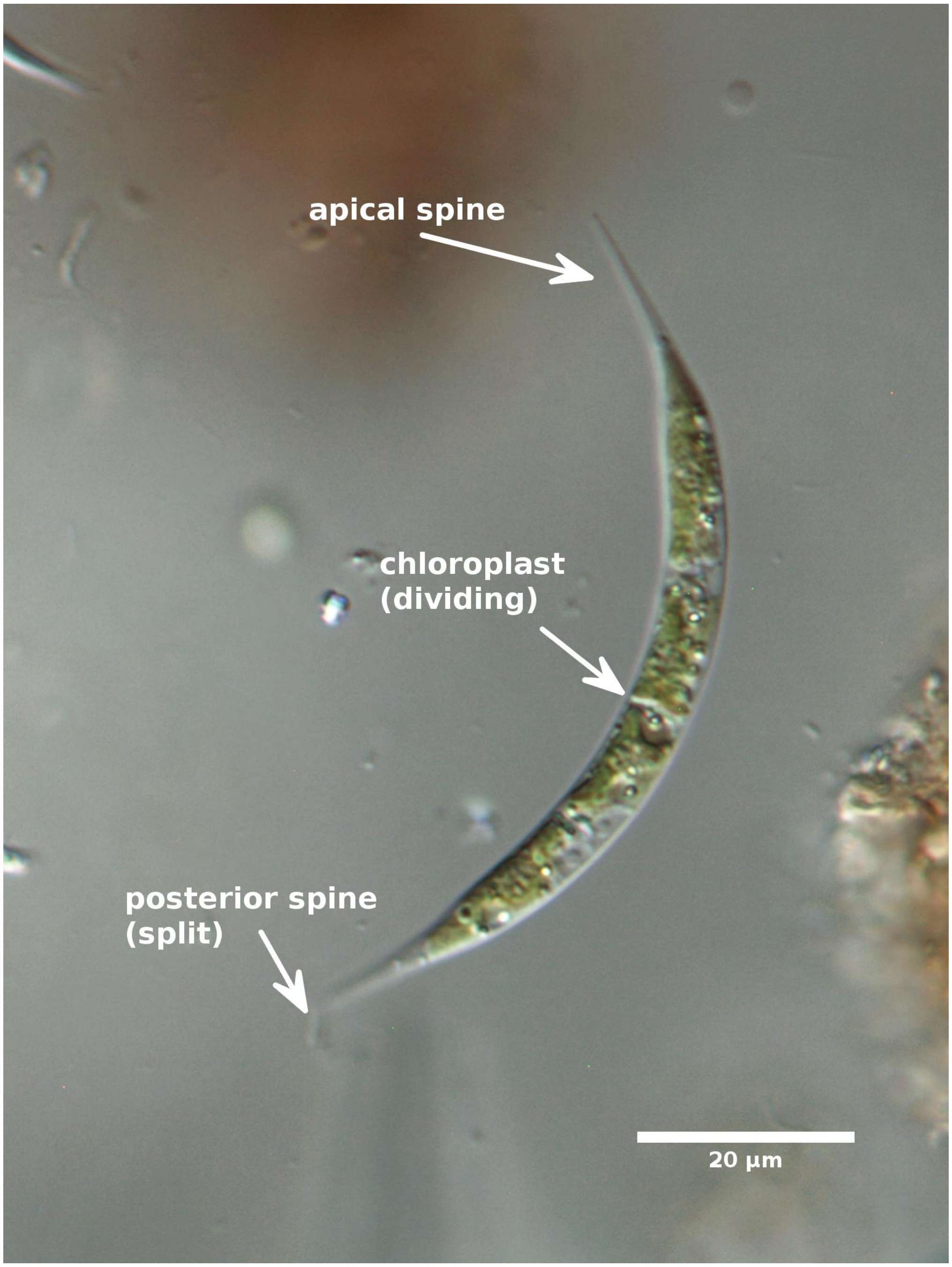

Figure 3.57: *Ankyra judayi* dividing (600x DIC), Goss Lake, IWS water quality sampling site, Island County, July 22, 2013.

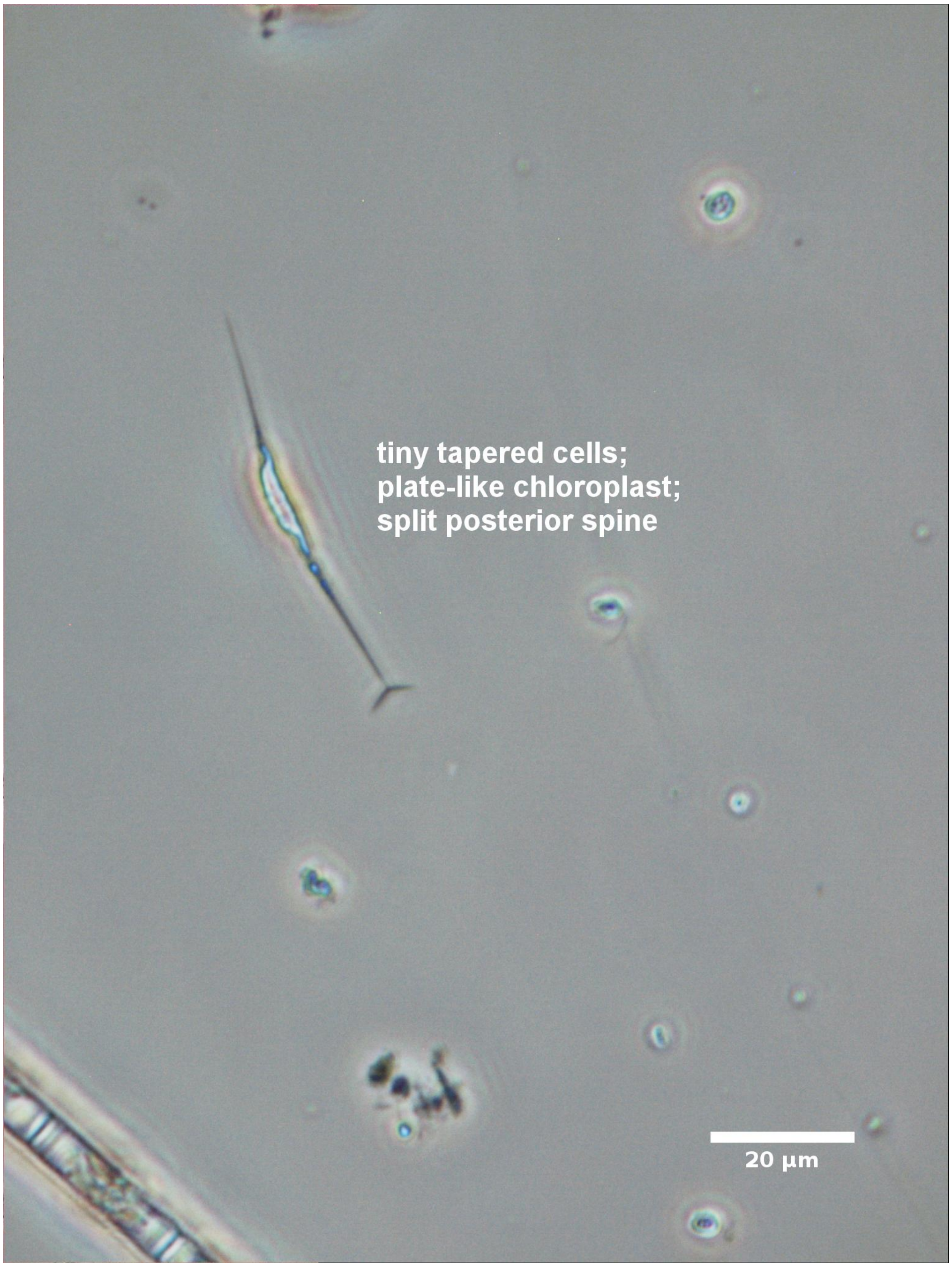

Figure 3.58: *Ankyra judayi*? in Lugol's iodine solution (400x phase contrast), Heart Lake, IWS water quality sampling site, Skagit County, August 29, 2009.

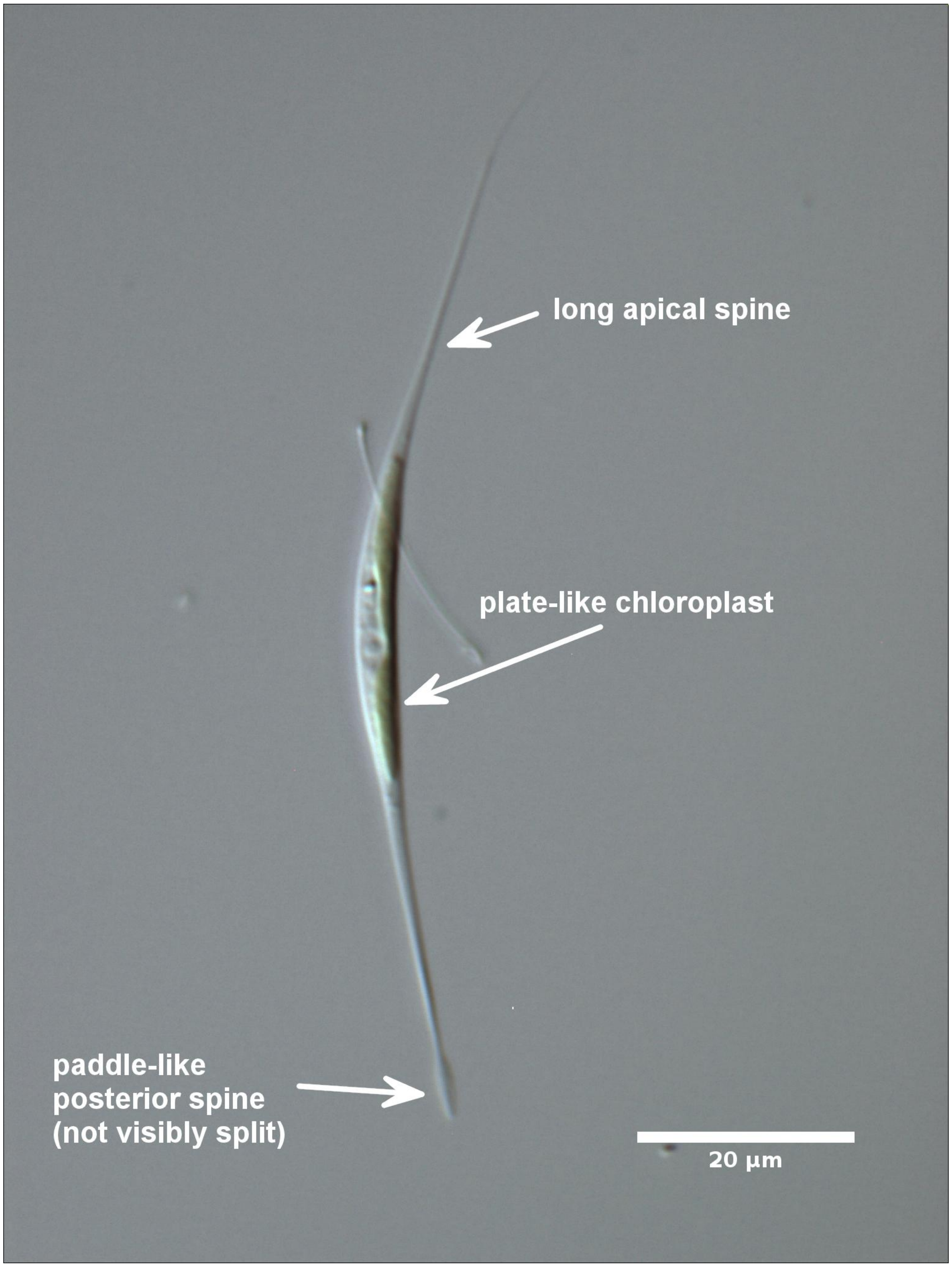

Figure 3.59: *Ankyra lanceolata* (600x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, August 16, 2007.

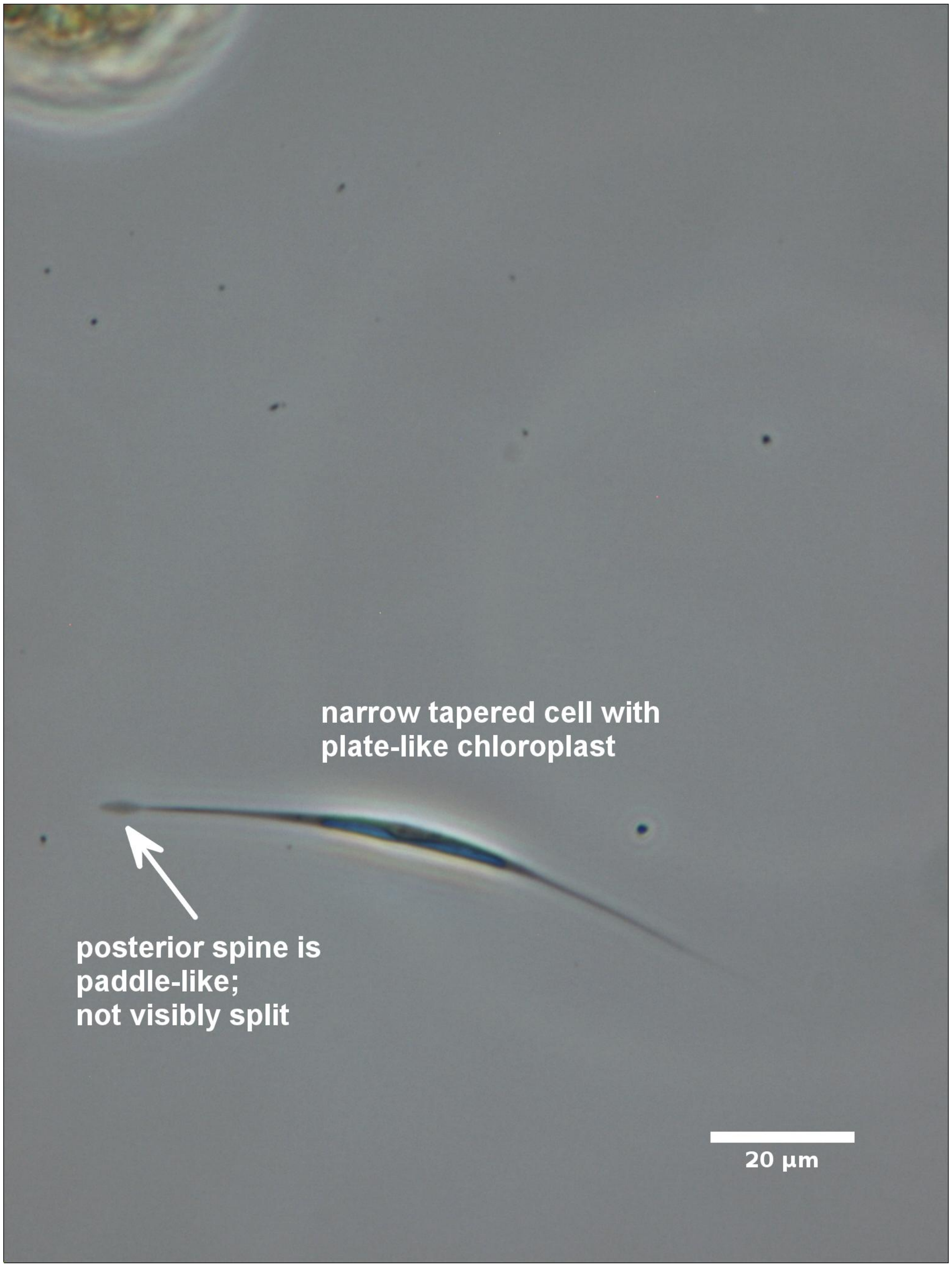

Figure 3.60: *Ankyra lanceolata* (400x phase contrast), Lake Fazon, IWS water quality sampling site, Whatcom County, August 16, 2007.

3.5 *Apiocystis* Nägeli

Local taxon

Apiocystis brauniana Nägeli

Abundance

Infrequently collected in plankton samples; moderately common epiphyte.

Local measurements		Width	Length	Biovolume†
Apiocystis brauniana	min	6.8 μm	–	165 μm^3
cells (sphere)	med	8.8 μm	–	351 μm^3
	max	11.3 μm	–	755 μm^3

†Calculated using original measurements, not summary values.

Description

Apiocystis brauniana cells are loosely arranged inside an expanded, sack-like colonial mucilage that is attached at one end to aquatic plants or other solid substrates. The individual cells are smooth-walled and spherical, with a cup-shaped chloroplast (Figures 3.61–3.64). Although nonmotile, the cells have long pseudocilia, and may also have an eyespot. The cells divide to form 4-cell subgroups, resembling *Tetraspora* (Section 3.37, page 508), but tend to disperse within the colonial sack, so the subgroups are not obvious.

Apiocystis belongs to the order **Tetrasporales**, which contains nonmotile cells that are closely related to the motile **Volvocales** (e.g., *Volvox*, Section 2.13, page 134). Although *Apiocystis* cells are nonmotile in the vegetative state, the cells have long pseudocilia that are structurally similar to flagella. Other **Tetrasporales** that are found in local lakes and streams include *Asterococcus* (Section 3.6, page 245), *Paulschulzia* (Section 3.27, page 421), *Schizochlamys* (Section 3.31, page 465), and *Tetraspora* (Section 3.37, page 508).

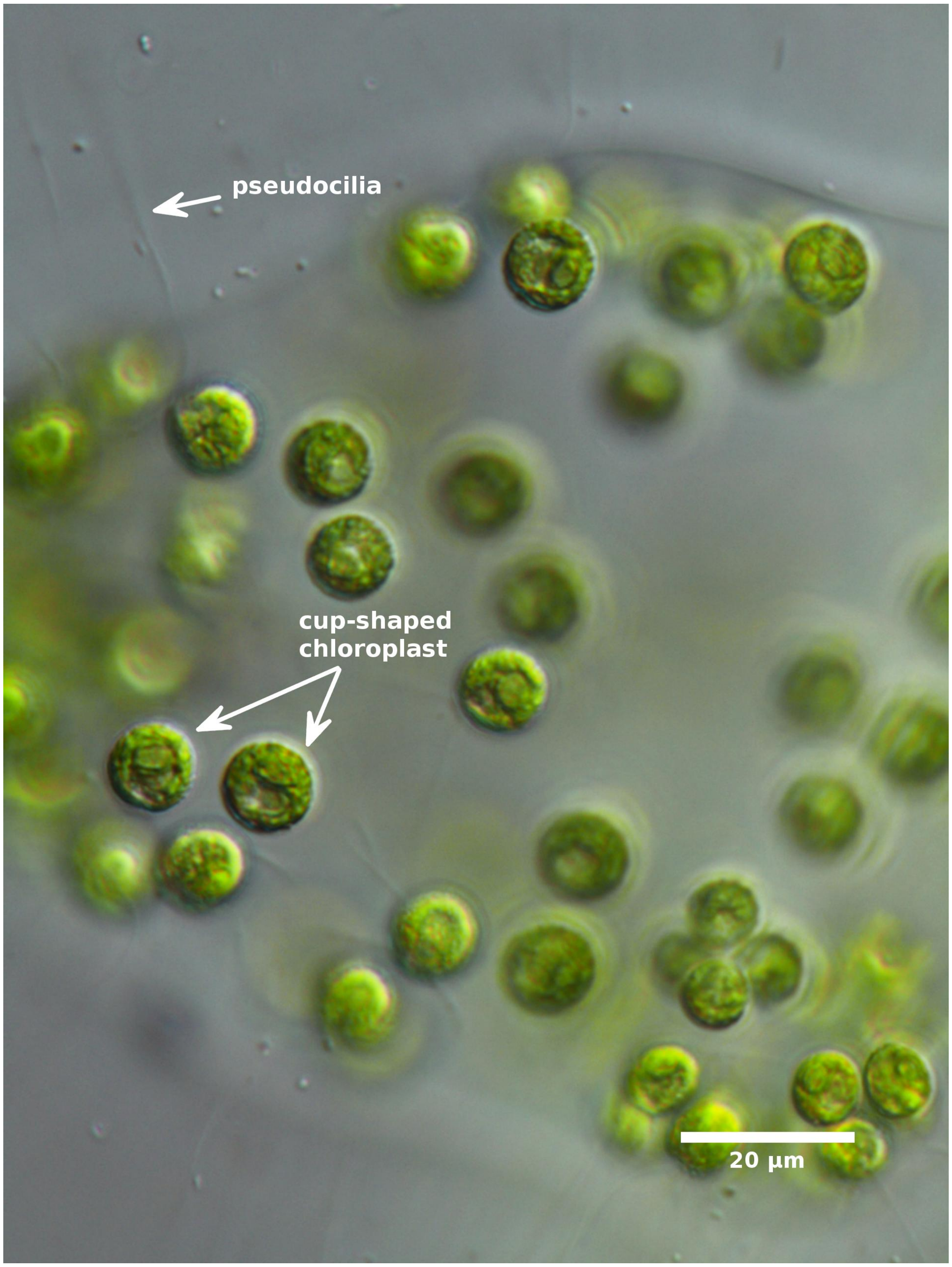

Figure 3.61: *Apiocystis brauniana* (600x DIC), small pond near Fairhaven College, Whatcom County, April 13, 2015.

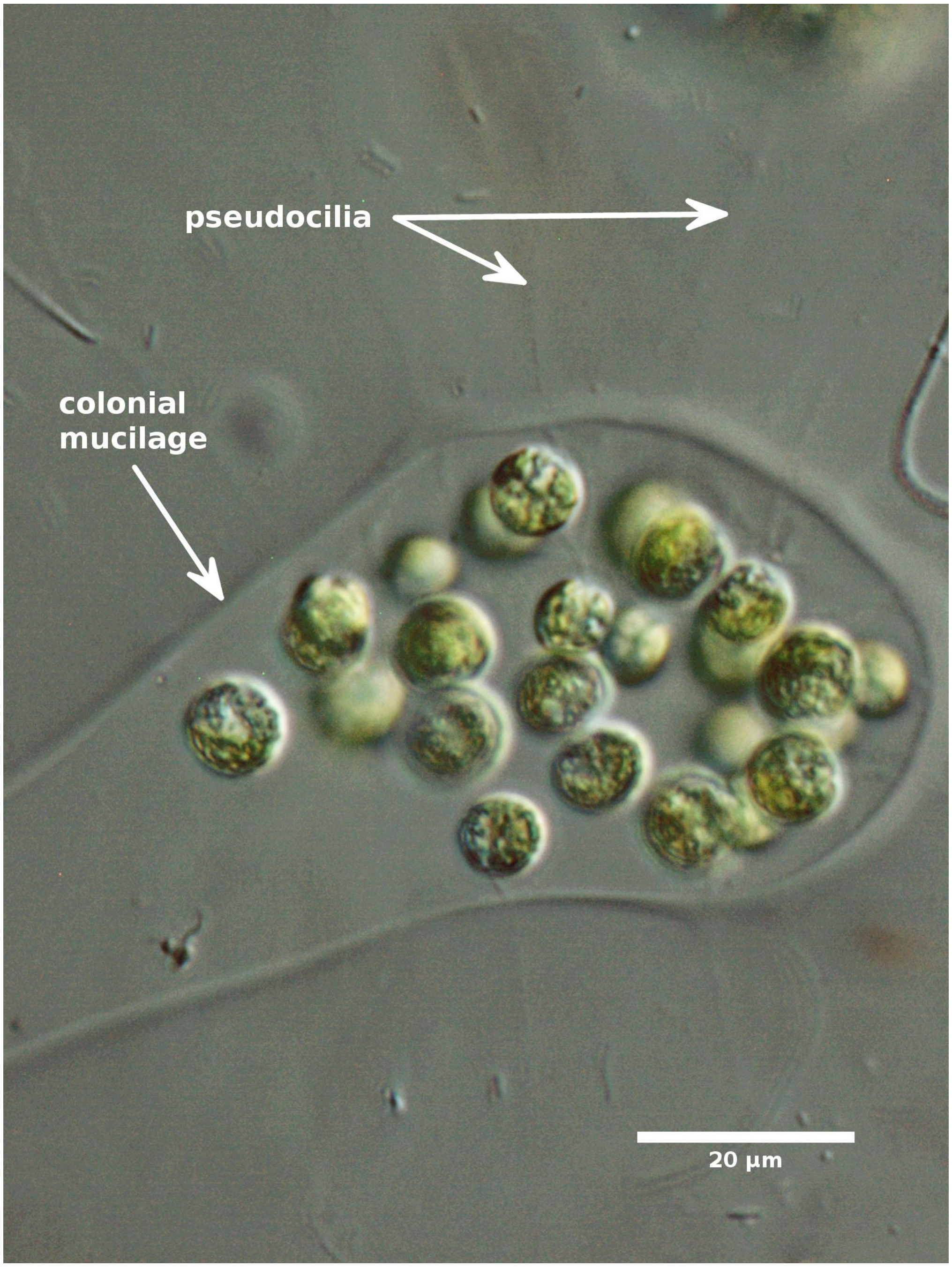

Figure 3.62: *Apiocystis brauniana* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 29, 2013.

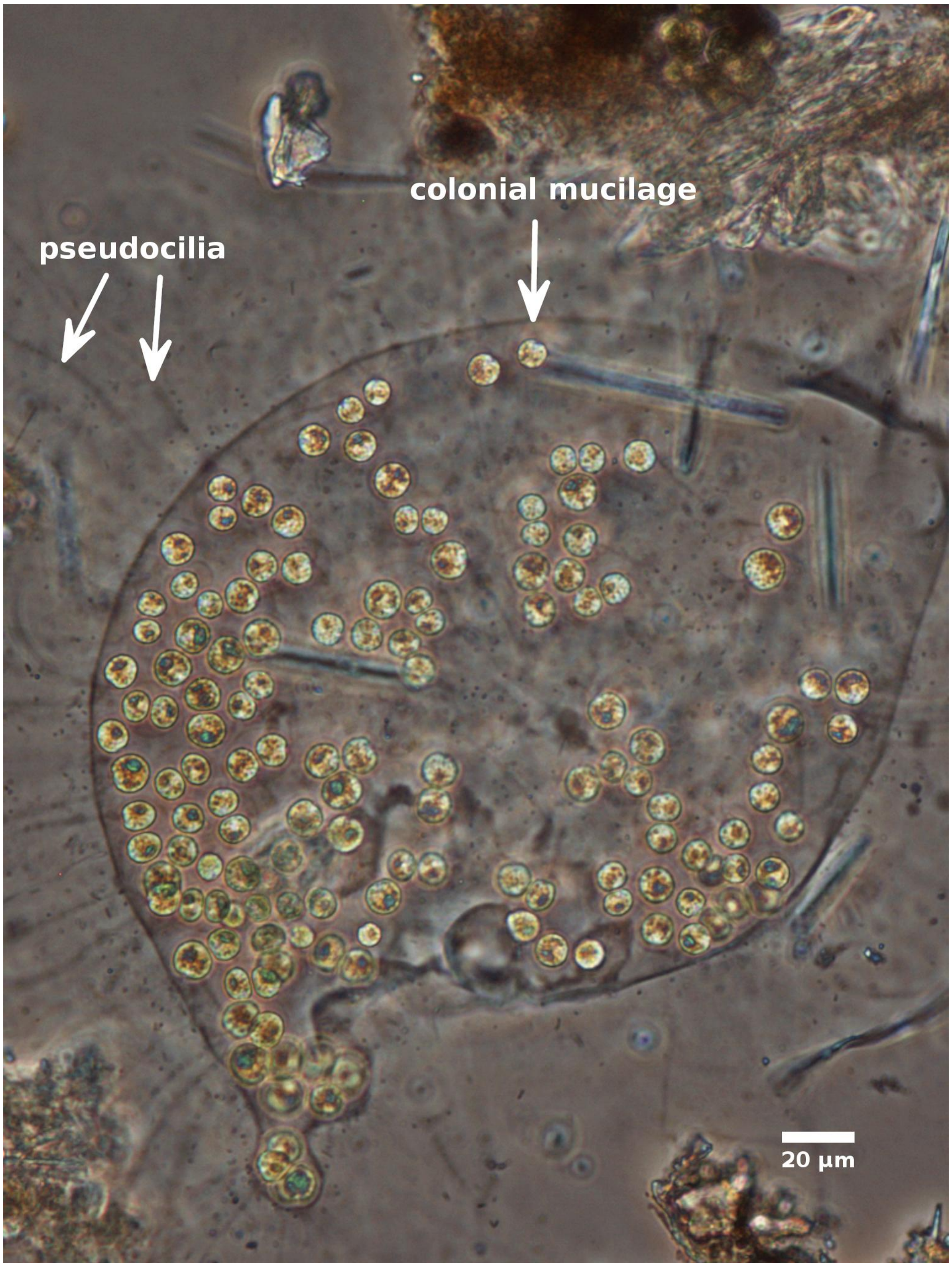

Figure 3.63: *Apiocystis brauniana* (200x phase contrast), Lake Terrell, IWS water quality sampling site, Whatcom County, July 29, 2013.

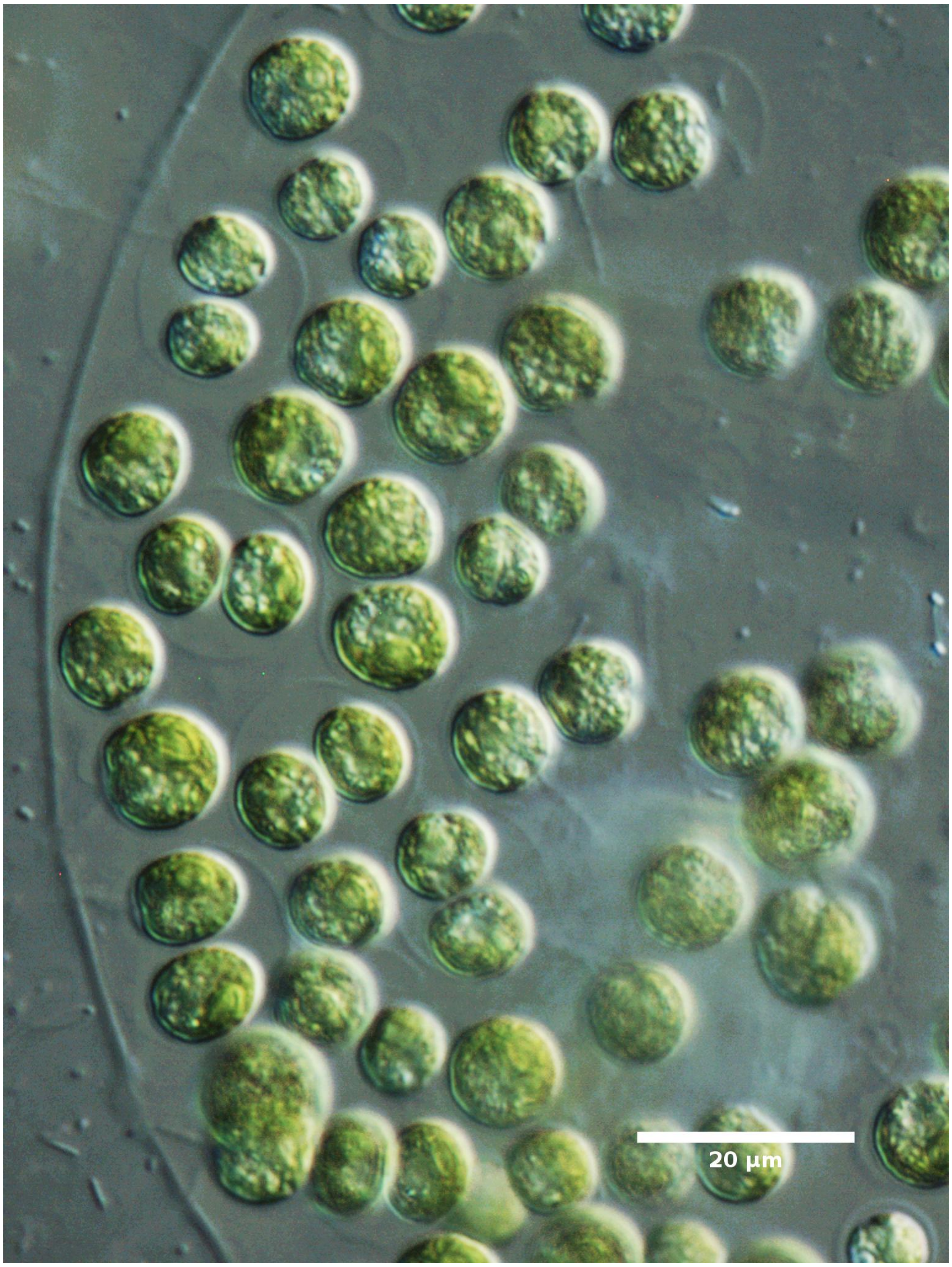

Figure 3.64: *Apiocystis brauniana* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 29, 2013.

3.6 *Asterococcus* Scherffel

Local taxon

Asterococcus superbus (Cienkowski) Scherffel?

Abundance

Moderately common; rarely present in large numbers.

Local measurements		Width	Length	Biovolume[†]
Asterococcus superbus?	min	9.7 μm	10.5 μm	542 μm^3
cells (spheroid)	med	13.7 μm	15.9 μm	1,620 μm^3
	max	30.7 μm	33.2 μm	15,700 μm^3

[†]Calculated using original measurements, not summary values.

Description

Asterococcus cells are spherical, oval, or broadly elliptical (Figures 3.65–3.71). The cells may be solitary or in small colonies of 2–16 cells surrounded by a wide, clear mucilage layer. The chloroplast is dense and stellate, radiating from a central pyrenoid. In older cells the chloroplast may expand to fill most of the cell.

Asterococcus belongs to the order **Tetrasporales**, which contains nonmotile cells that are closely related to the motile **Volvocales** (e.g., *Volvox*, Section 2.13, page 134). Although *Asterococcus* cells are nonmotile in the vegetative state, the cells often have an eyespot. Other members of this group have long pseudocilia that, while not providing motility, are structurally similar to flagella. Other **Tetrasporales** that are found in local lakes and streams include *Apiocystis* (Section 3.5, page 240), *Paulschulzia* (Section 3.27, page 245), *Schizochlamys* (Section 3.31, page 465), and *Tetraspora* (Section 3.37, page 508).

All of the local *Asterococcus* specimens were tentatively identified as *Asterococcus superbus*. This species is characterized by nearly spherical cells that are usually solitary, but may form 4-cell colonies during division. The cells are surrounded by a stratified mucilage layer that may be difficult to see unless stained or viewed using phase contrast illumination. *Asterococcus superbus* is described as having relatively large cells (30–43 μm diameter) by John, et al. (2011), but Ettl & Gärtner (1988) describe a larger size variation (11–40 $\times$ 7–35 μm). The local specimens also show considerable variation in size and mucilage structure.

Compare *Asterococcus* to *Chlorella* (Section 3.9, page 282), which does not form distinct colonies and has little if any mucilage surrounding the cells. Also compare specimens to *Gloeocystis* (Section 3.16, page 343), which has cup-shaped chloroplasts and stratified mucilage surrounding the cells and colony; *Planktosphaeria* (Section 3.29, page 451), which is characterized by solitary cells surrounded by a firm, unstratified mucilage; and *Sphaerocystis* (Section 3.35, page 493), which forms irregular colonies containing large and small cells surrounded by a diffuse, unstriated colonial mucilage.

Figure 3.65: *Asterococcus superbus*? (600x DIC), Bear Lake, IWS water quality sampling site, Snohomish County, August 16, 2013.

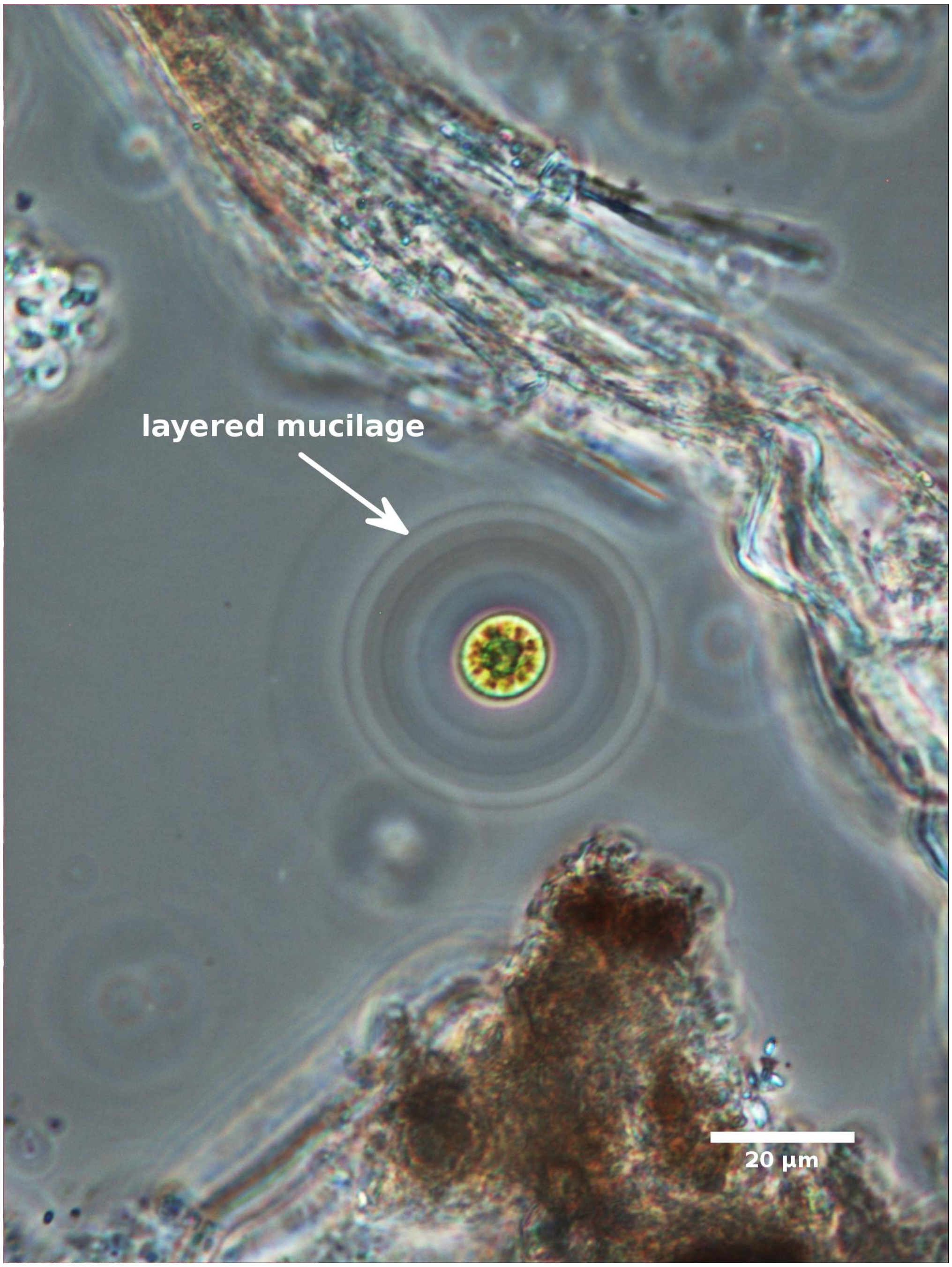

Figure 3.66: *Asterococcus superbus*? (400x phase contrast), Deer Lake, IWS water quality sampling site, Island County, July 19, 2011.

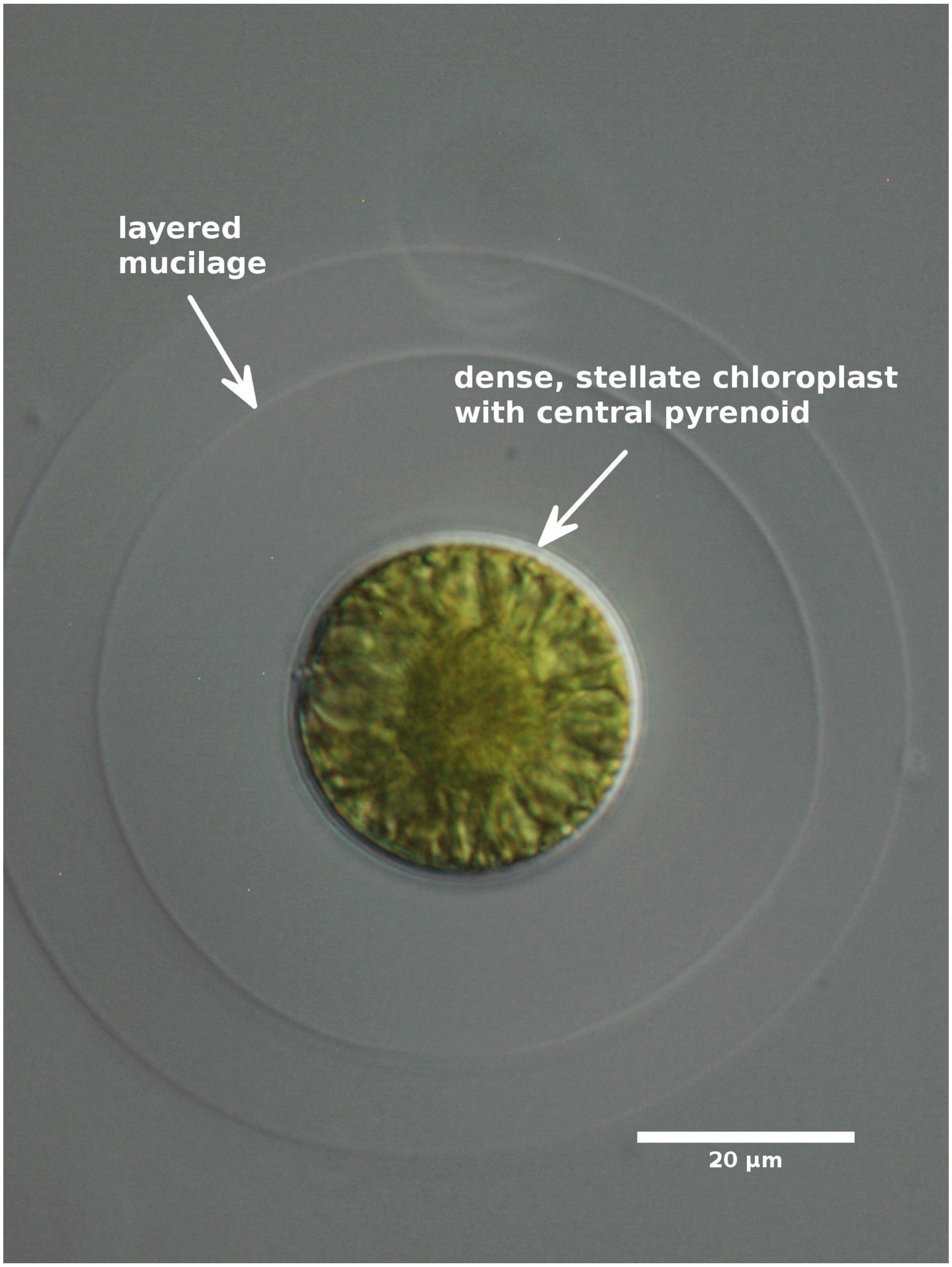

Figure 3.67: *Asterococcus superbus*? (600x DIC), small pond near Lake Anderson, North Cascades along Hwy 20, August 23, 2013.

Figure 3.68: *Asterococcus superbus*? (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, September 5, 2013.

Figure 3.69: *Asterococcus superbus*? (600x DIC), Clear Lake, IWS water quality sampling site, Skagit County, July 28, 2011.

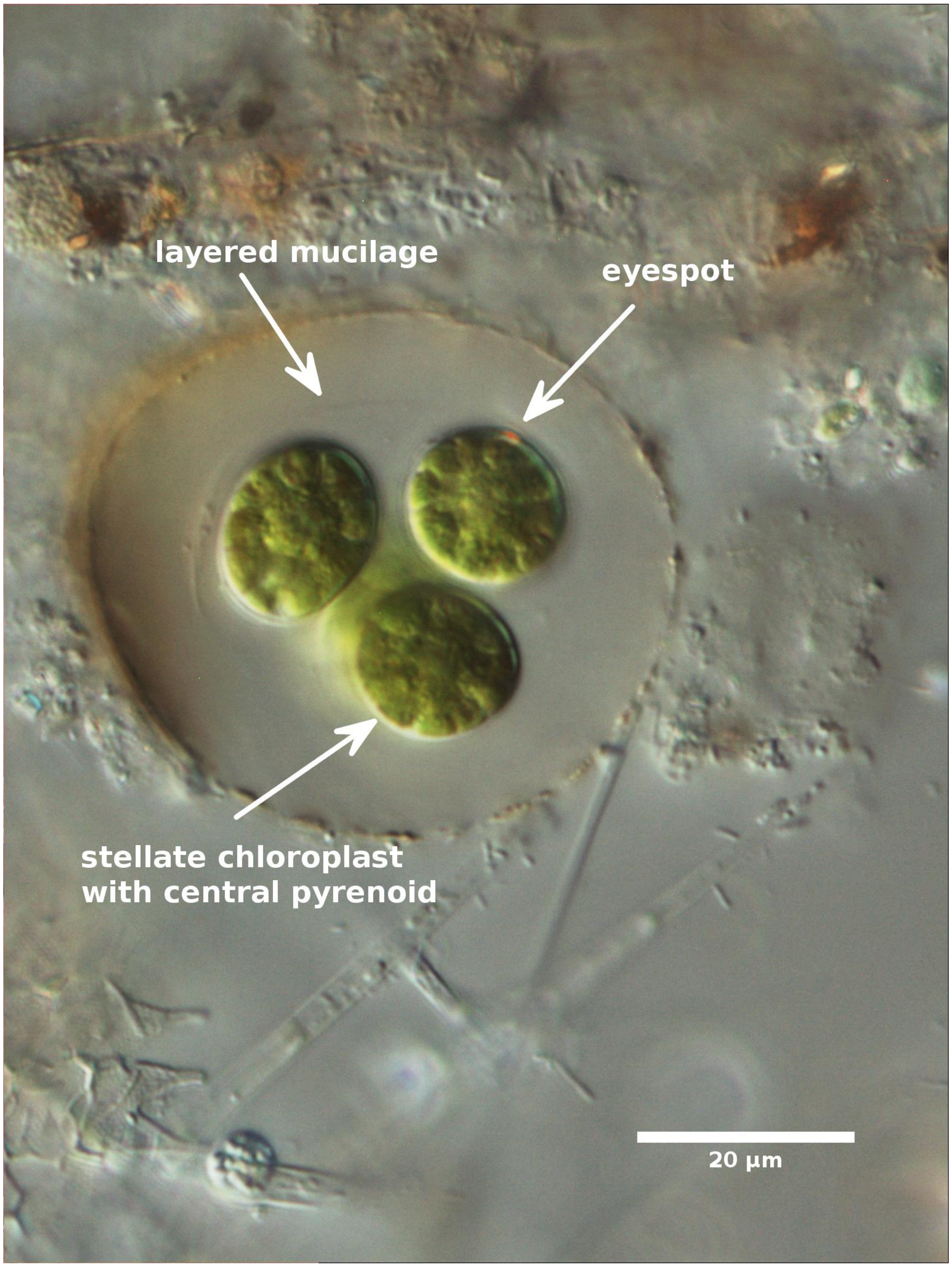

Figure 3.70: *Asterococcus superbus*? (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, March 30, 2012.

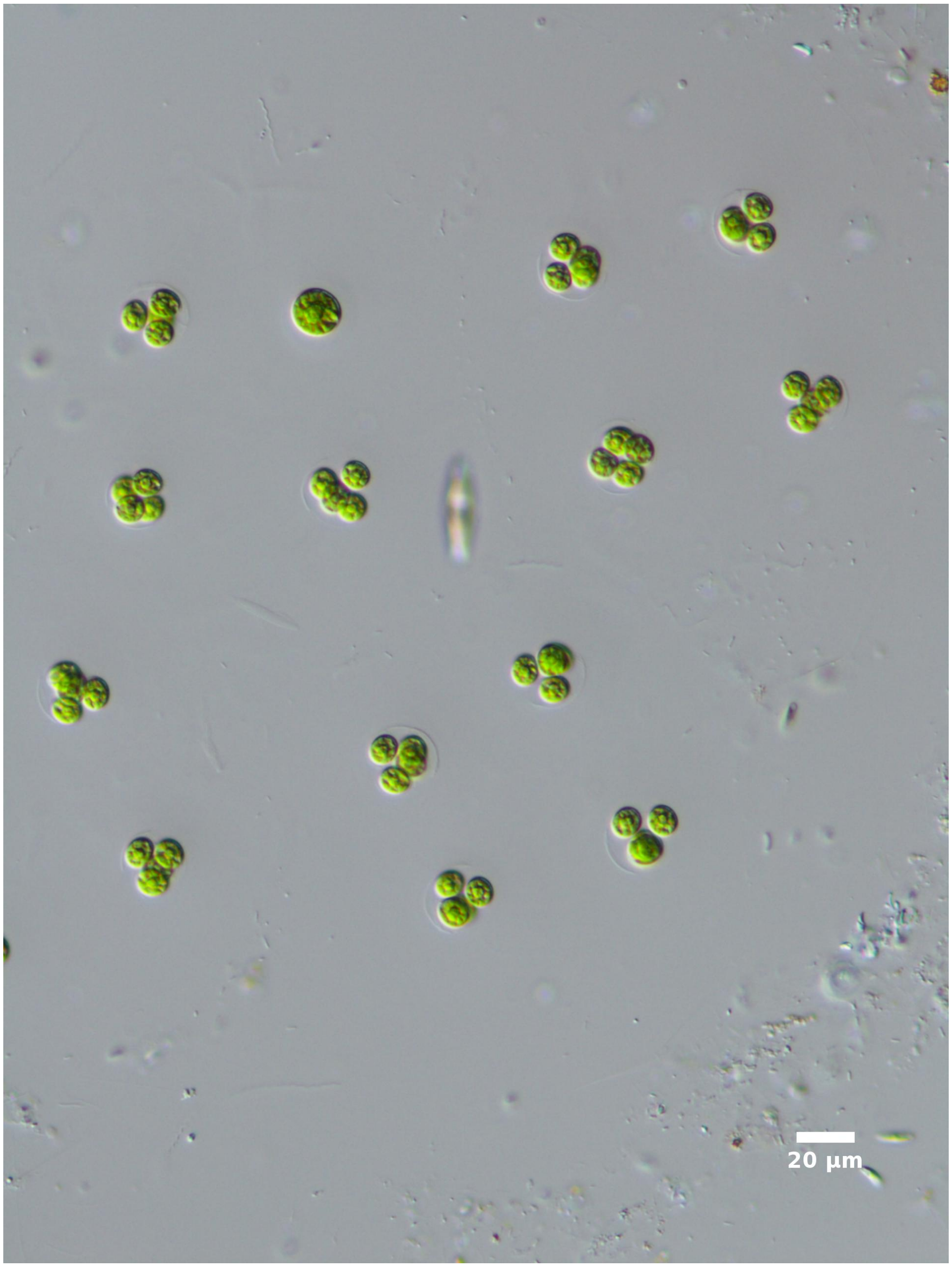

Figure 3.71: *Asterococcus superbus*? bloom (200x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, July 9, 2015.

3.7 *Botryococcus* Kützing and *Botryosphaerella* P. C. Silva

Local taxa

Botryococcus braunii Kützing;
Botryococcus protuberans West & G. S. West;
Botryococcus sp.1;
Botryosphaerella sudetica (Lemmermann) P. C. Silva
(=*Botryococcus sudeticus* Lemmermann);
Botryosphaerella sp.

Abundance

Moderately common; may form dense blooms.

Local measurements		Width	Length	Biovolume†
Botryococcus braunii	not measured; individual cells not visible			
Botryococcus protuberans	min	4.8 μm	8.2 μm	105 μm^3
cells (spheroid)	med	9.6 μm	15.2 μm	753 μm^3
	max	11.7 μm	16.3 μm	1,100 μm^3
Botryococcus sp.1	min	4.3 μm	7.2 μm	75.0 μm^3
cells (spheroid)	med	5.4 μm	8.9 μm	140 μm^3
	max	7.5 μm	12.8 μm	377 μm^3
Botryosphaerella sudetica	min	8.3 μm	9.1 μm	352 μm^3
cells (spheroid)	med	8.8 μm	10.1 μm	398 μm^3
	max	10.8 μm	11.8 μm	721 μm^3
Botryosphaerella sp.1	min	5.3 μm	7.2 μm	113 μm^3
cells (spheroid)	med	6.1 μm	8.0 μm	156 μm^3
	max	7.7 μm	9.1 μm	276 μm^3

†Calculated using original measurements, not summary values.

Botryococcus and *Botryosphaerella* colonies contain dense masses of small spherical, oval, or broadly elliptical cells (Figures 3.72–3.88). The individual cells are usually embedded in a dark colonial mucilage, forming clumps that are joined by clear strands of mucilage to form large orange or green colonies. The cells contain starch and oil droplets that are visible in compressed cells.

Botryococcus braunii cells are completely embedded in a very dense, dark colonial mucilage (Figures 3.72–3.74). The small oval cells are rarely visible, even in compressed colonies. This species is described as common and widely distributed (John, et al., 2011), but seems to be less common than *Botryococcus protuberans* in local lakes.

Botryococcus protuberans is characterized by dark green, brown, or orange colonies containing many oval cells (Figures 3.75–3.79). The cells are only partially embedded in the colonial mucilage, leaving the outer cell margin clearly visible. The cells are grouped in clumps interconnected by stringy mucilage to form macroscopic colonies.

Botryococcus sp.1 fits the general descriptions for *Botryococcus protuberans* var. *minor* G. M. Smith. This variety has slightly smaller cells compared to *B. protuberans*, and forms smaller, more delicate colonies (Figures 3.80–3.83). The individual cells are only partially embedded in the colonial mucilage.

Botryosphaerella closely resembles *Botryococcus*, and the species are often included under the genus *Botryococcus* in taxonomic keys. *Botryosphaerella* cells are clearly visible, forming grape-like clusters connected by clear strands of mucilage (Figures 3.84–3.88). The individual spherical or oval cells are slightly embedded along their posterior margin in clear mucilage, but the degree of embeddedness is much less that *Botryococcus protuberans*. *Botryosphaerella* cells contain starch and oil, which may cause the colony to float.

Botryosphaerella sudetica is common in sphagnum bogs or lakes with sphagnum forming part of the lake shore vegetation (John, et al., 2011), and all of the local samples were collected from lakes that fit this description. The specimens in Figures 3.84–3.86 resemble online images of *Botryosphaerella sudetica* (protist.i.hosei.ac.jp) and fit the taxonomic descriptions by John, et al. (2011) and Dillard (1989a). *Botryosphaerella sudetica* resembles *Westella botryoiodes* (Section 3.39, page 524), which forms small colonies ($\leq$16 cells), with the cells arranged in groups of 4, joined by old cell wall fragments.

The specimens in Figures 3.87–3.88 also fit descriptions for *Botryosphaerella sudetica*, but do not look like the specimens in Figures 3.84–3.86. The cells in Figures 3.84–3.86 are nearly spherical and are attached to adjacent cells by no more than 25% of the cell wall. The cells in Figures 3.87–3.88 are oval and attach to adjacent cells along 50–75% of the cell wall. This amount of morphological variation suggests there may be varieties, subspecies, or undescribed species in northwest Washington lakes.

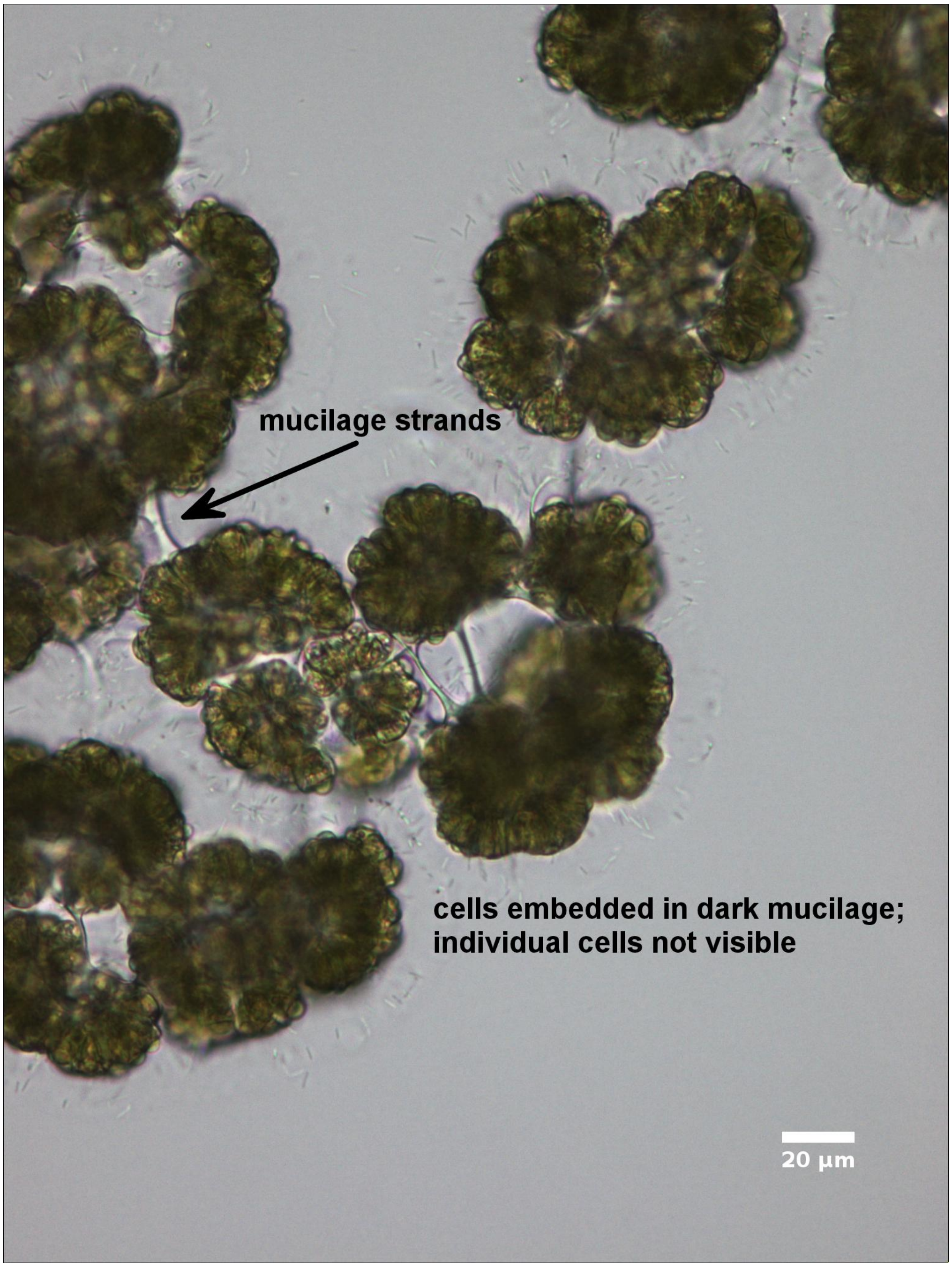

Figure 3.72: *Botryococcus braunii* (200x DIC), Crescent Lake, Olympic National Park, November 29, 2007.

Figure 3.73: *Botryococcus braunii* (400x DIC), Big Lake, IWS water quality sampling site, Skagit County, July 21, 2015.

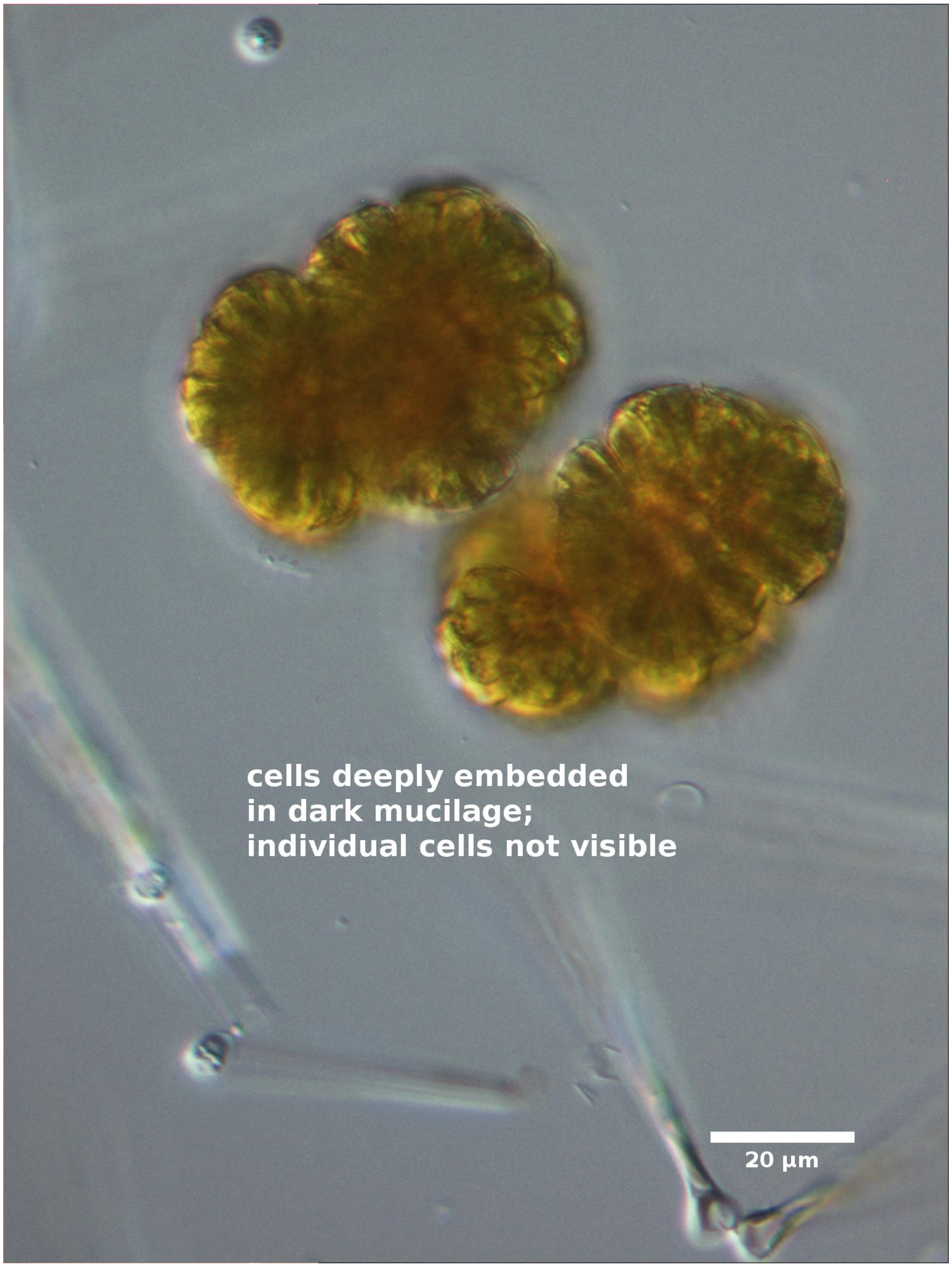

Figure 3.74: *Botryococcus braunii* (400x DIC), Sunset Pond, IWS water quality sampling site, Whatcom County, March 30, 2012.

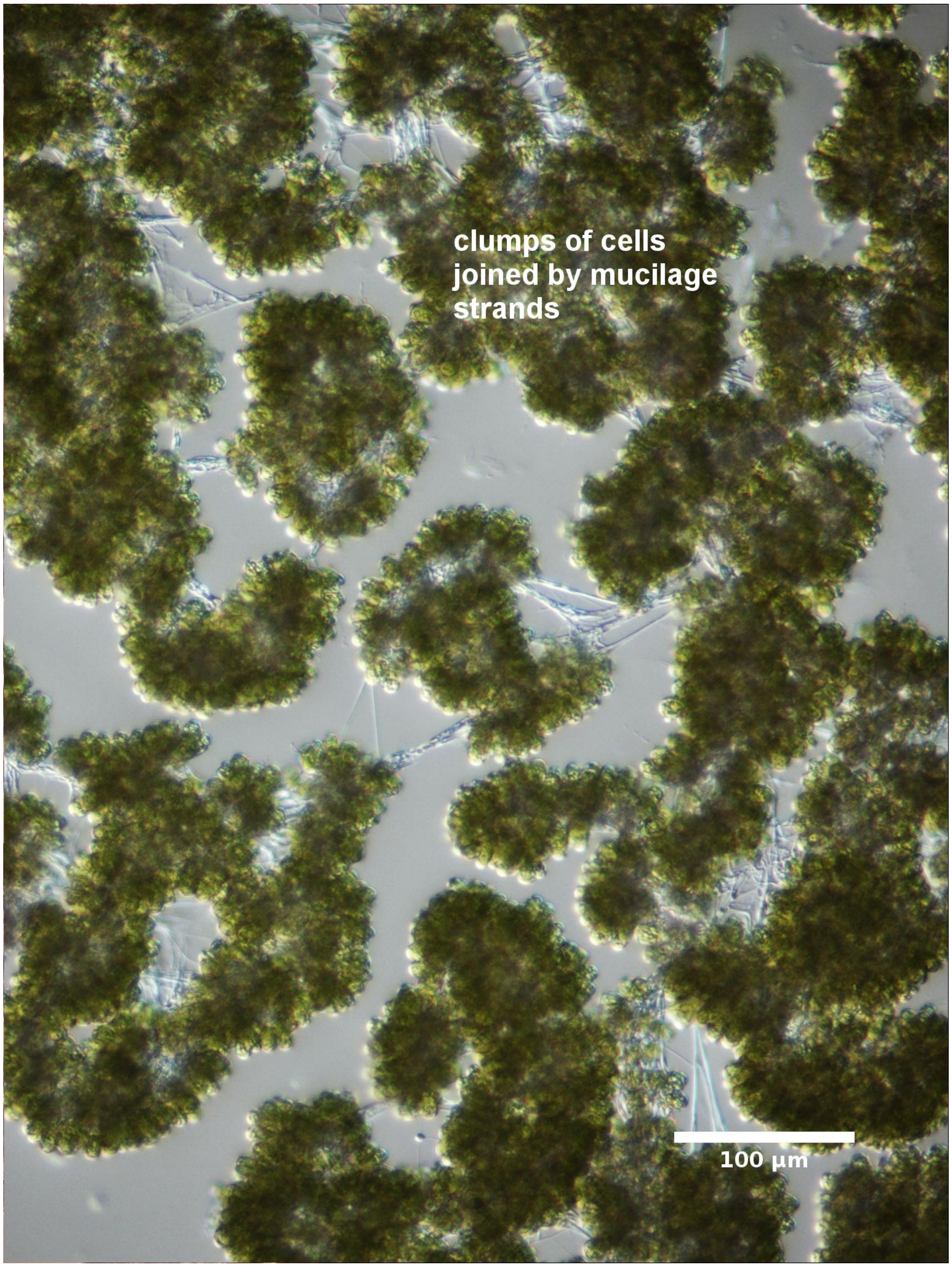

Figure 3.75: *Botryococcus protuberans* (100x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, February 10, 2010.

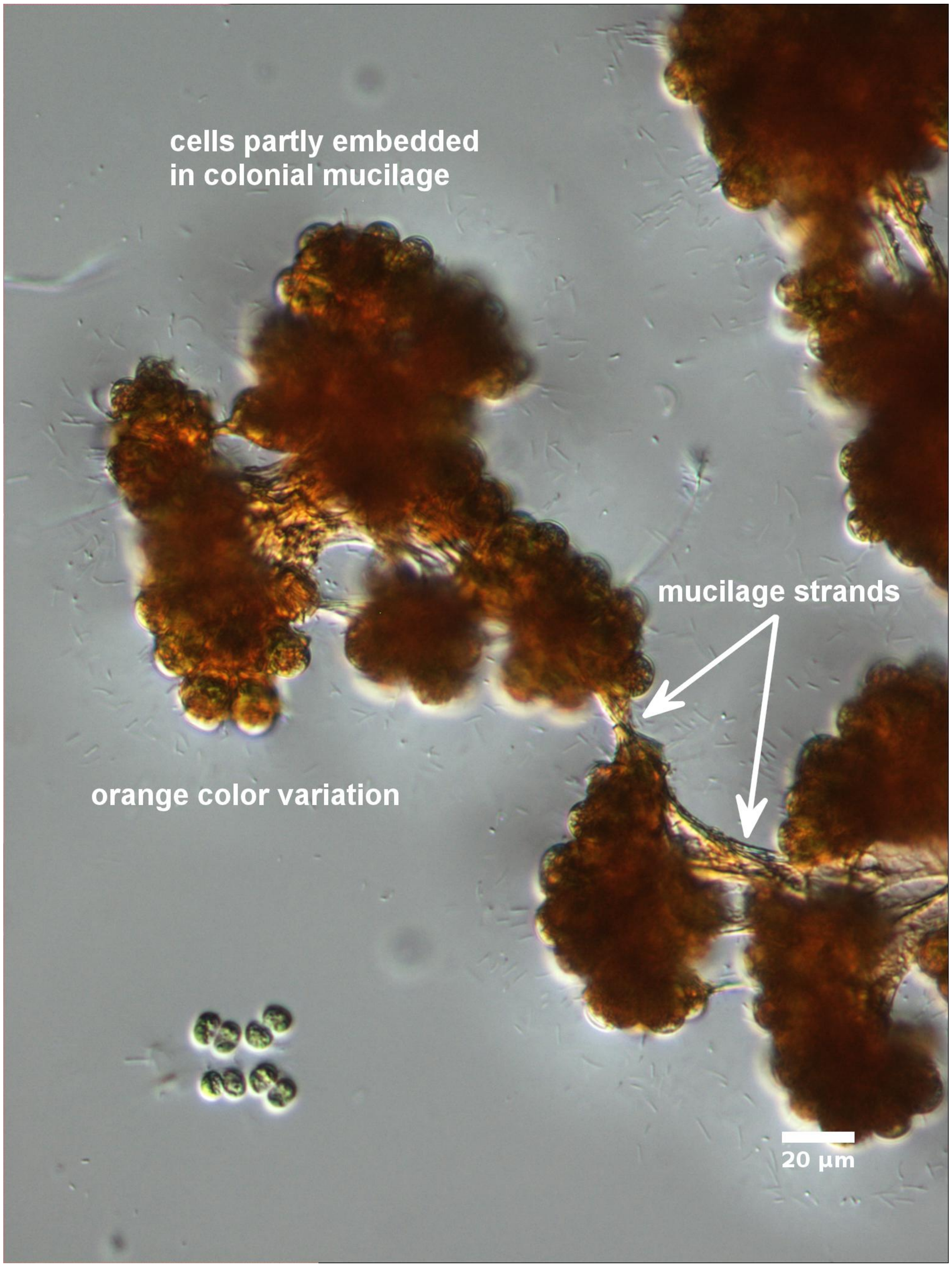

Figure 3.76: *Botryococcus protuberans* (200x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, September 17, 2009.

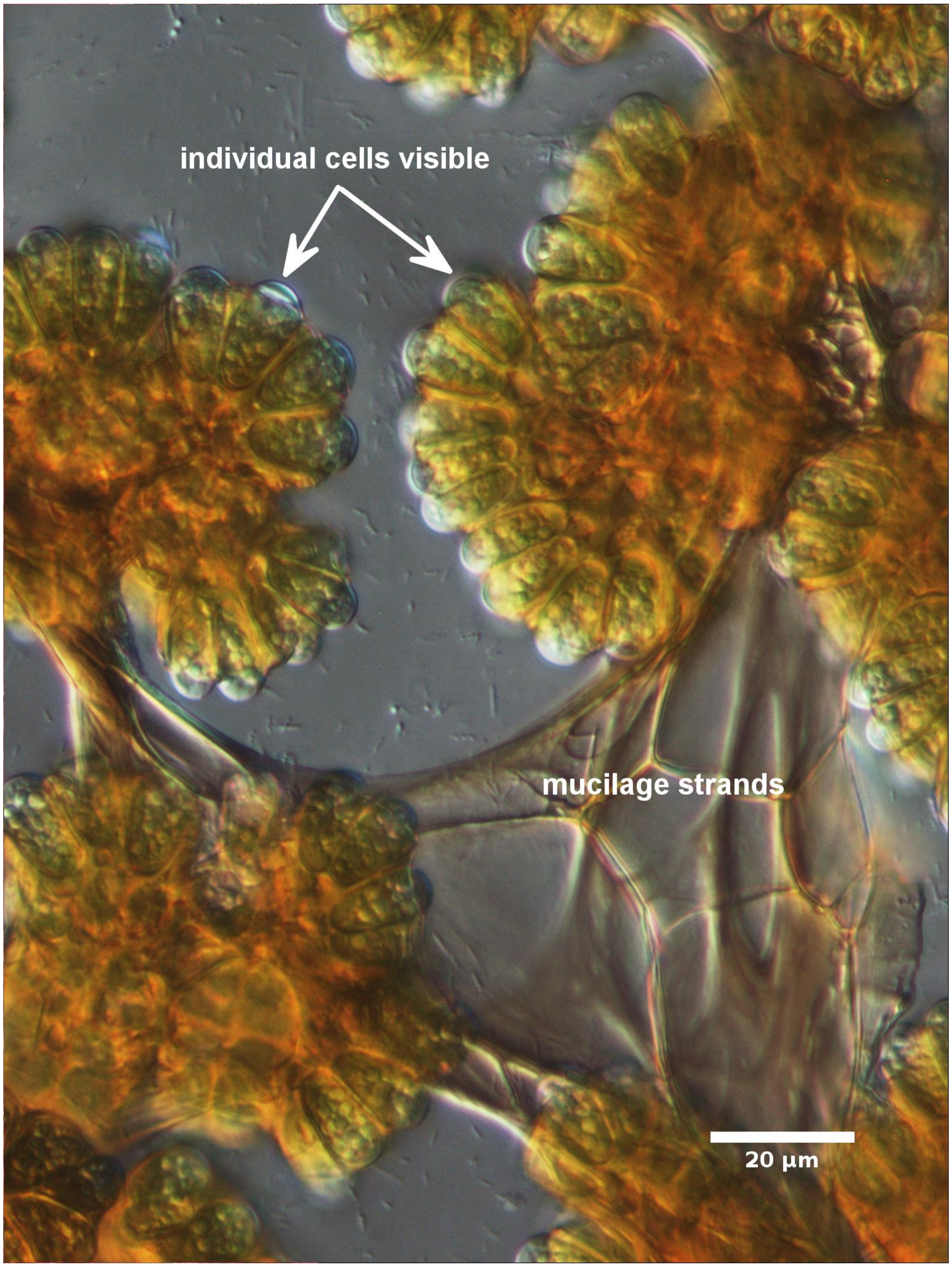

Figure 3.77: *Botryococcus protuberans* (400x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, July 8, 2011.

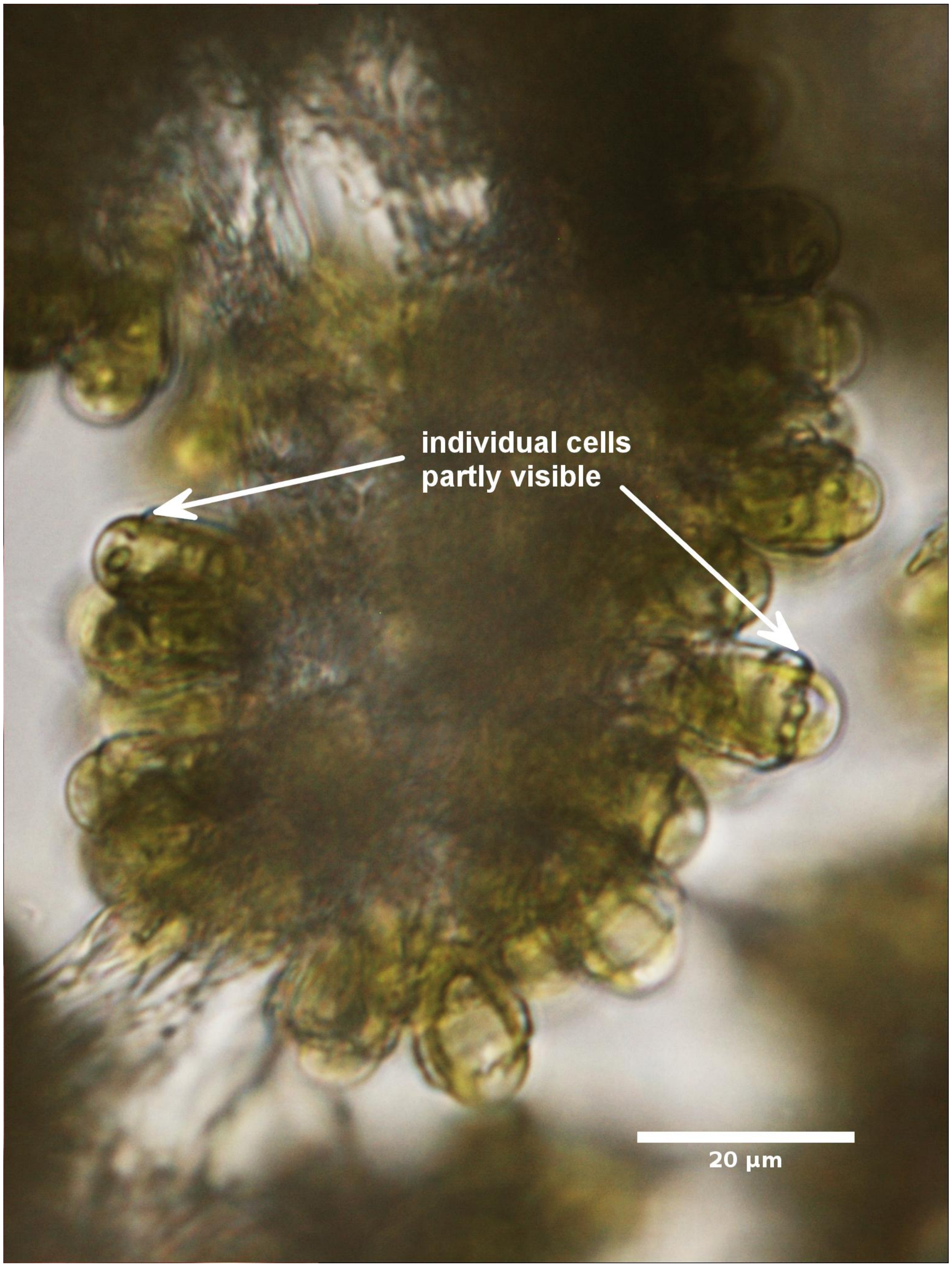

Figure 3.78: *Botryococcus protuberans* (600x brightfield), Lake Whatcom, IWS water quality sampling site, Whatcom County, December 3, 2009.

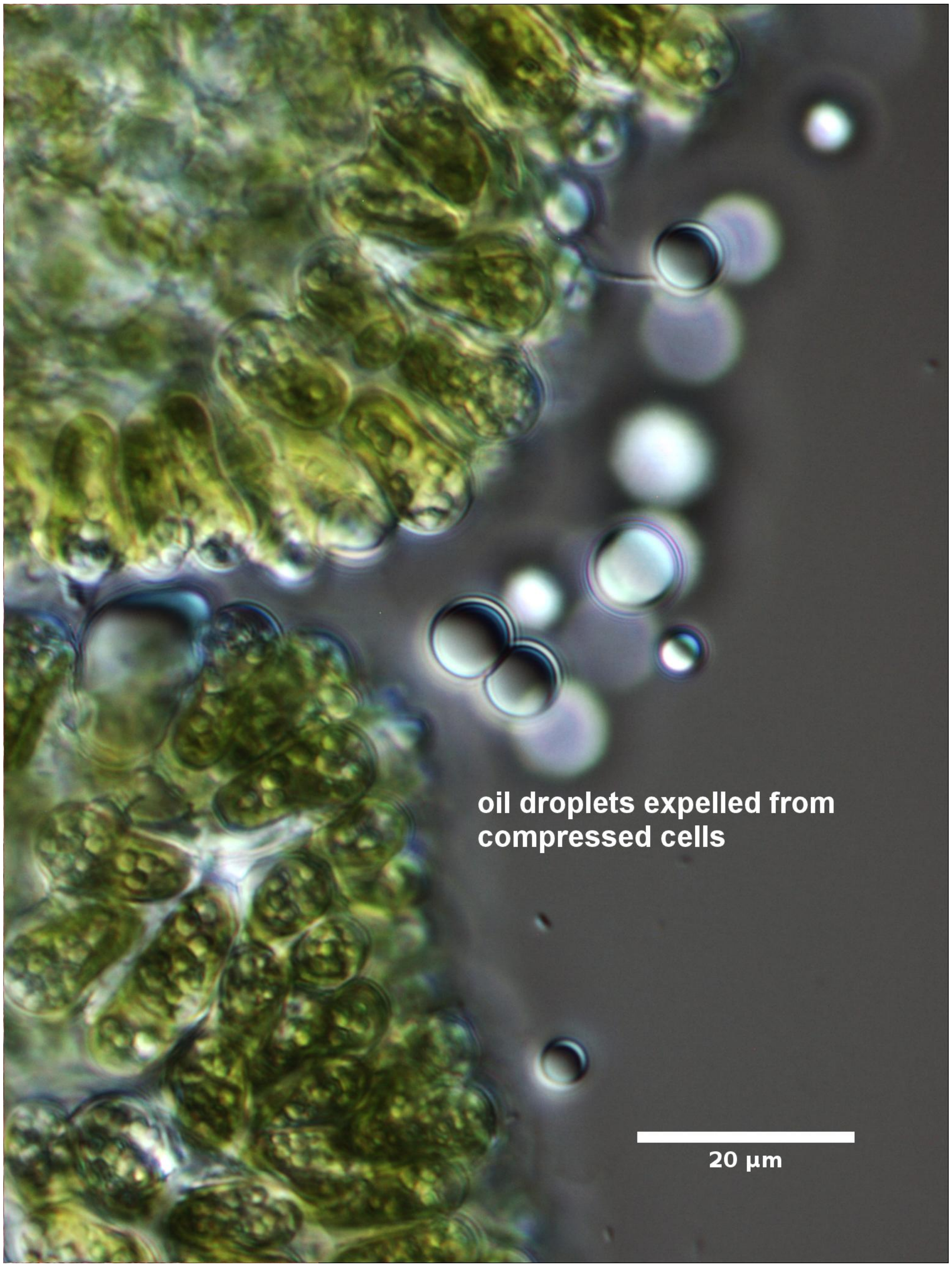

Figure 3.79: *Botryococcus protuberans* oil droplets (400x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, February 10, 2010.

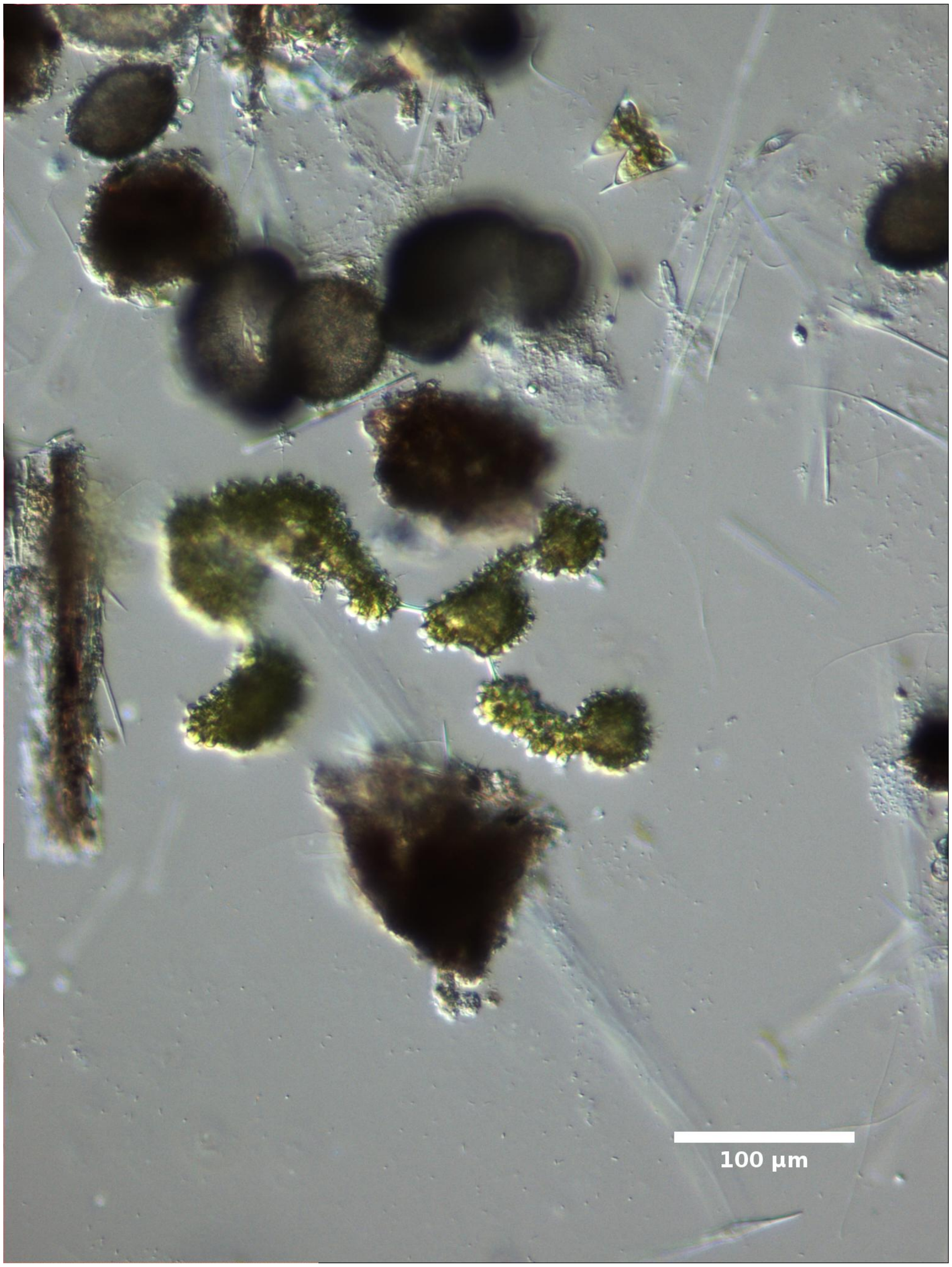

Figure 3.80: *Botryococcus* sp.1 (100x DIC), Lake Cavanaugh, IWS water quality sampling site, Skagit County, May 22, 2009.

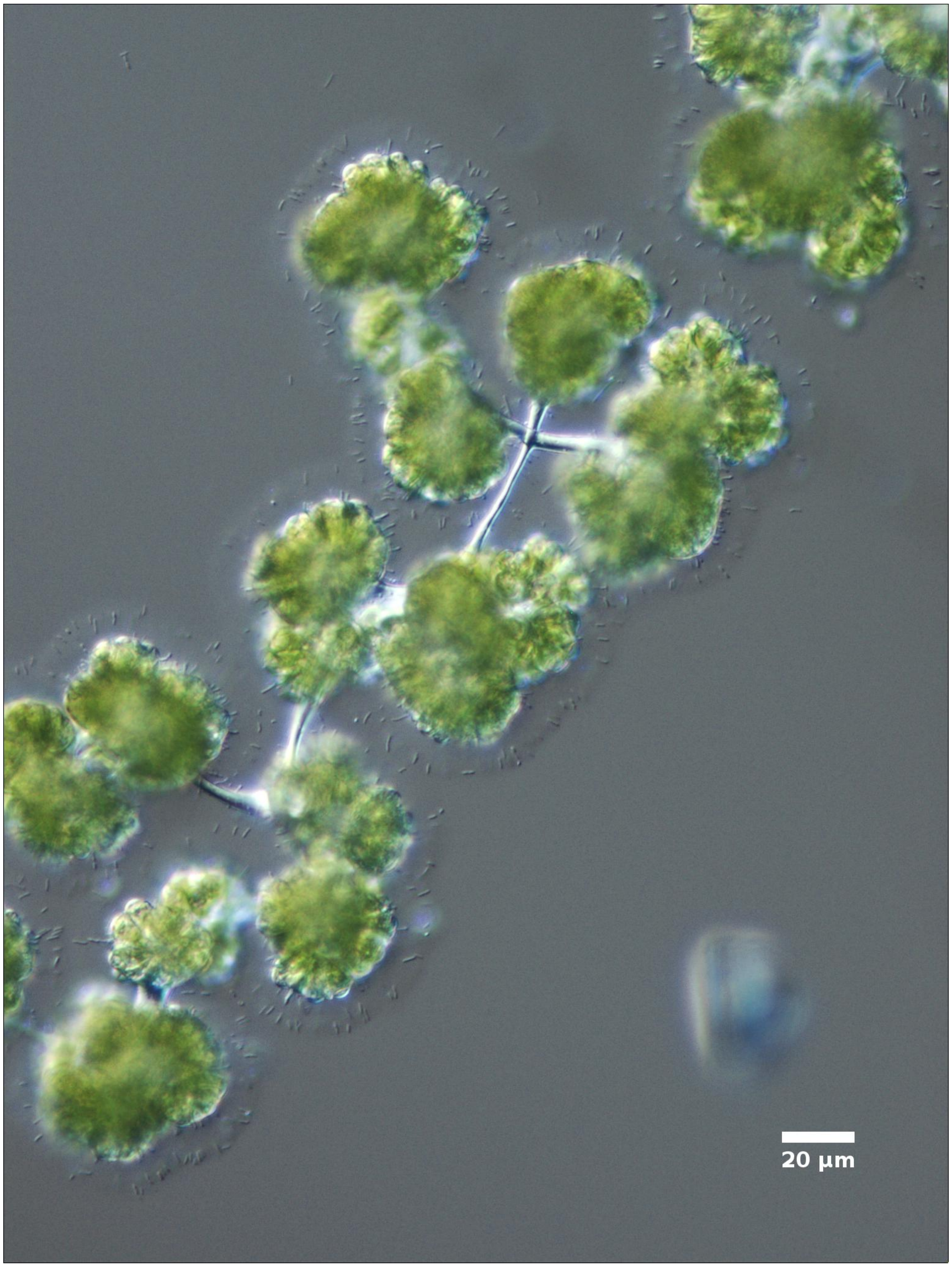

Figure 3.81: *Botryococcus* sp.1 (200x DIC), Crescent Lake, Olympic National Park, November 29, 2007.

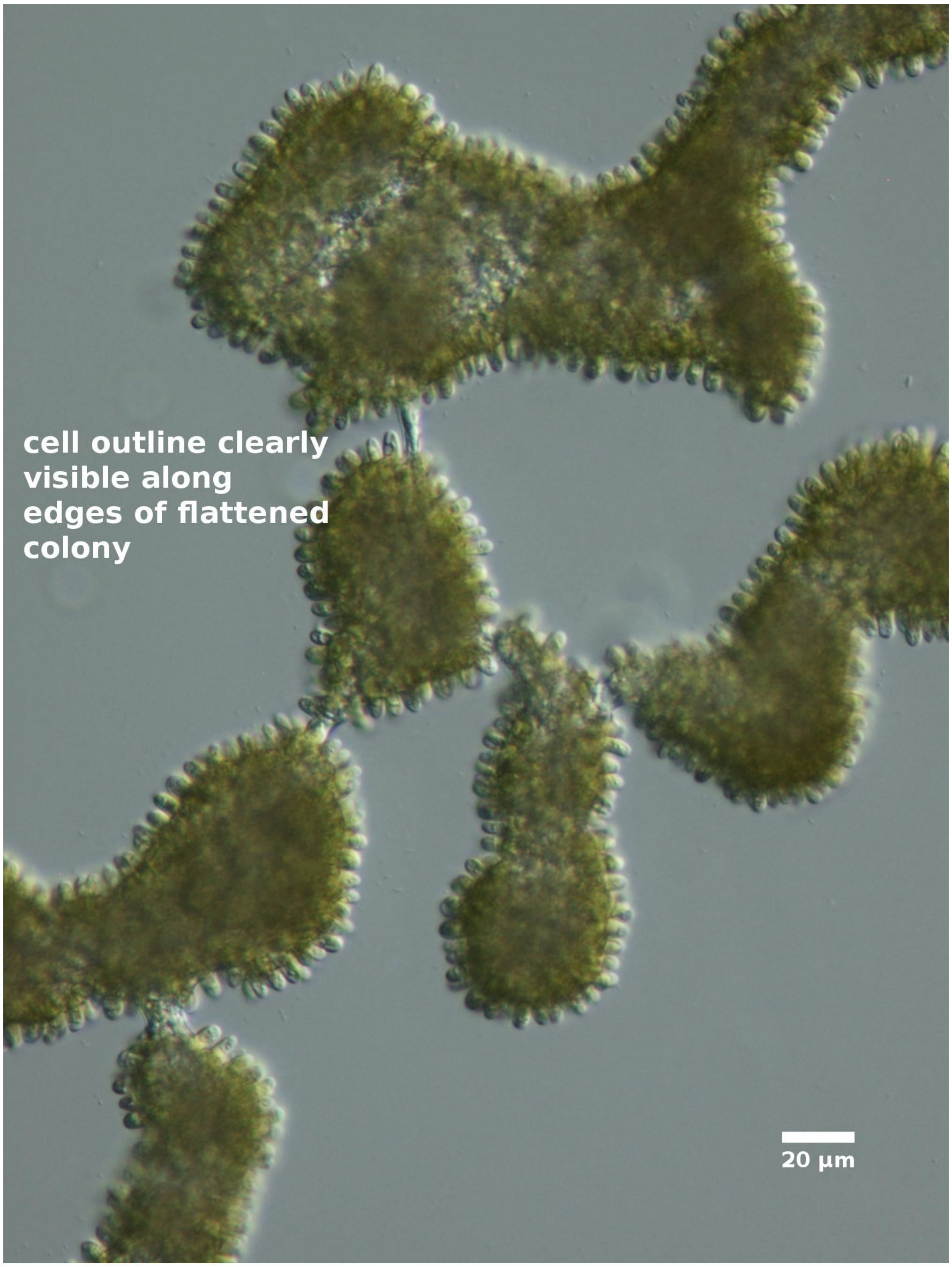

Figure 3.82: *Botryococcus* sp.1 (200x DIC), Grandy Lake, IWS water quality sampling site, Skagit County, August 6, 2013.

Figure 3.83: *Botryococcus* sp.1 (600x DIC), Bear Lake, IWS water quality sampling site, Snohomish County, August 16, 2013.

Figure 3.84: *Botryosphaerella sudetica* (200x DIC), small pond near Lake Anderson, North Cascades along Hwy 20, September 3, 2012.

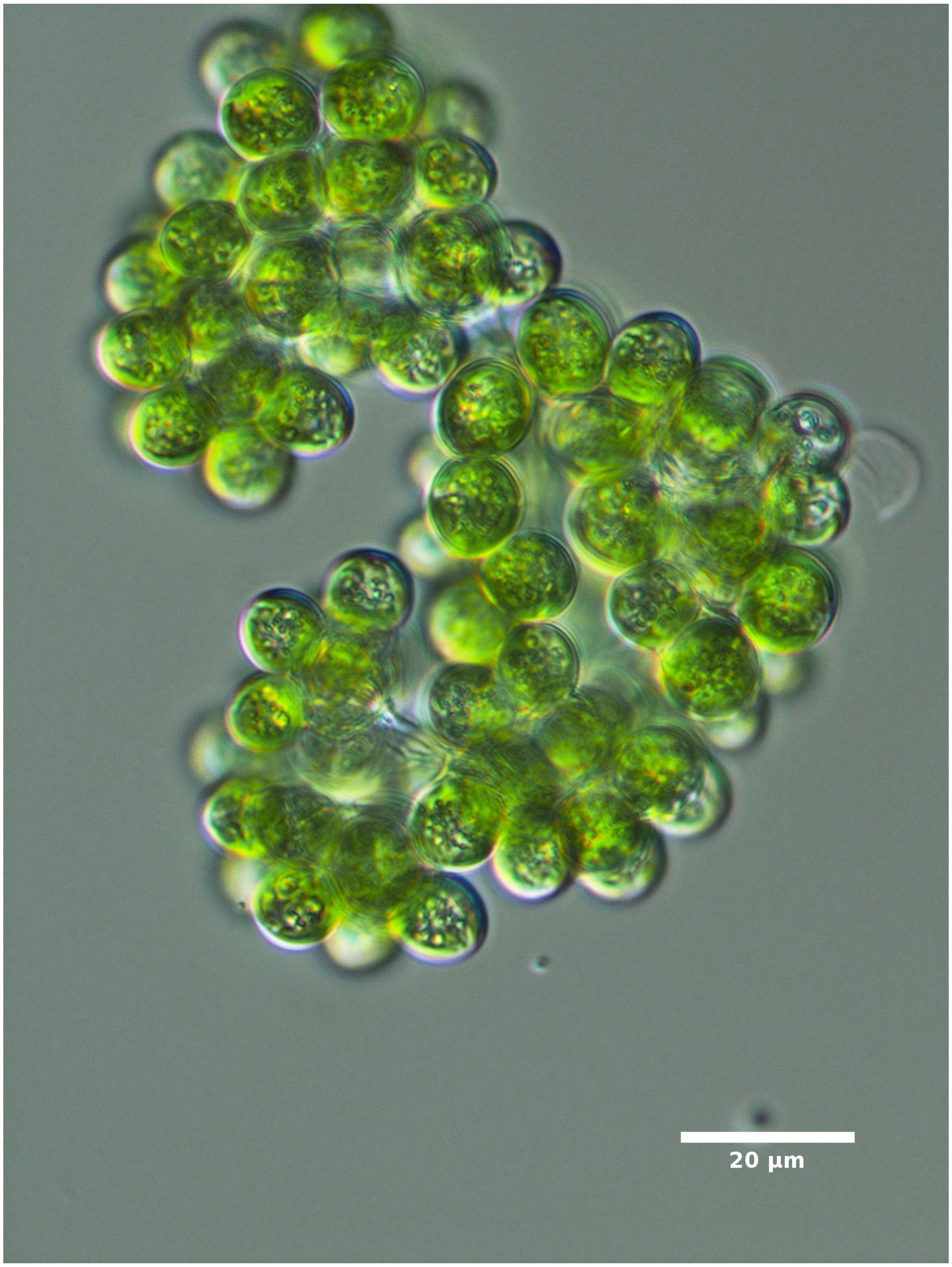

Figure 3.85: *Botryosphaerella sudetica* (600x DIC), Lake Twenty-two, Mt. Loop Hwy, July 25, 2014.

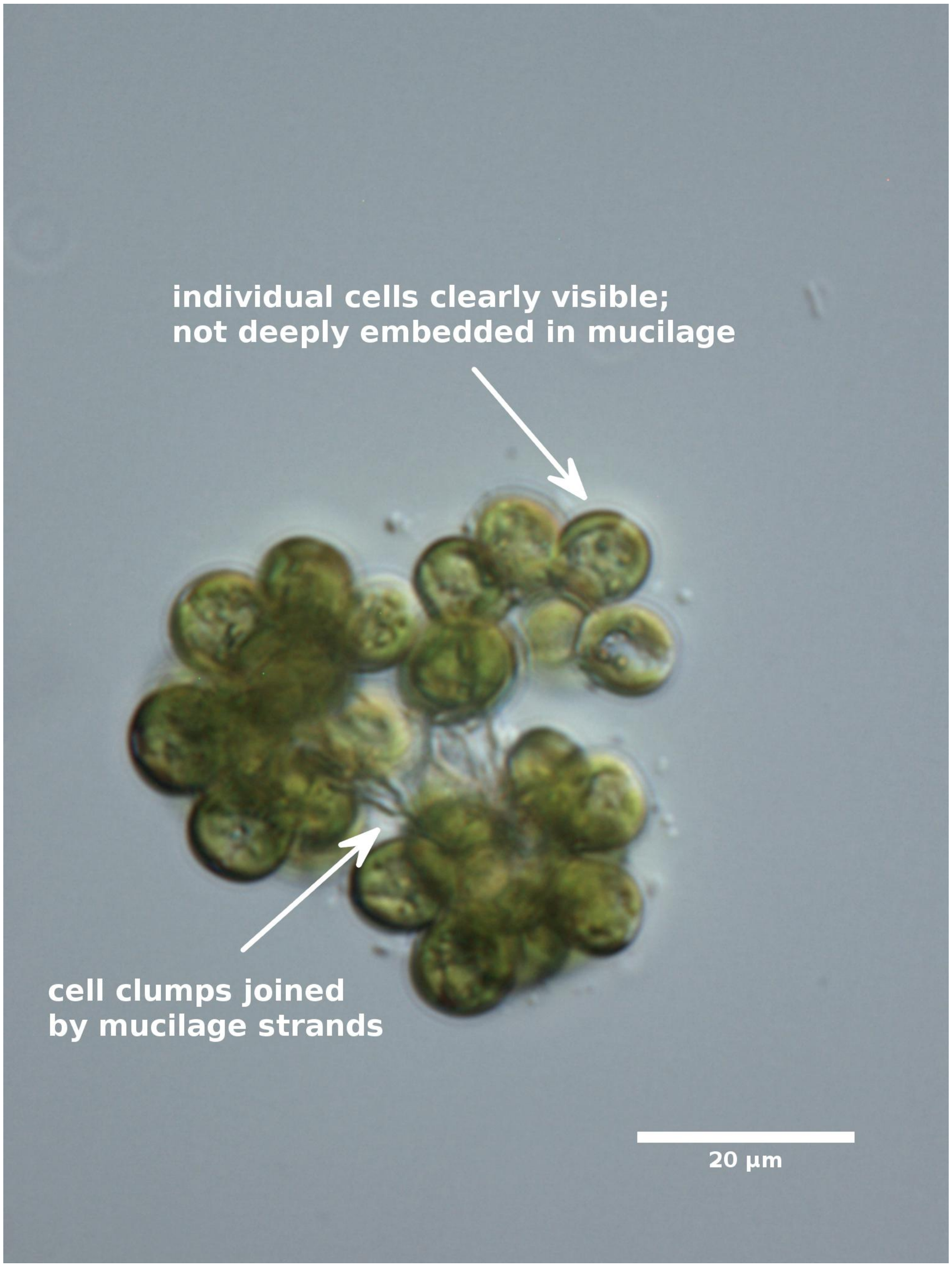

Figure 3.86: *Botryosphaerella sudetica* (600x DIC), small pond near Lake Anderson, North Cascades along Hwy 20, September 7, 2012.

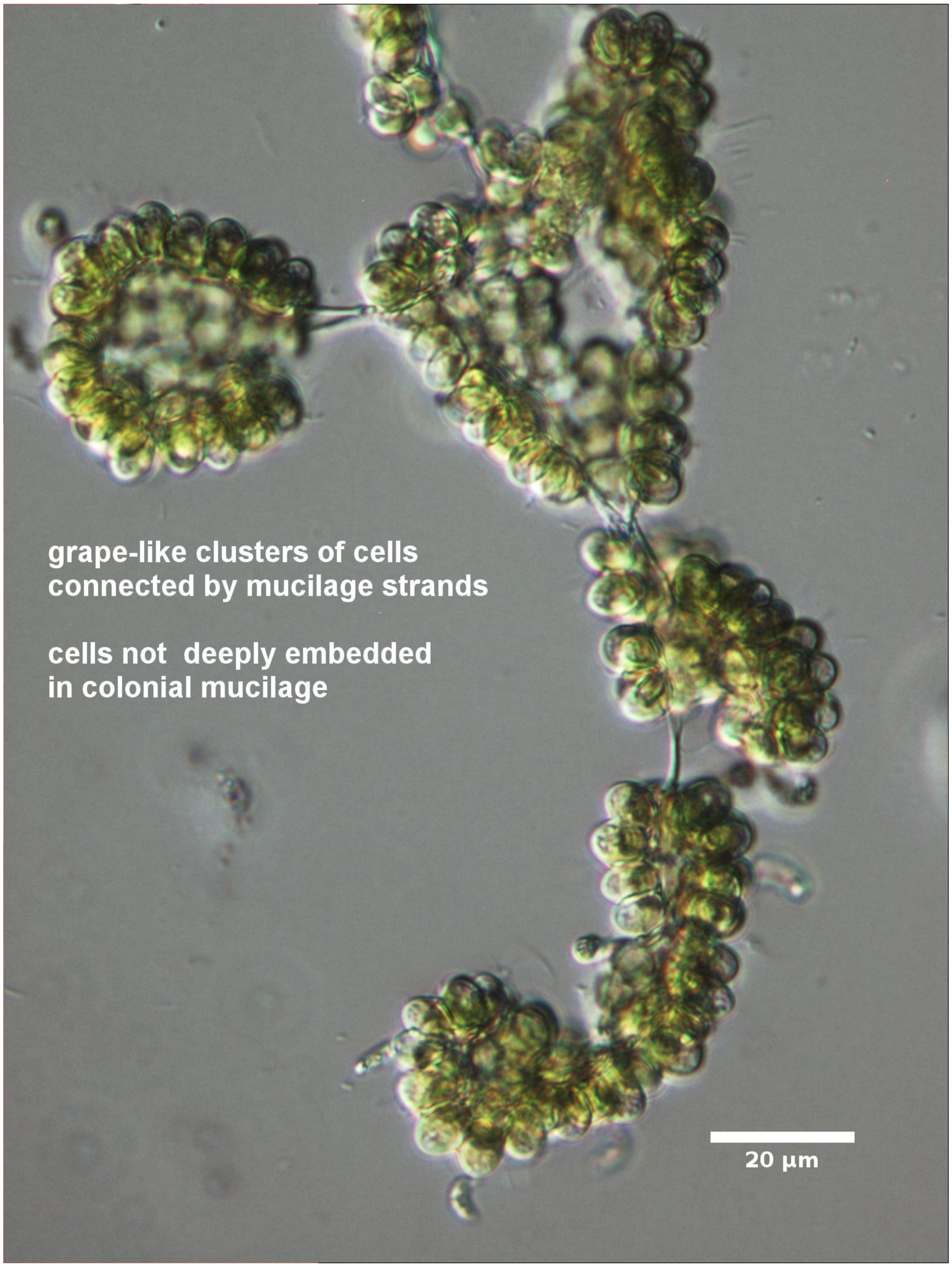

Figure 3.87: *Botryosphaerella* sp.1 (400x DIC), Picture Lake, IWS water quality sampling site, Whatcom County, September 30, 2011.

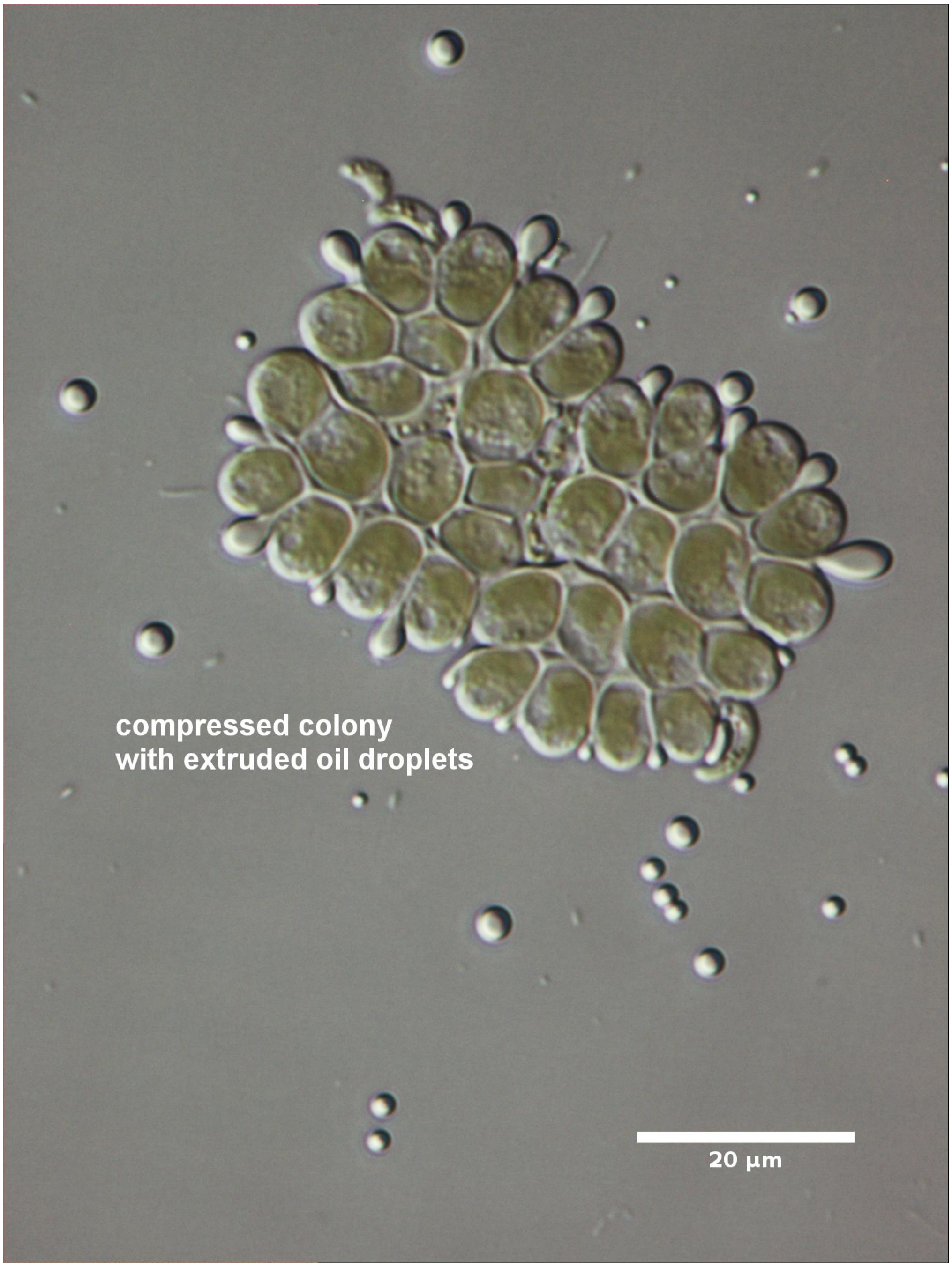

Figure 3.88: *Botryosphaerella* sp.1 oil droplets (600x DIC), Picture Lake, IWS water quality sampling site, Whatcom County, September 30, 2011.

3.8 *Characium* A. Braun and *Stylosphaeridium* Geitler & Gimesi

Local taxa

Characium ornithocephalum A. Braun;
Stylosphaeridium stipatum (Bachmann) Geitler & Gimesi
(=*Characium stipatum* [Bachmann] Wille)

Abundance

Infrequently collected in plankton samples; moderately common epiphyte; may be dense when present.

Local measurements		Width	Length	Biovolume†
Characium	min	3.4 μm	7.2 μm	24.8 μm^3
ornithocephalum	med	4.2 μm	9.4 μm	45.1 μm^3
cells (fusiform)	max	5.6 μm	11.9 μm	97.7 μm^3
Stylosphaeridium stipatum	min	4.3 μm	5.8 μm	58.1 μm^3
cells (spheroid)	med	5.3 μm	7.3 μm	115 μm^3
	max	6.7 μm	9.1 μm	189 μm^3

†Calculated using original measurements, not summary values.

Description

Most species of *Characium* and *Stylosphaeridium* are single-celled epiphytes attached to filamentous or colonial algae, macrophytes, or other solid surfaces (Figures 3.89–3.94). Both genera are included in this section because of their morphological similarity. The cells are oval, elliptical, or fusiform; curved or straight; blunt or sharply pointed; and are attached by a stipe or basal attachment disk. The chloroplast is band-shaped, parietal, and has one or more pyrenoids. *Characium* and *Stylosphaeridium* are difficult to distinguish from *Characiopsis* and *Pseudocharaciopsis*, which are yellow-green algae.[15] *Characiopsis* and *Pseudocharaciopsis* have disk-shaped yellow-green chloroplasts that lack starch and will not stain brown or purple in Lugol's iodine solution.

[15]See **Freshwater Algae in Northwest Washington, Volume IV. Chrysophyceae, Xanthophyceae, and Haptophyta**.

Characium ornithocephalum cells are strongly curved, asymmetric, and blunt or sharply pointed.. The cells are epiphytic, attached by a thick, irregular (wavy) stipe with a distinct attachment disc (Figures 3.89–3.90). This species is common on colonies of *Woronichinia*, a common type of colonial Cyanobacteria.[16]

Stylosphaeridium stipatum is a solitary epiphyte that is also common on *Woronichinia* colonies. The cells are spherical or oval, with a cup-shaped parietal chloroplast and single pyrenoid (Figures 3.91–3.94). The cells are attached to their plant host by a narrow stipe. Although some older keys may list *Stylosphaeridium stipatum* as *Characium stipatum*, *Stylosphaeridium* is more closely related to motile green algae like *Chlamydomonas*. Despite being an epiphyte, *Stylosphaeridium* cells may have an eyespot.

[16]See **Freshwater Algae in Northwest Washington, Volume I. Cyanobacteria**.

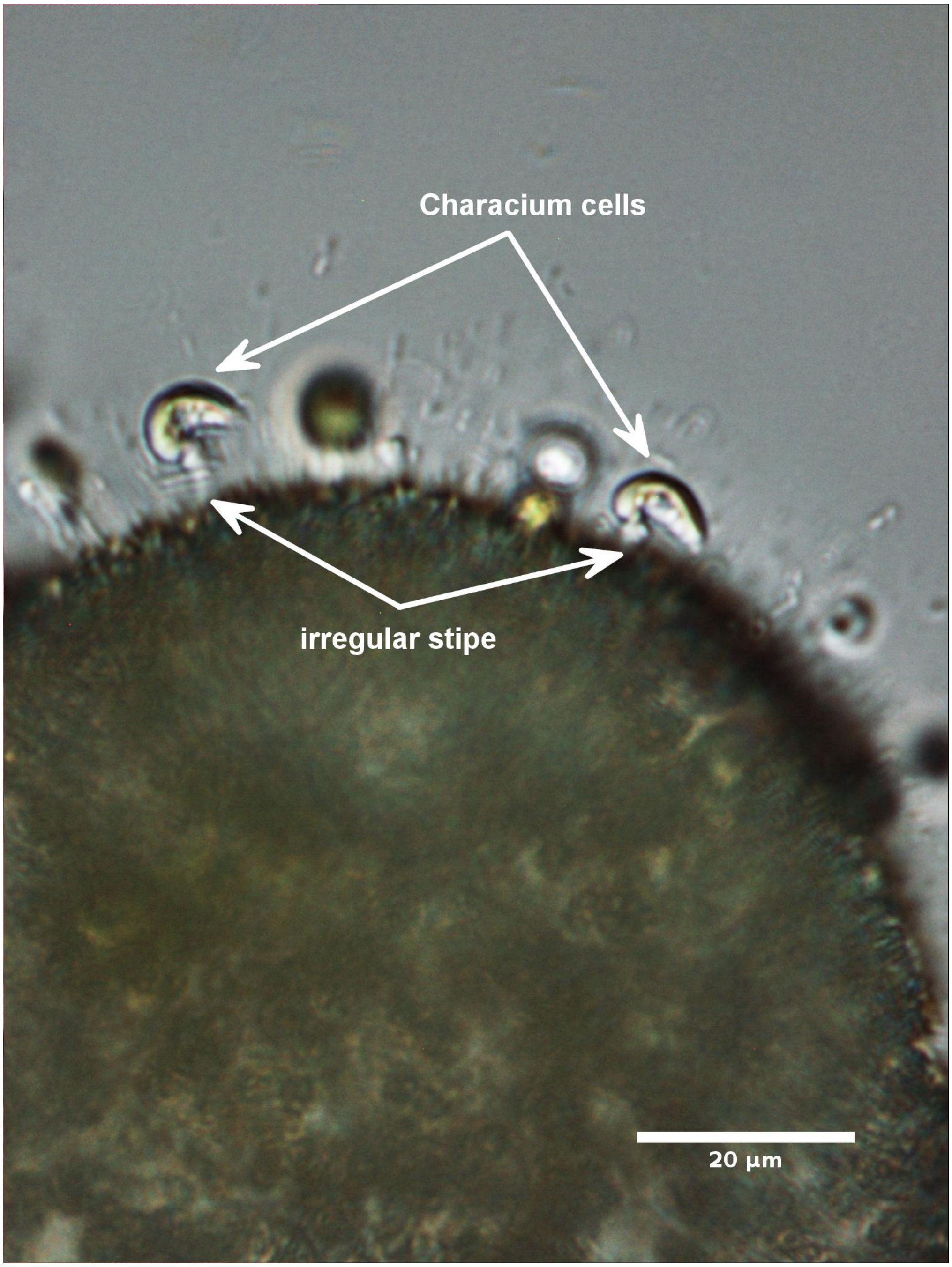

Figure 3.89: *Characium ornithocephalum* (600N), Lone Lake, IWS water quality sampling site, Island County, September 30, 2009.

Figure 3.90: *Characium ornithocephalum* (600N), Lone Lake, IWS water quality sampling site, Island County, September 30, 2009.

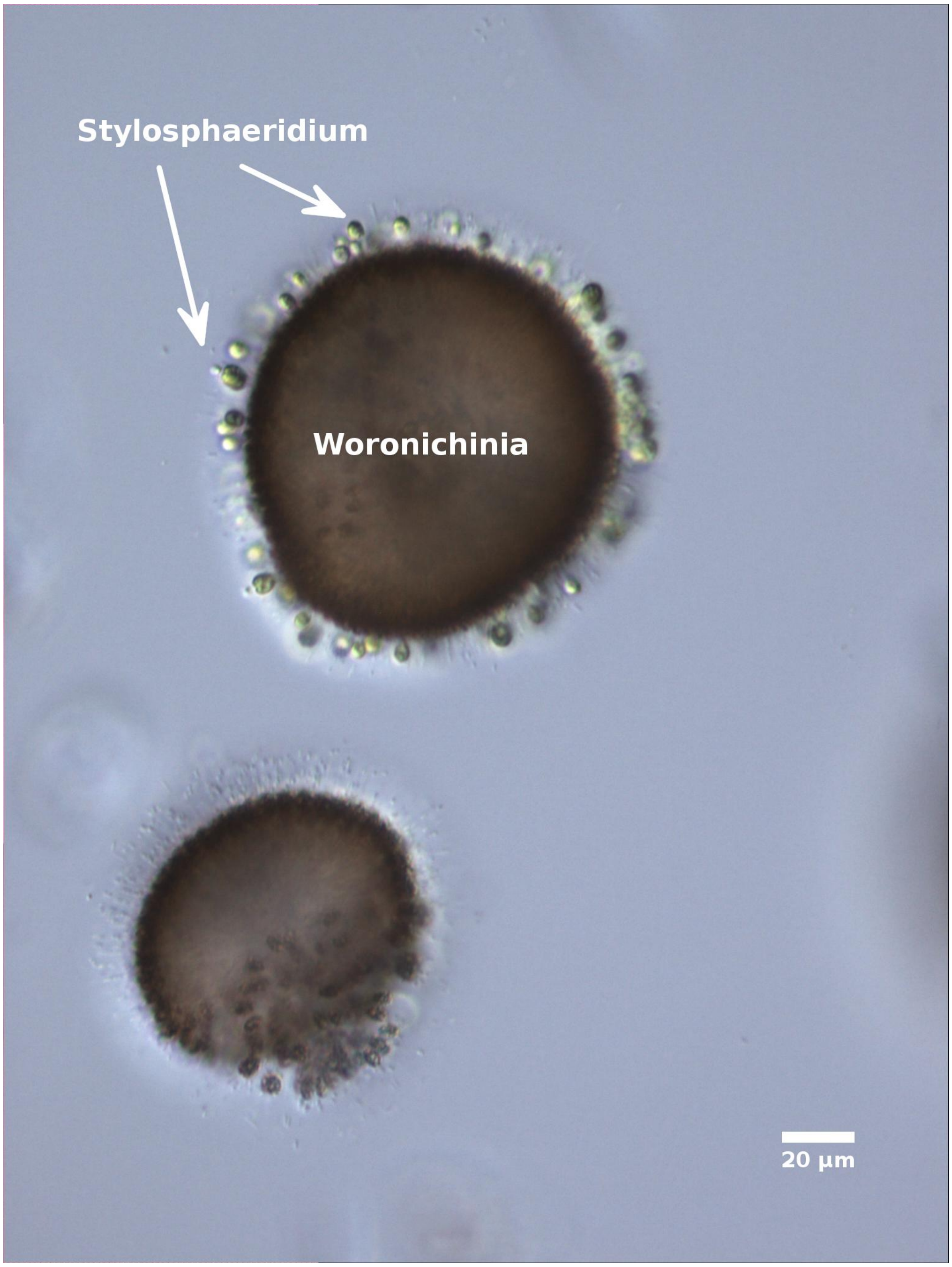

Figure 3.91: *Stylosphaeridium stipatum* (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, June 29, 2010.

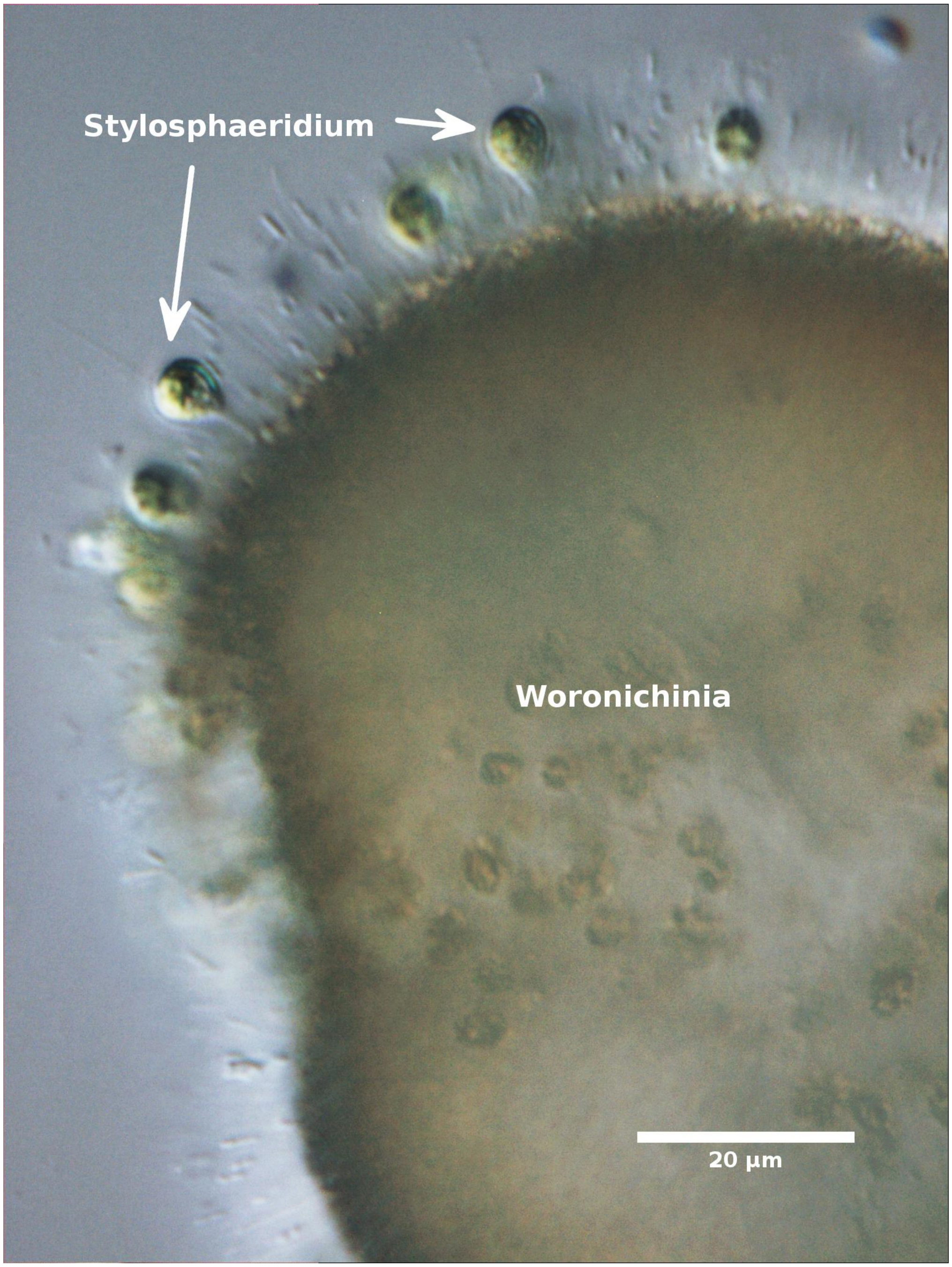

Figure 3.92: *Stylosphaeridium stipatum* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, June 29, 2010.

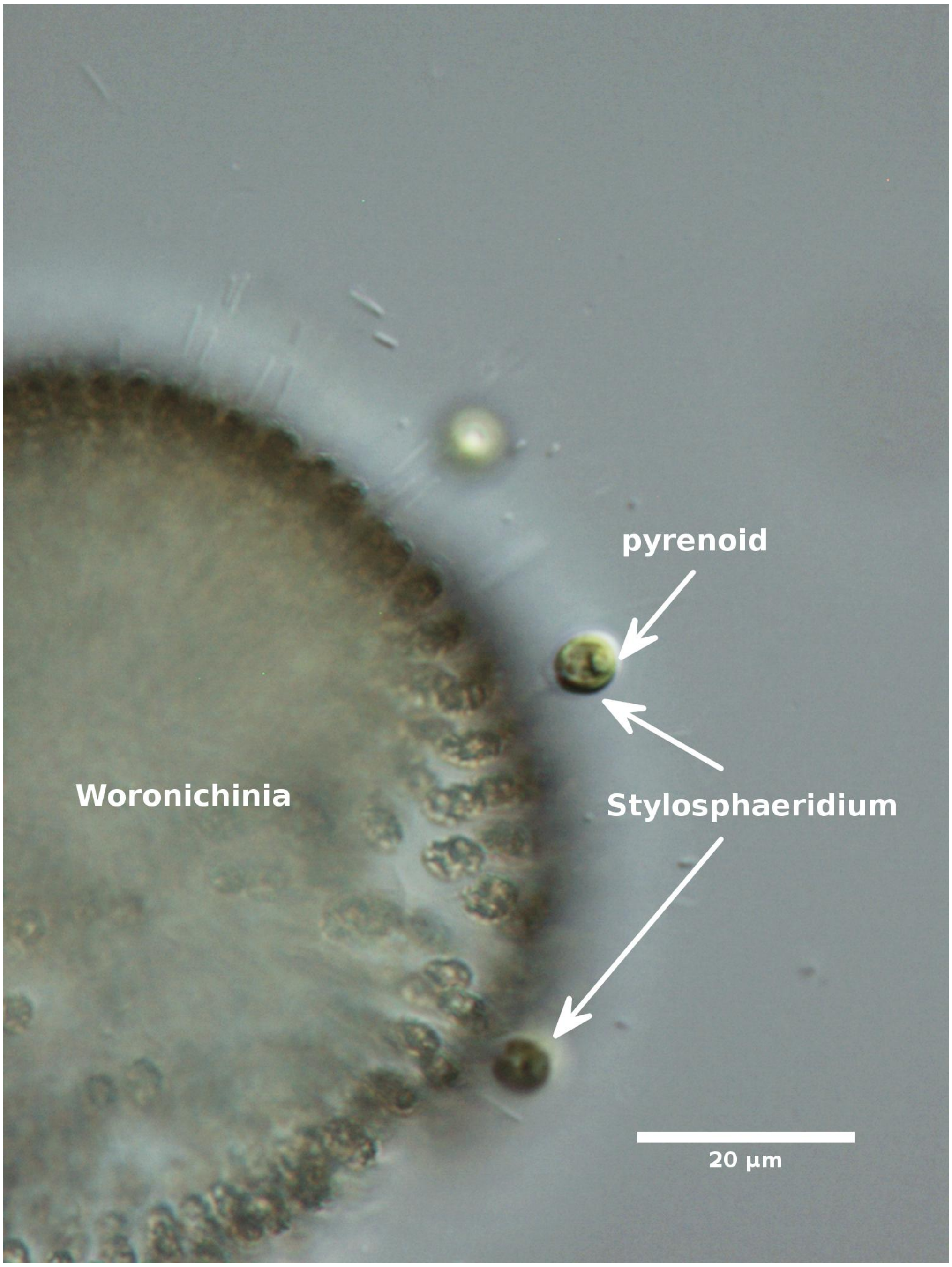

Figure 3.93: *Stylosphaeridium stipatum* (600x DIC), Lake Sixteen, IWS water quality sampling site, Skagit County, September 12, 2012.

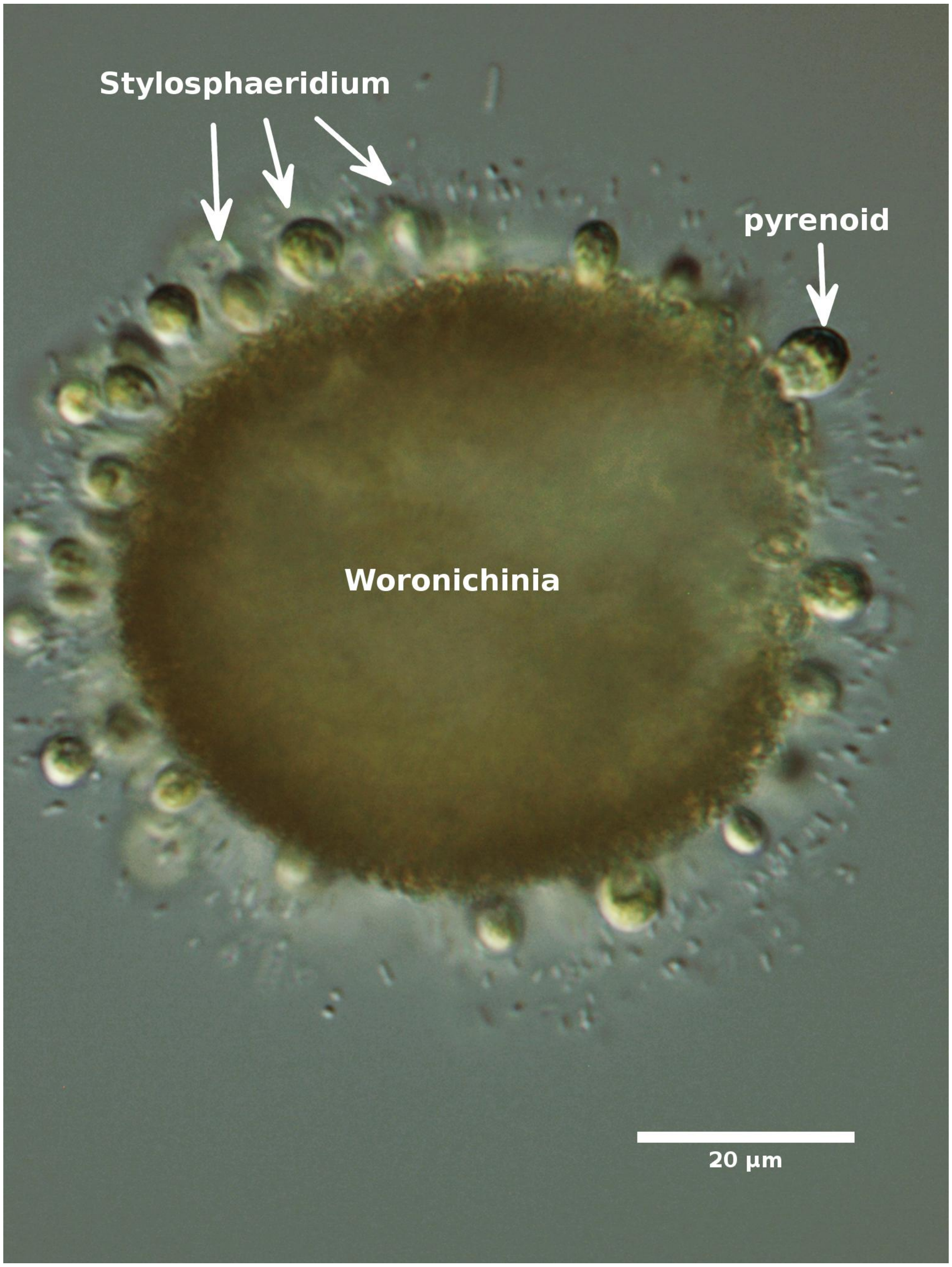

Figure 3.94: *Stylosphaeridium stipatum* (600x DIC), Lake Ketchum, IWS water quality sampling site, Snohomish County, July 15, 2013.

3.9 *Chlorella* Beyerinck [Beijerinck] (and similar taxa)

Local taxa

Chlorella spp. (including zoochlorella)

Abundance

Moderately common; difficult to identify correctly.

Local measurements		Width	Length	Biovolume†
Chlorella type A	min	4.2 μm	–	38.8 μm^3
cells (sphere)	med	4.9 μm	–	63.7 μm^3
	max	6.1 μm	–	119 μm^3
Chlorella type B	min	6.0 μm	–	113 μm^3
cells (sphere)	med	8.8 μm	–	358 μm^3
	max	11.3 μm	–	755 μm^3
Zoochlorella‡	min	4.6 μm	–	51.0 μm^3
cells (sphere)	med	5.5 μm	–	84.8 μm^3
	max	5.9 μm	–	108 μm^3

†Calculated using original measurements, not summary values.
‡May include more than one genus or species.

Description

Chlorella cells are spherical, smooth-walled, with a cup-shaped or plate-like chloroplast and no eyespot (Figures 3.95–3.99). Some species also have a central pyrenoid. Although *Chlorella* cells are described as solitary, they often aggregate into clumps, as in Figure 3.97. The cells lack a distinct mucilaginous envelope, which distinguishes *Chlorella* from similar Chlorophyta such as *Asterococcus* (Section 3.6, page 245), *Planktosphaeria* (Section 3.29), and single-celled species of *Gloeocystis* (Section 3.16, page 343). *Chlorella* cells also resembles *Tetraspora*, but *Tetraspora* cells have pseudocilia and mucilage surrounding the cell groups (see Section 3.37 on page 508).

Note that cells resembling *Chlorella* might be nonmotile forms of *Chlamydomonas* (Section 2.3, page 35). *Chlamydomonas* often lose their flagella when stressed or during reproduction. A distinguishing feature is that nonmotile forms of *Chlamydomonas* will have a reddish eyespot.

According to John, et al. (2011), genetic evidence has revealed that many of the 100+ species listed for the genus *Chlorella* are not closely related. Separation of *Chlorella* species is not feasible based strictly on morphological features, and even confirmation of the genus may not be possible. For simplicity, I will include in the *Chlorella* section all small, smooth-walled, spherical, ⇒nonmotile Chlorophyta cells with a cup-shaped chloroplast that resemble *Chlamydomonas* and can not be separated based on any other unique features.

Two morphological dissimilar types of *Chlorella* are common in local lakes. *Chlorella* type A has very small cells that resemble cultured *Chlorella* specimens (Figure 3.98). *Chlorella* type B has larger cells that seem more likely to form clumped aggregations (Figure 3.99).

Zoochlorella are single-celled Chlorophyta that live in the cytoplasm of some types of freshwater protozoa and invertebrates (Figures 3.100–3.102). The exact function of the endosymbiotic algal cells is not clear, but they are not digested by the host cell and appear to provide some benefit. These endosymbiotic algae are sometimes collectively named *Chlorella parasitica* (K. Brandt) Beijerinck (=*Zoochlorella parasitica* K. Brandt), but the group has been revised and split based on genetic information and host specificity (Pröschold, et al., 2011). Taxonomic identification of these symbiotic algae is beyond the scope of this book.

The zoochlorella in Figure 3.102 live in a particularly interesting colonial ciliate, *Ophrydium versatile* (Müller) Ehrenberg. The ciliates forms large (macroscopic), jelly-like masses containing hundreds of individual ciliates lined up in regular rows in a colonial mucilage.

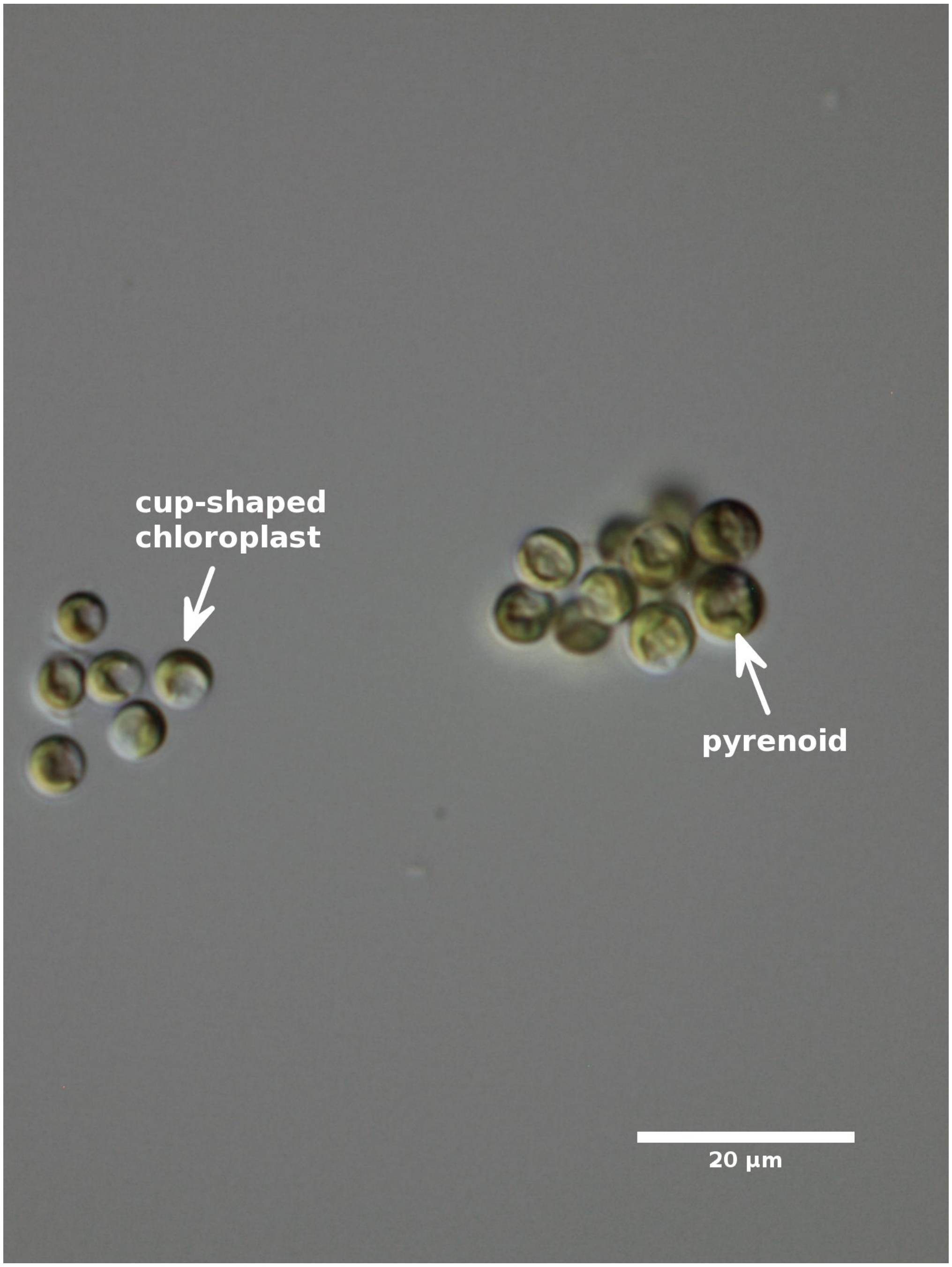

Figure 3.95: *Chlorella* (600N), Carolina Biological Supply Co., April 9, 2013.

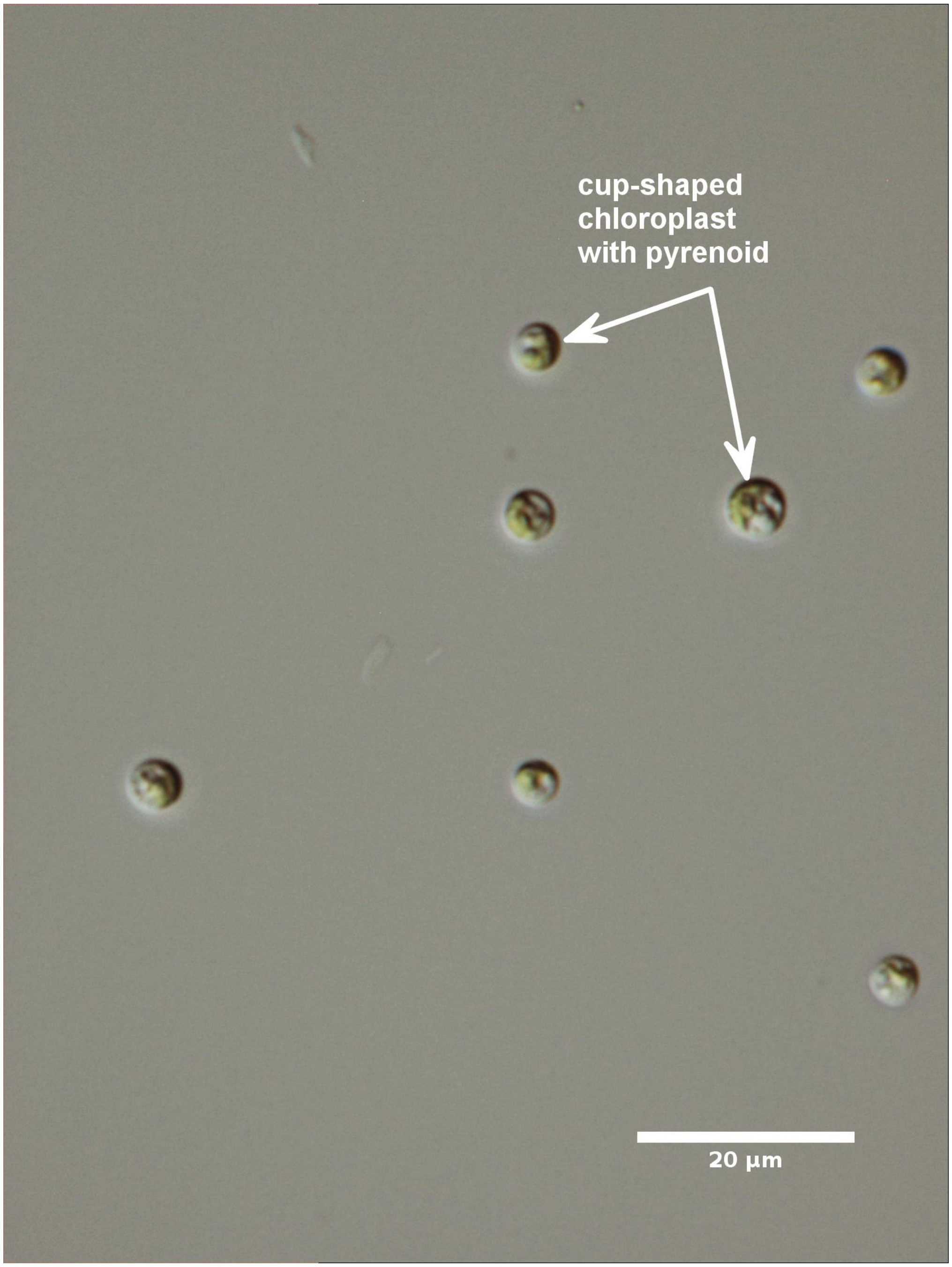

Figure 3.96: *Chlorella* (600N), Carolina Biological Supply Co., May 16, 2011.

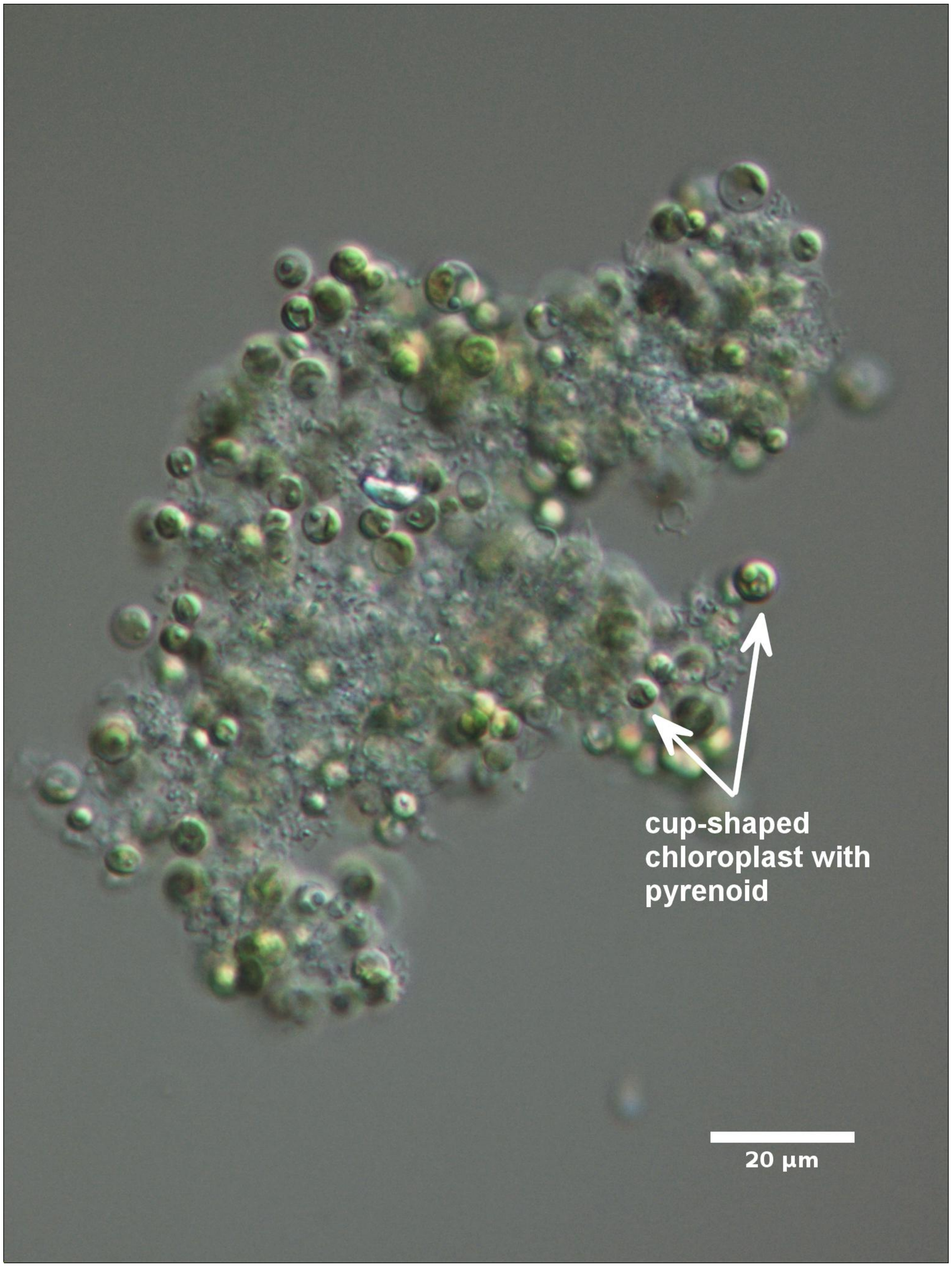

Figure 3.97: *Chlorella* (400N), Wards Biological Supply Co., October 9, 2007.

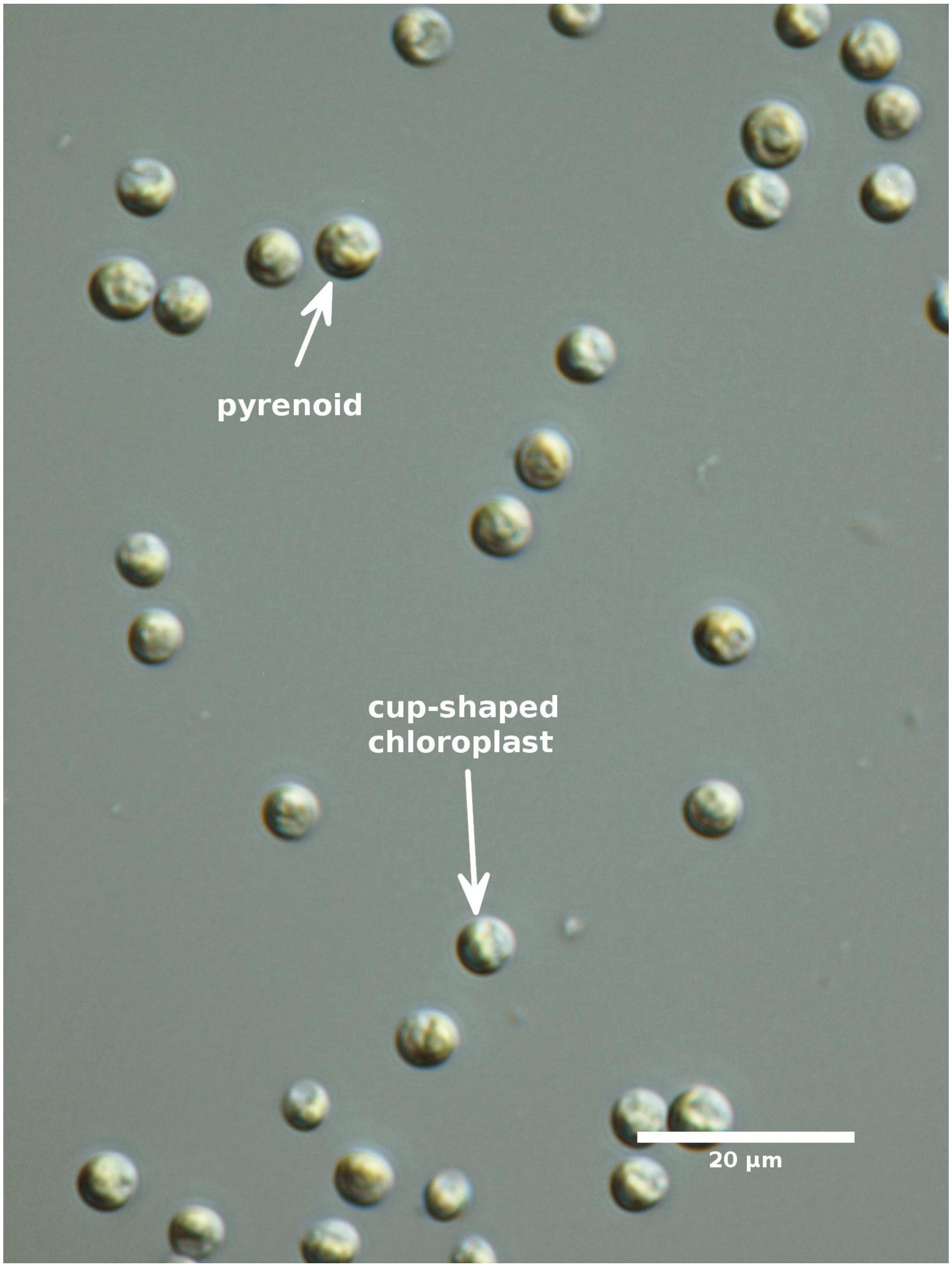

Figure 3.98: *Chlorella* type A (600N), Heather Meadows Pond, IWS water quality sampling site, Whatcom County, August 28, 2012.

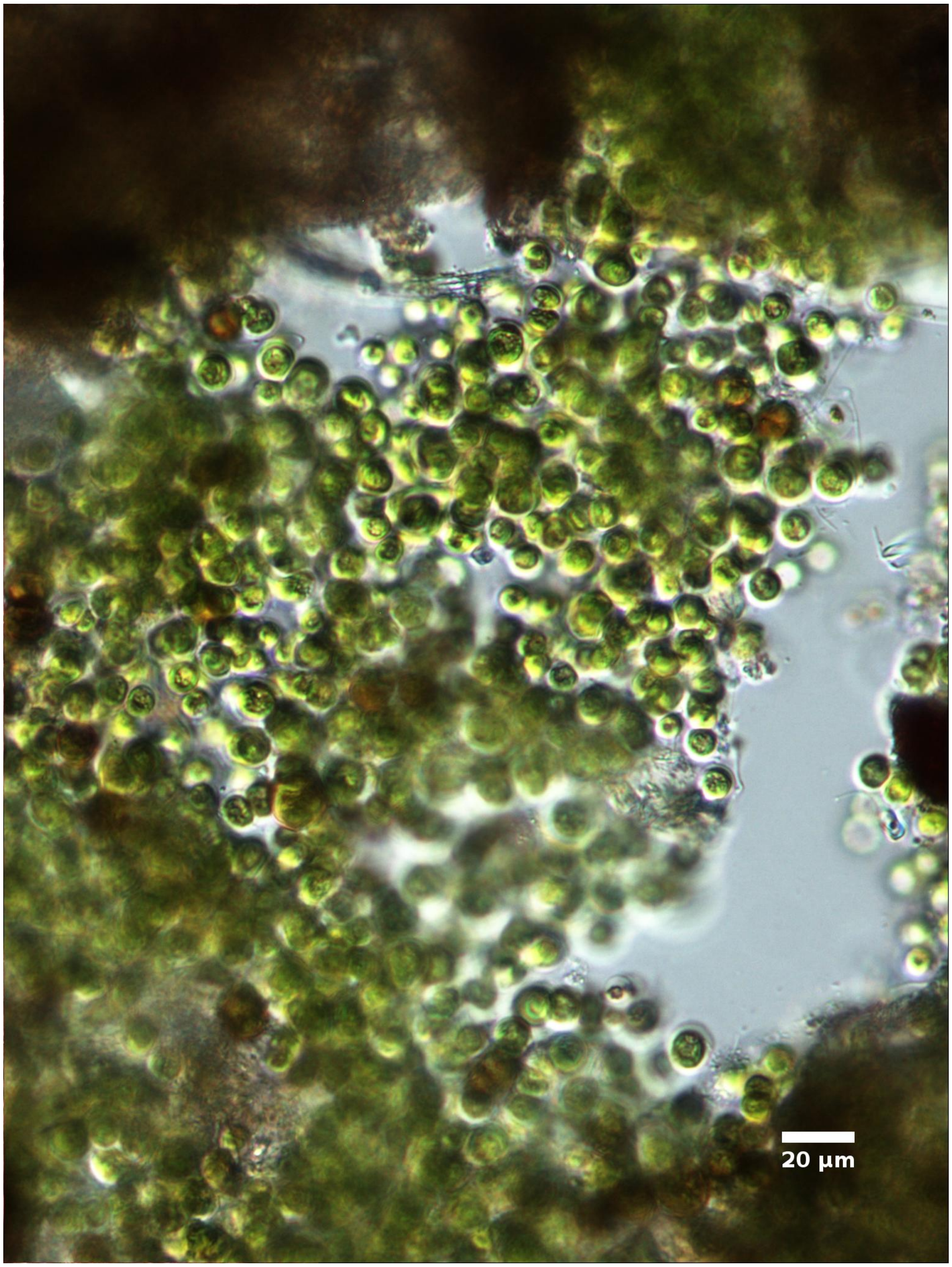

Figure 3.99: *Chlorella* type B (200N), small eutrophic pond, Whatcom County, May 15, 2009.

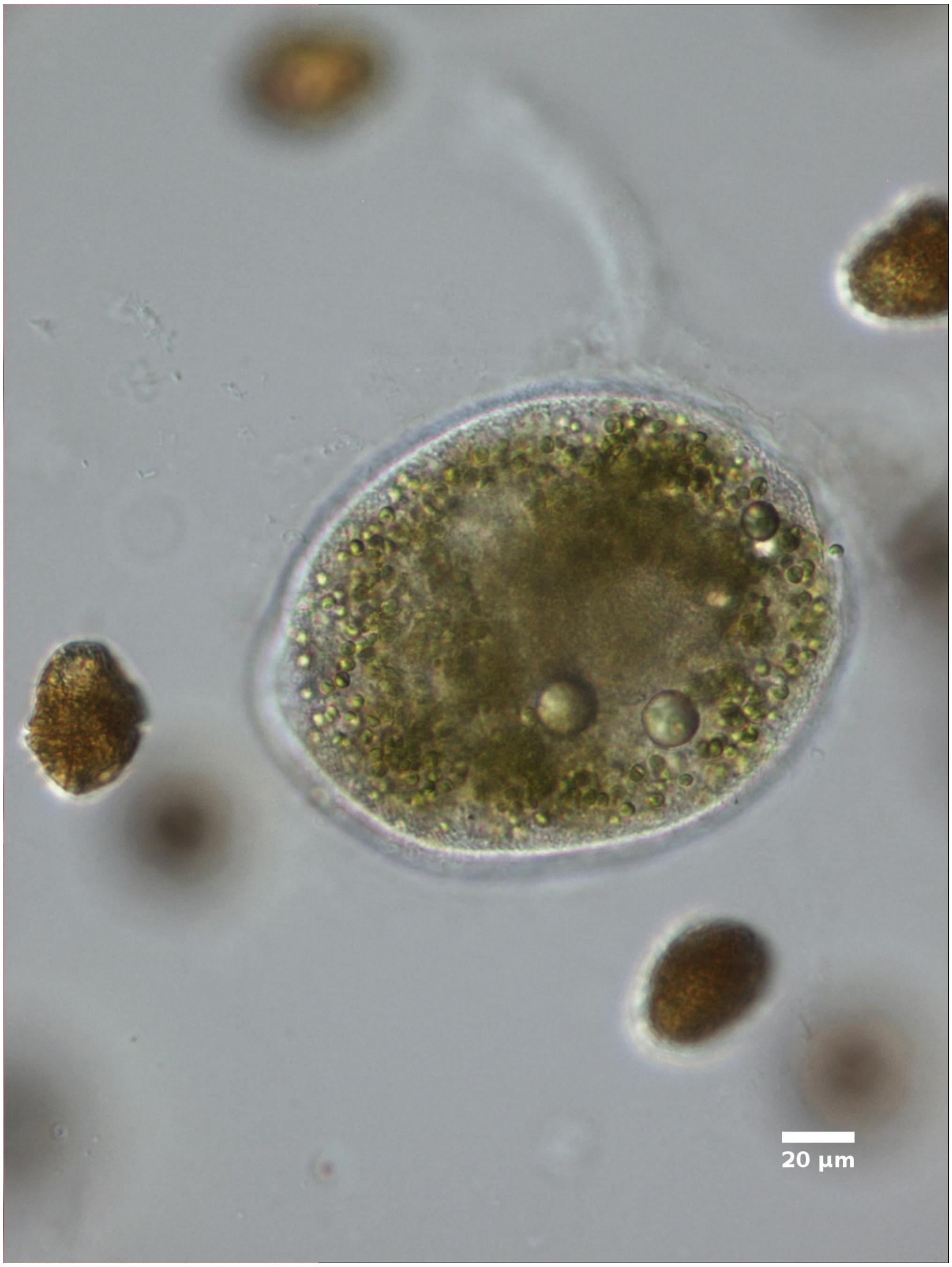

Figure 3.100: Zoochlorella in ciliate (200N), Judy Reservoir, IWS water quality sampling site, Skagit County, May 24, 2011.

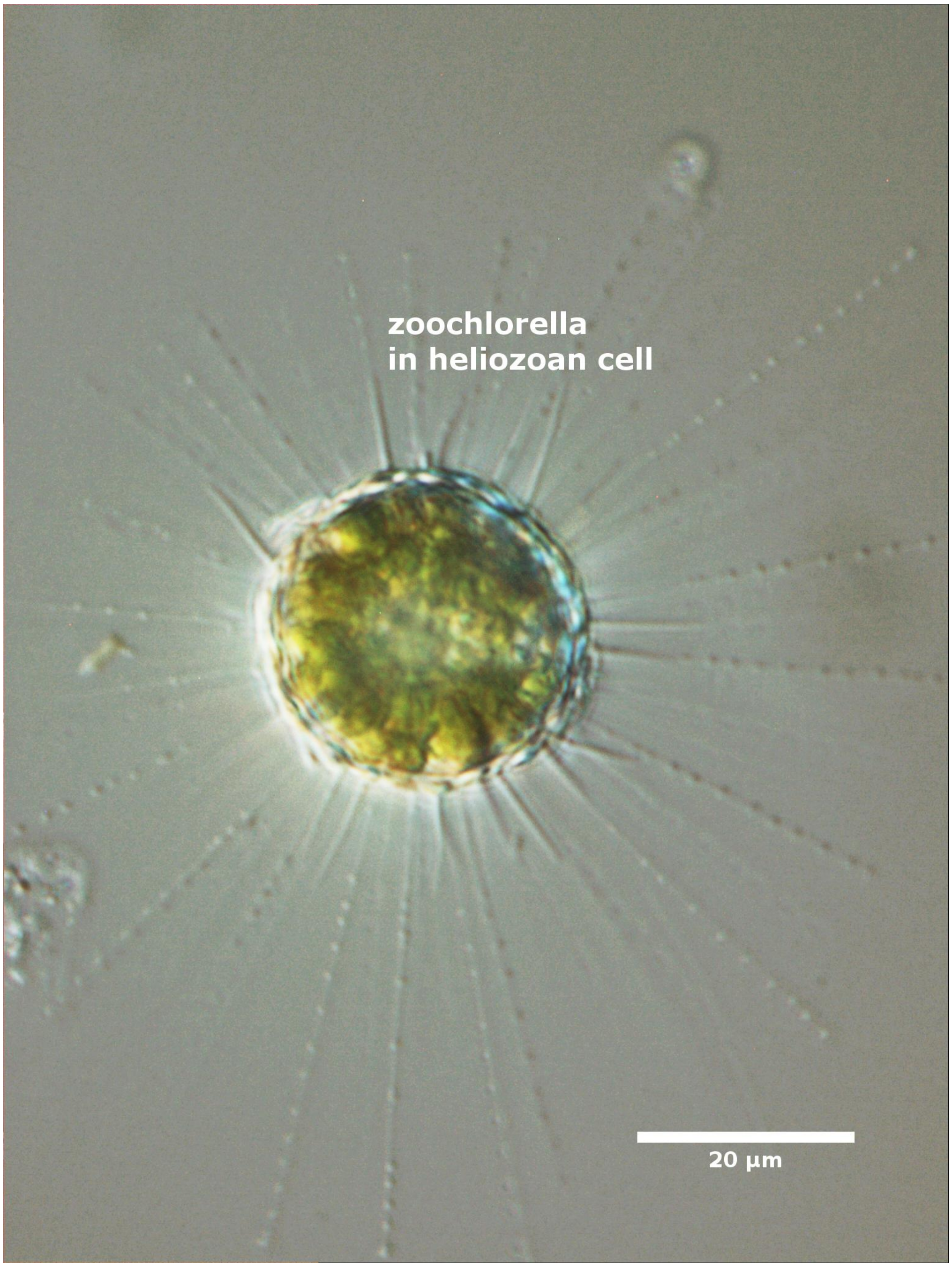

Figure 3.101: Zoochlorella in amoeba (600N), Cedar Lake, IWS water quality sampling site, Whatcom County, April 9, 2012.

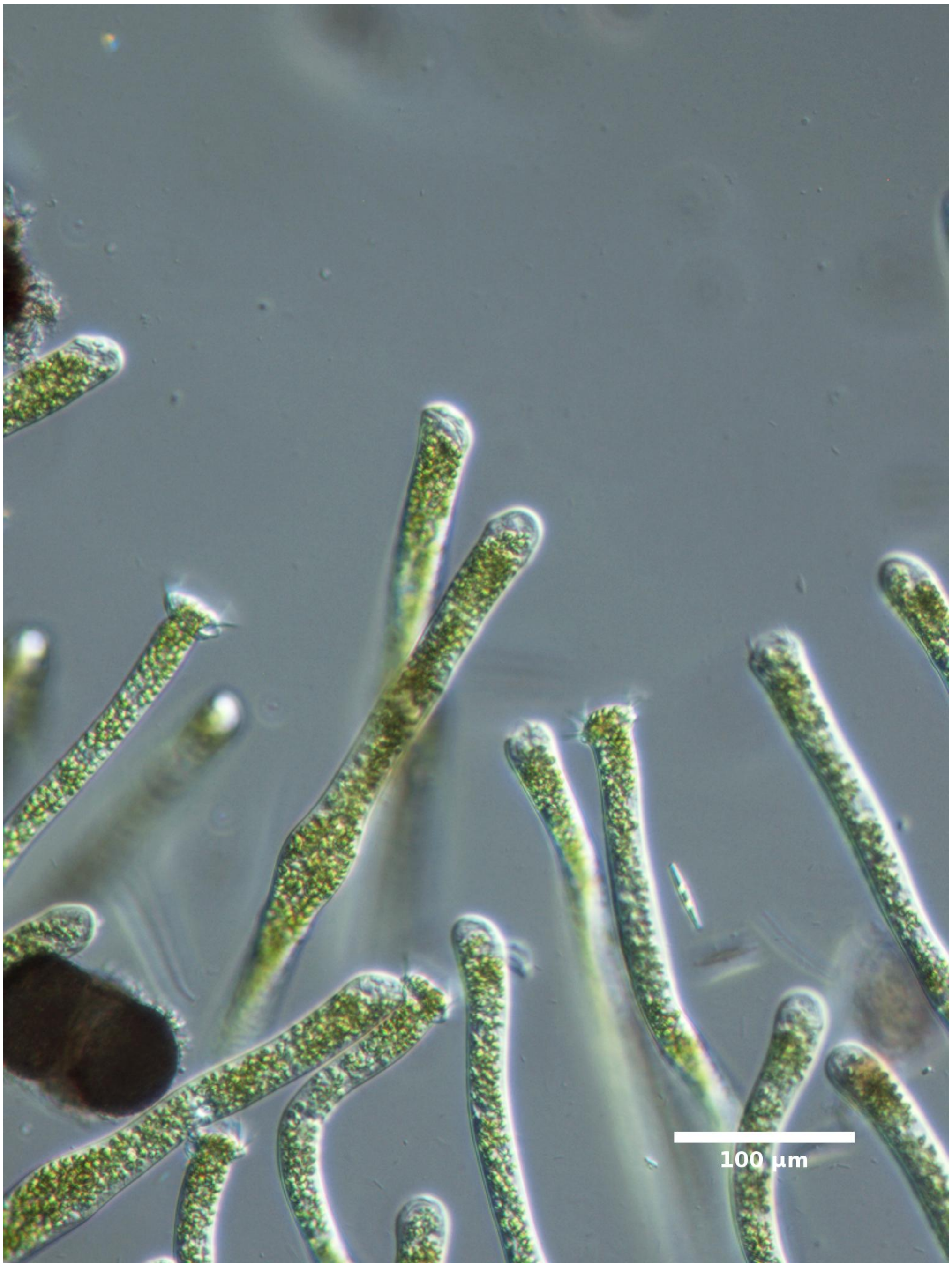

Figure 3.102: Zoochlorella in colonial ciliate *Ophrydium versatile* (100x DIC), Lake Evan, IWS water quality sampling site, Snohomish County, August 16, 2012.

3.10 *Coelastrum* Nägeli

Local taxa
Coelastrum astroideum De Notaris;
Coelastrum microporum Nägeli;
Coelastrum reticulatum (Dangeard) Senn (=*Hariotina reticulata* Dangeard)

Abundance
Moderately common; rarely present in large numbers.

Local measurements		Width	Length	Biovolume†
Coelastrum astroideum	min	6.3 μm	6.5 μm	139 μm^3
cells (spheroid)	med	8.3 μm	8.9 μm	325 μm^3
	max	14.7 μm	14.8 μm	1,610 μm^3
Coelastrum astroideum	min	15.2 μm	–	–
colonies‡	med	33.4 μm	–	–
	max	52.7 μm	–	–
Coelastrum microporum	min	8.9 μm	9.6 μm	398 μm^3
cells (spheroid)	med	12.8 μm	13.6 μm	1,110 μm^3
	max	17.6 μm	17.8 μm	2,890 μm^3
Coelastrum microporum	min	29.3 μm	–	–
colonies‡	med	35.9 μm	–	–
	max	43.6 μm	–	–
Coelastrum reticulatum	min	9.2 μm	9.5 μm	421 μm^3
cells (spheroid)	med	13.8 μm	14.7 μm	1,420 μm^3
	max	16.6 μm	17.3 μm	2,500 μm^3
Coelastrum reticulatum	min	33.3 μm	–	–
colonies‡	med	75.2 μm	–	–
	max	100.3 μm	–	–

†Calculated using original measurements, not summary values.
‡Colony biovolume can estimated using a spherical shape.

Description

Coelastrum colonies contain approximately 8–32 spherical, oval, or angular cells joined to form a hollow colony (Figures 3.103–3.111). The cells often have wall extensions where they join other cells in the colony. The chloroplast is cup-shaped or parietal, with a single pyrenoid.

Coelastrum astroideum cells are spherical or slightly oval due to cell compression (Figures 3.103–3.104). The cells lack wall extensions, and are joined at the base to adjacent cells. The spherical colonies are small ($\leq$100 μm) and contain relatively few cells (4–32). The cells are tightly compressed, with small intercellular spaces. This species closely resembles *Coelastrum microporum*, which has smooth, spherical cells.

Coelastrum microporum colonies are also small ($\leq$100 μm), spherical, and contain only a few cells (4–32). The individual cells are spherical, lack wall extensions, and have very small intercellular spaces (Figures 3.105–3.106). This species is difficult to distinguish from *Coelastrum astroideum*.

Coelastrum reticulatum is characterized by large spherical colonies of 8–32 cells. (Figures 3.107–3.111). The individual cells are spherical, with smooth wall extensions and large intercellular spaces. One of the characteristic for this species is that daughter colonies are often contained within the old mother colony.

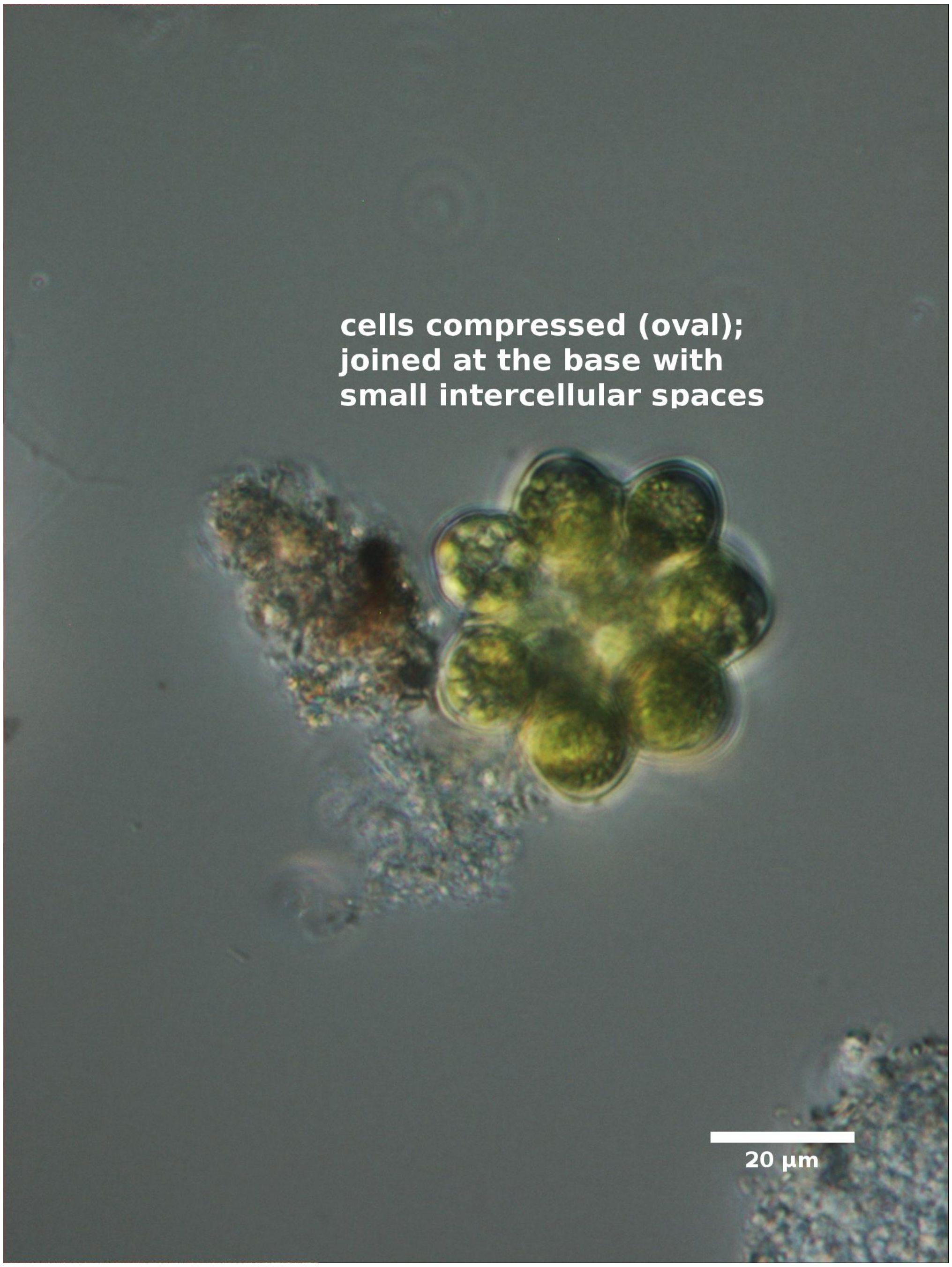

Figure 3.103: *Coelastrum astroideum* (400x DIC), Lake Erie, IWS water quality sampling site, Skagit County, September 21, 2010.

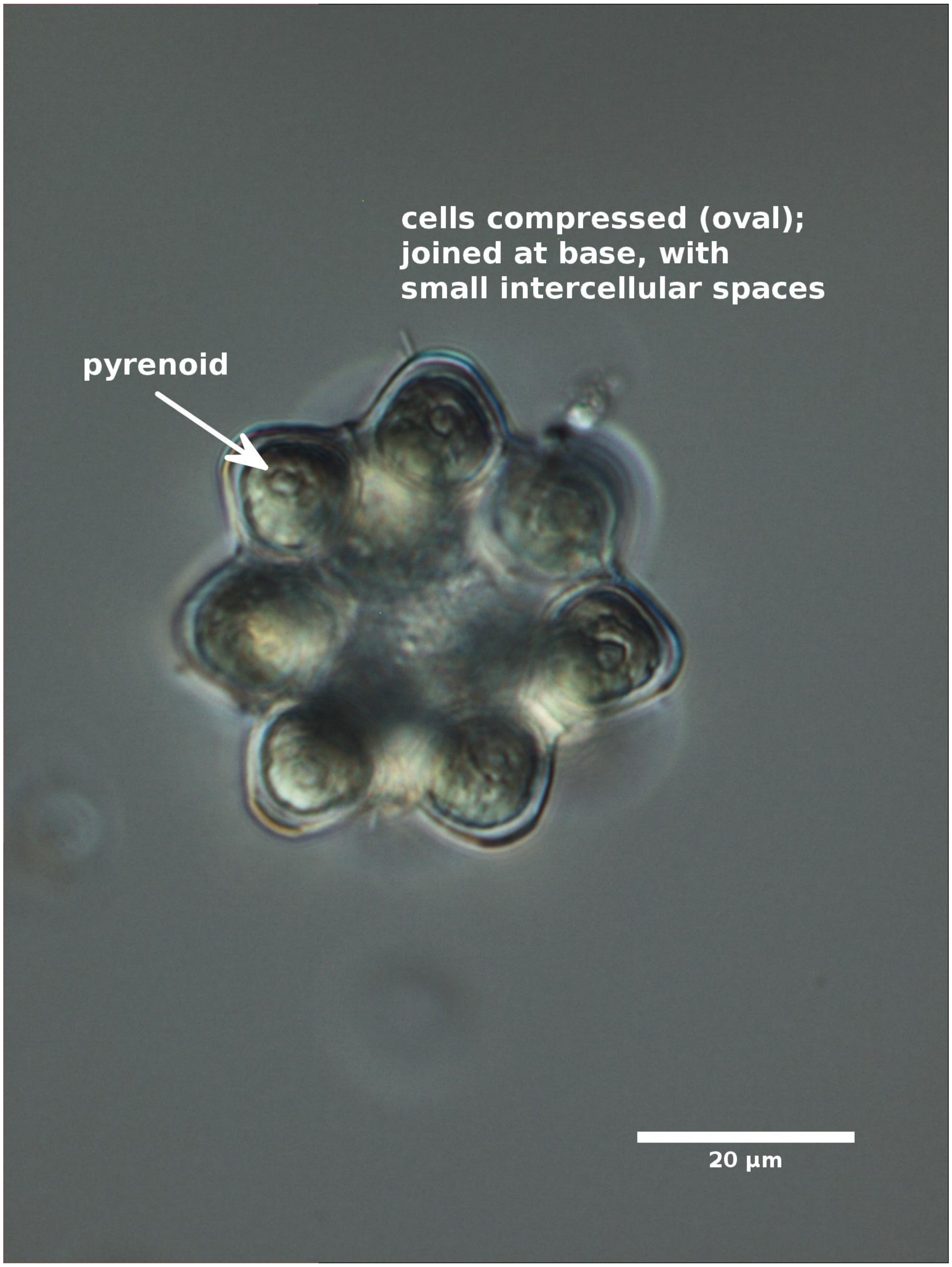

Figure 3.104: *Coelastrum astroideum* in Lugol's iodine solution (600x DIC), Lake Campbell, IWS water quality sampling site, Skagit County, September 3, 2009.

Figure 3.105: *Coelastrum microporum* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 5, 2011.

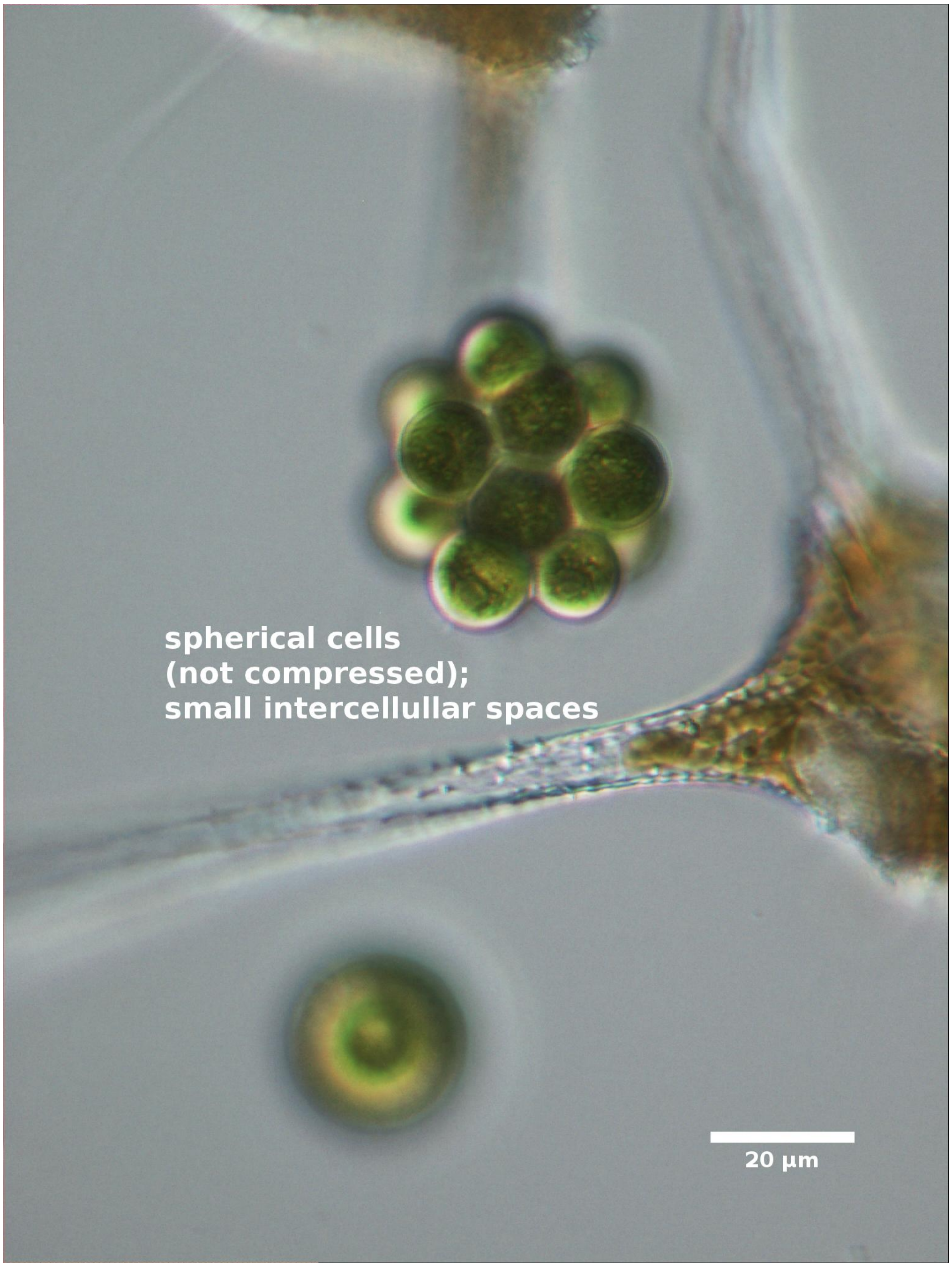

Figure 3.106: *Coelastrum microporum* (400x DIC), Heart Lake, IWS water quality sampling site, Skagit County, September 20, 2010.

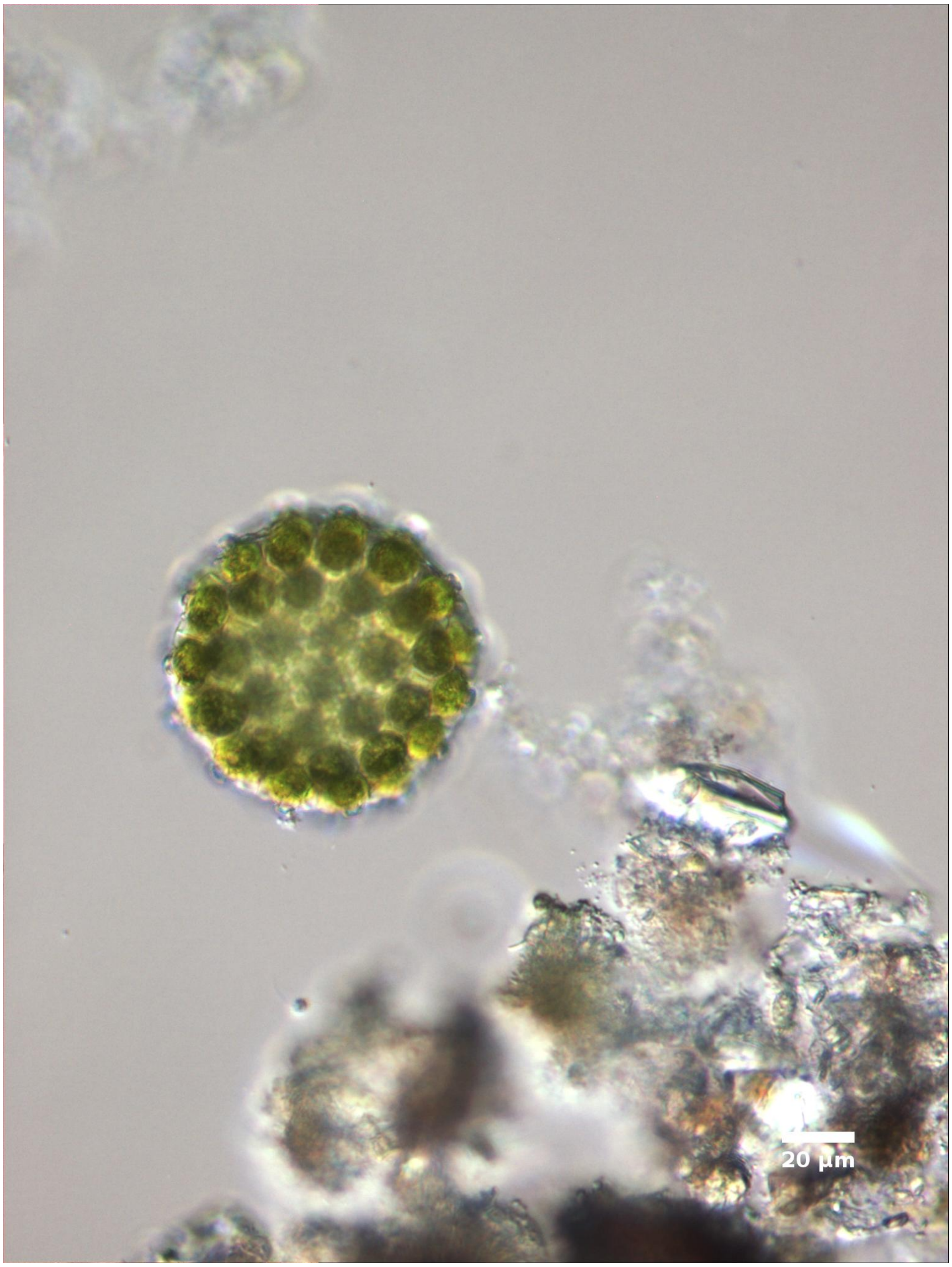

Figure 3.107: *Coelastrum reticulatum* (200x DIC), Picture Lake, IWS water quality sampling site, Whatcom County, September 11, 2009.

Figure 3.108: *Coelastrum reticulatum* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, June 5, 2015.

Figure 3.109: *Coelastrum reticulatum* (200x DIC), Picture Lake, IWS water quality sampling site, Whatcom County, September 11, 2009.

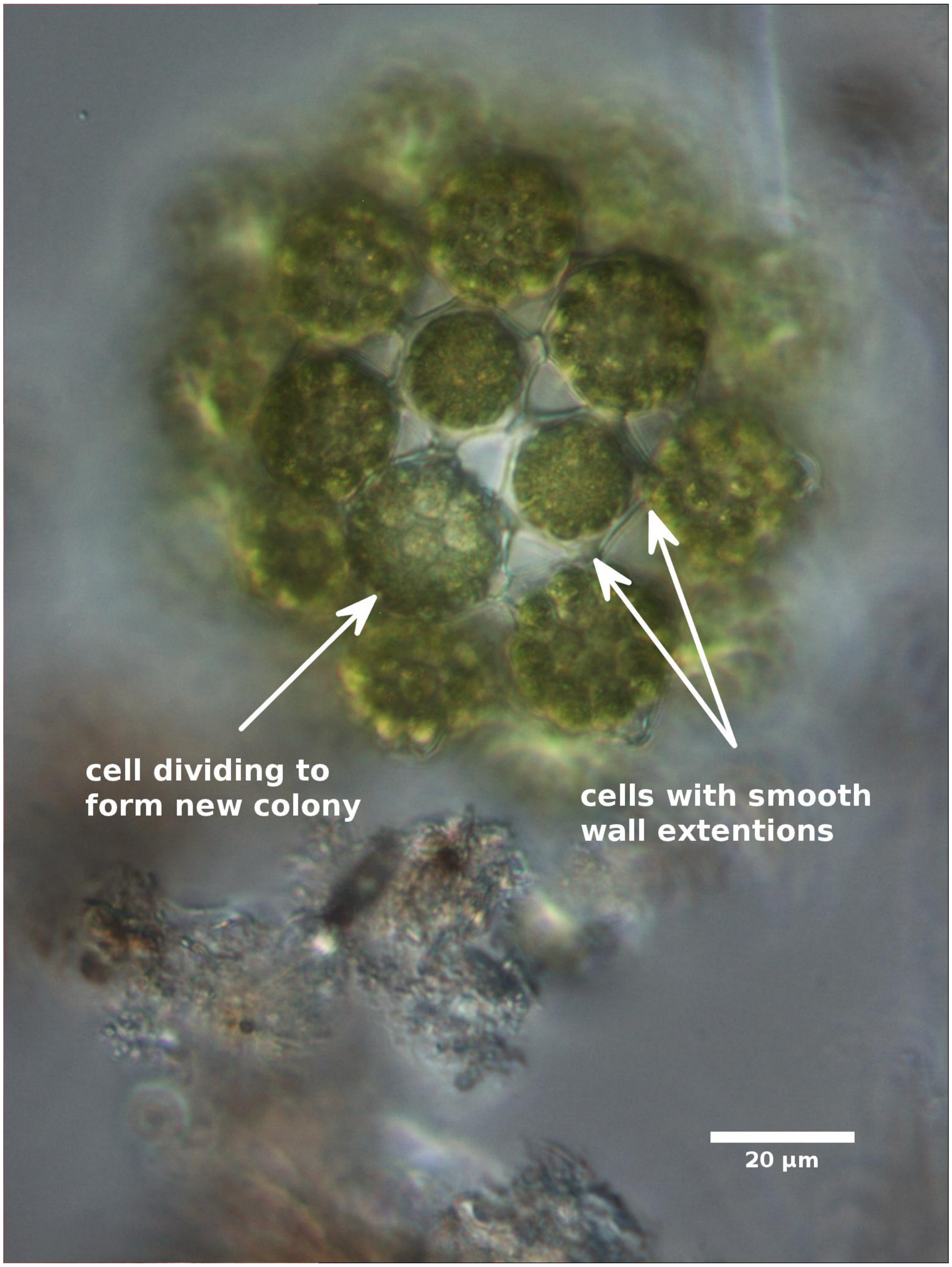

Figure 3.110: *Coelastrum reticulatum* (400x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, May 5, 2009.

Figure 3.111: *Coelastrum reticulatum* (400x DIC), Picture Lake, IWS water quality sampling site, Whatcom County, September 9, 2009.

3.11 *Crucigenia* Morren and *Crucigeniella* Lemmermann

Local taxa

Crucigenia crucifera (Wolle) Kuntze
(=*Willea crucifera* [Wolle] D. M. John, M. J. Wynn & Tsarenko);
Crucigenia quadrata Morren;
Crucigenia rectangularis (Nägeli) Gay
(=*Willea rectangularis* [A. Braun] D. M. John, W. J. Wynne & Tsarenko)
Crucigenia tetrapedia (Kirchner) Kuntze;
Crucigeniella irregularis (Wille) Tsarenko & D. M. John
(=*Willea irregularis* [Wille] Schmidle)

Abundance

Moderately common; rarely present in large numbers.

Local measurements		Width	Length	Biovolume†
Crucigenia crucifera	min	3.0 μm	4.8 μm	26.2 μm^3
cells (spheroid)	med	3.5 μm	5.7 μm	35.3 μm^3
	max	4.2 μm	6.3 μm	56.3 μm^3
Crucigenia quadrata	min	3.3 μm	3.1 μm	21.8 μm^3
cells (spheroid)	med	4.2 μm	4.1 μm	33.4 μm^3
	max	5.1 μm	4.6 μm	57.8 μm^3
Crucigenia rectangularis	min	4.5 μm	7.3 μm	85.6 μm^3
cells (spheroid)	med	6.3 μm	10.5 μm	225 μm^3
	max	8.0 μm	12.2 μm	395 μm^3
Crucigenia tetrapedia	min	3.9 μm	7.5 μm	–
individual cells‡	med	5.0 μm	8.4 μm	–
	max	5.5 μm	9.8 μm	–

continued on next page

Local measurements		Width	Length	Biovolume[†]
Crucigenia tetrapedia	min	5.4 μm	5.9 μm	172 μm^3
colonies (rectangular box)[‡]	med	9.6 μm	10.3 μm	949 μm^3
	max	11.0 μm	11.9 μm	1,440 μm^3
Crucigeniella irregularis?	min	4.8 μm	8.3 μm	107 μm^3
cells (spheroid)	med	5.8 μm	9.7 μm	166 μm^3
	max	7.1 μm	11.6 μm	306 μm^3

[†]Calculated using original measurements, not summary values.
[‡]Biovolume estimated using colony width and colony length measurements from 4-cell colonies; est. colony depth = colony width.

Description

Crucigenia and *Crucigeniella* are very similar in appearance, and the species are sometimes combined in taxonomic keys under the genus *Crucigenia*. Recent nomenclature revisions have moved many species into the genus *Willea* Schmidle, but this revision may not be mentioned in older taxonomic keys. All of the taxa are characterized by flattened, oval or wedge-shaped cells that form 4-cell colonies or colonies containing 4-cell subgroups.

Crucigenia crucifera cells are rectangular, with rounded edges, and form small colonies with large central spaces between the cells (Figures 3.112–3.113). The outer walls are slightly concave and the inner walls are straight or slightly convex.

Crucigenia quadrata cells are triangular and tightly packed into 4-cell subgroups, with almost no space between the cells (Figures 3.114–3.116). The outer cell walls are convex; the inner cell walls are joined along their entire length. The 4-cell subgroups resemble *Crucigenia tetrapedia*, which has triangular cells with straight outer walls (not concave).

Crucigenia rectangularis cells are oval or elliptical and slightly asymmetric, with a convex outer wall (Figures 3.117–3.119). *Crucigenia rectangularis* often forms large, rectangular colonies ($>$16 cells) containing obvious 4-cell subgroups.

Crucigenia tetrapedia cells are also triangular and tightly packed into 4-cell groups, with almost no space between the cells. The major distinguishing feature, compared to *Crucigenia quadrata*, is that the outer cell walls are straight or slightly concave (Figure 3.120).

Crucigeniella irregularis forms large colonies of oval or elliptical cells (Figures 3.121–3.122). This species closely resembles *Crucigenia rectangularis*, but *Crucigeniella irregularis* cells exhibit extreme slippage, so adjacent cells may overlap, making the 4-cell groups less obvious.

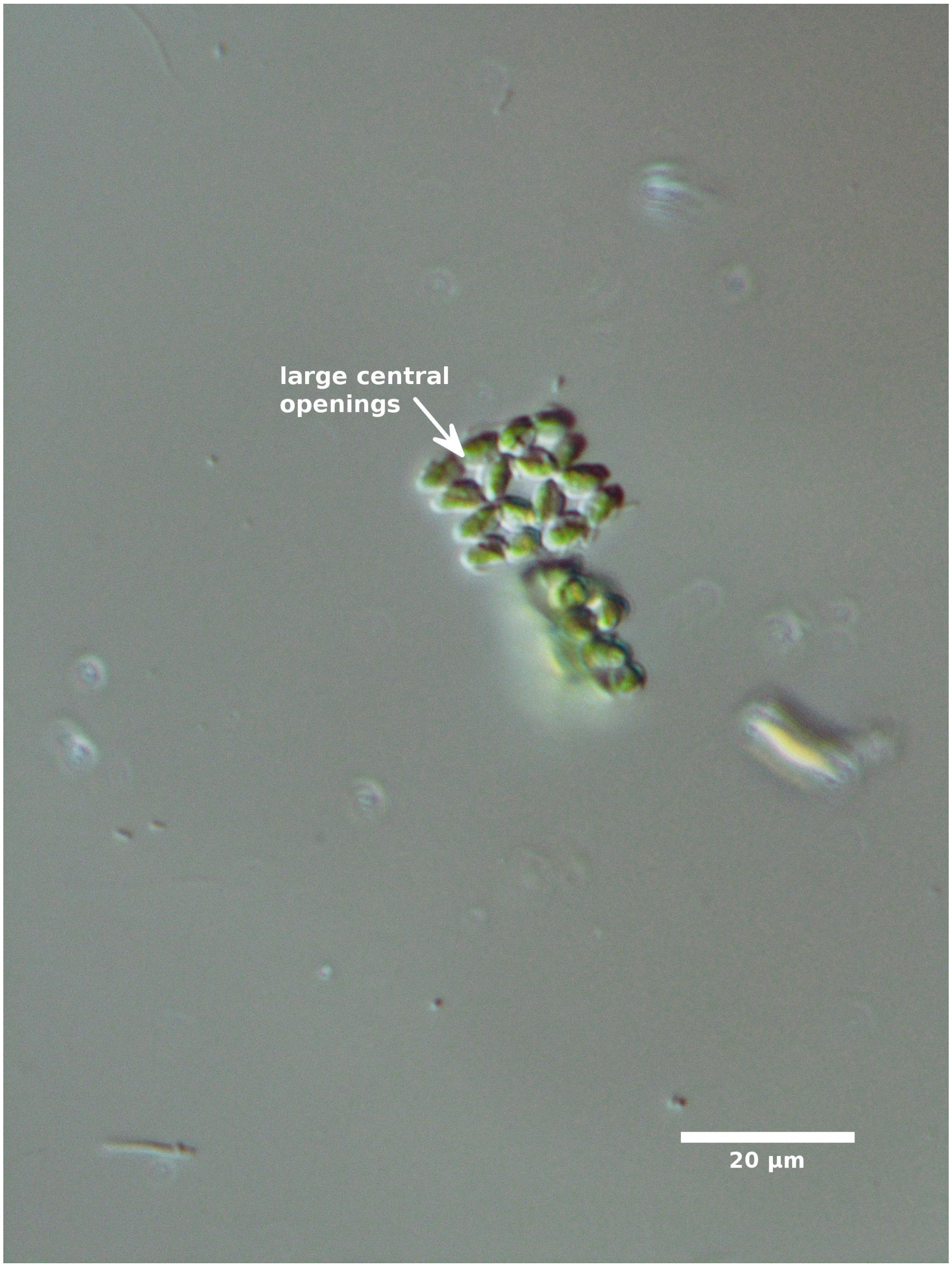

Figure 3.112: *Crucigeniella crucifera* (600x DIC), storm water treatment pond, Whatcom County, February 9, 2016.

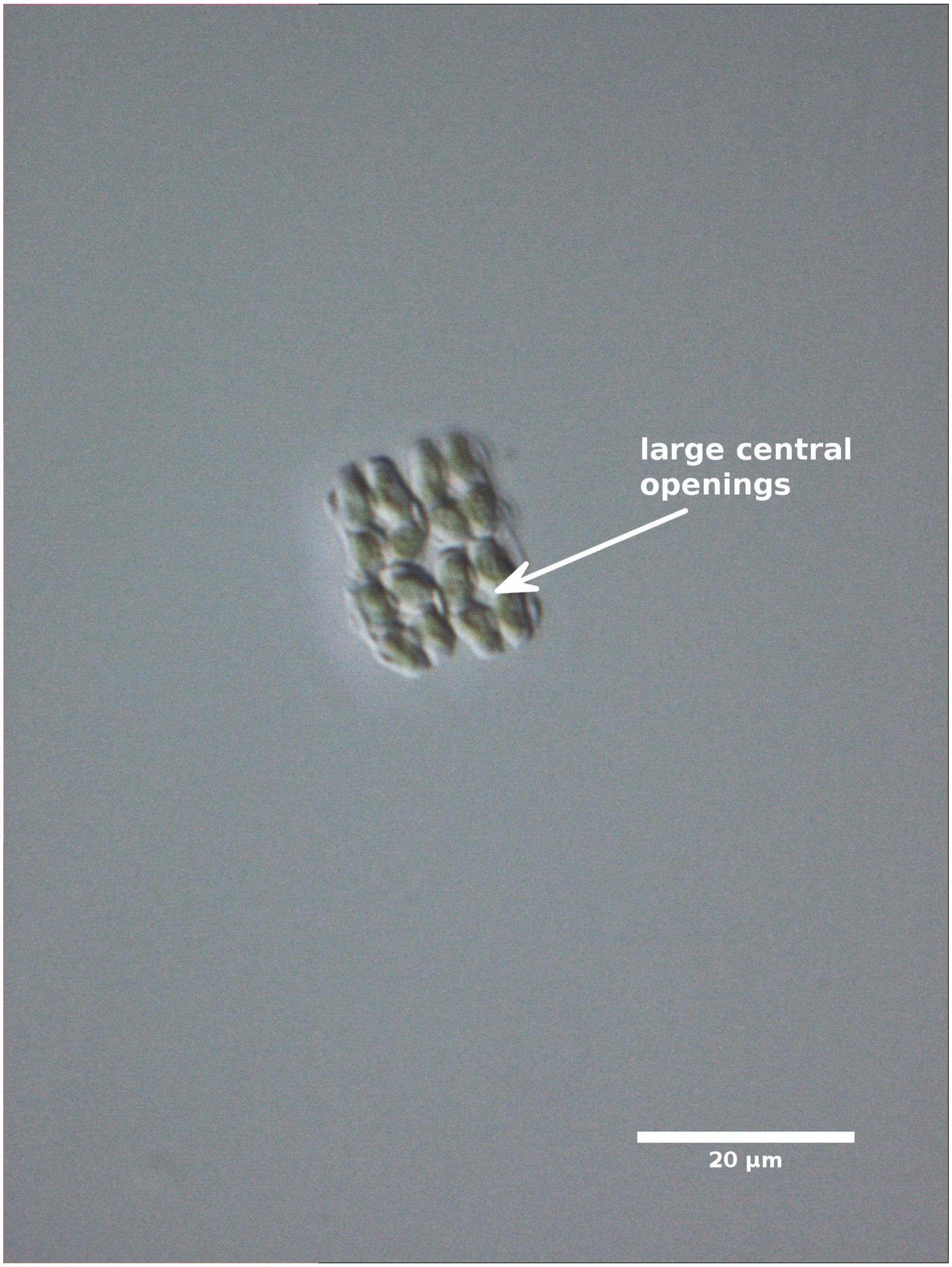

Figure 3.113: *Crucigeniella crucifera* (600x DIC), Summer Lake, IWS water quality sampling site, Skagit County, July 12, 2010.

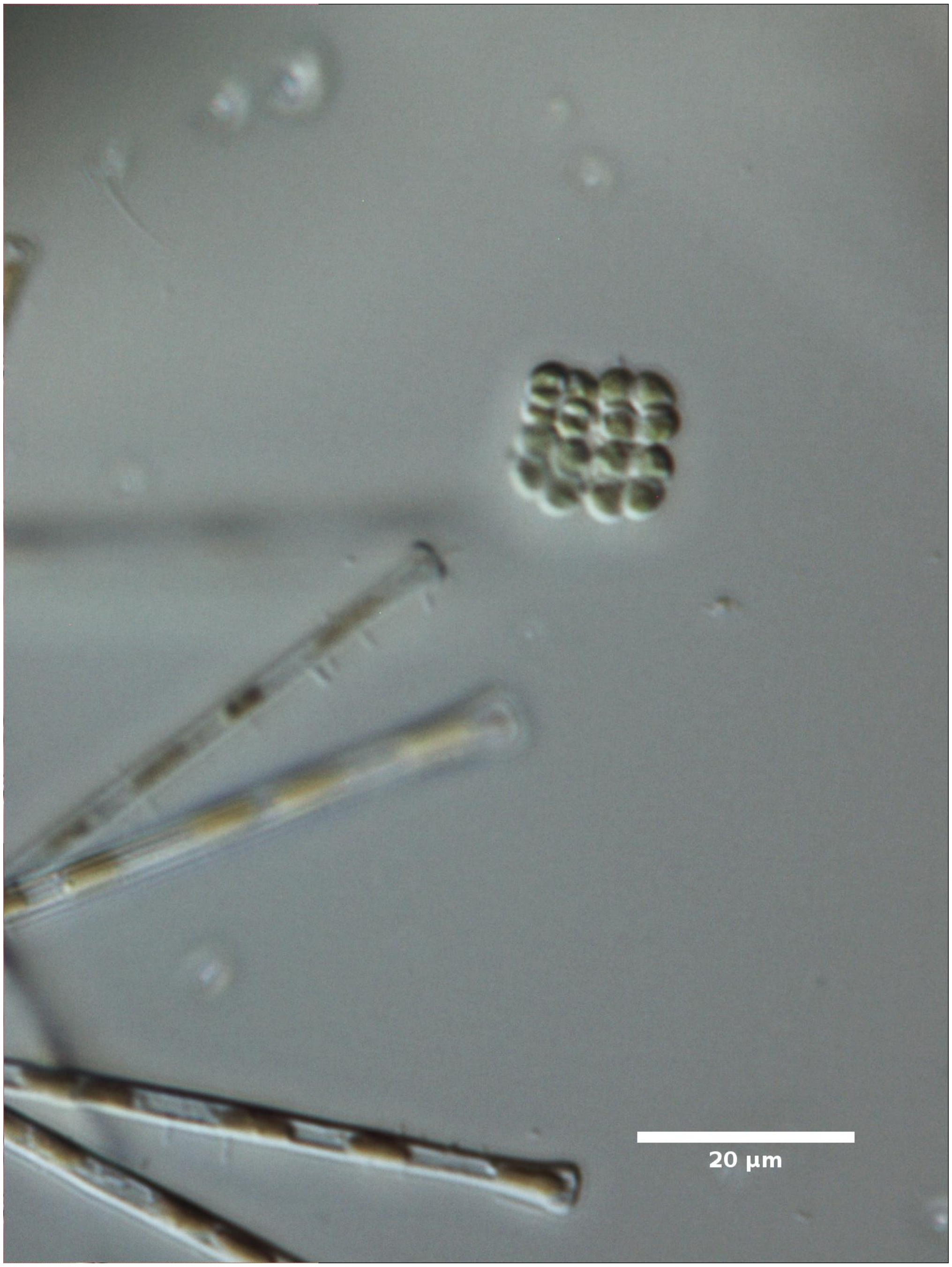

Figure 3.114: *Crucigenia quadrata* (600x DIC), Sunset Pond, IWS water quality sampling site, Whatcom County, April 22, 2009.

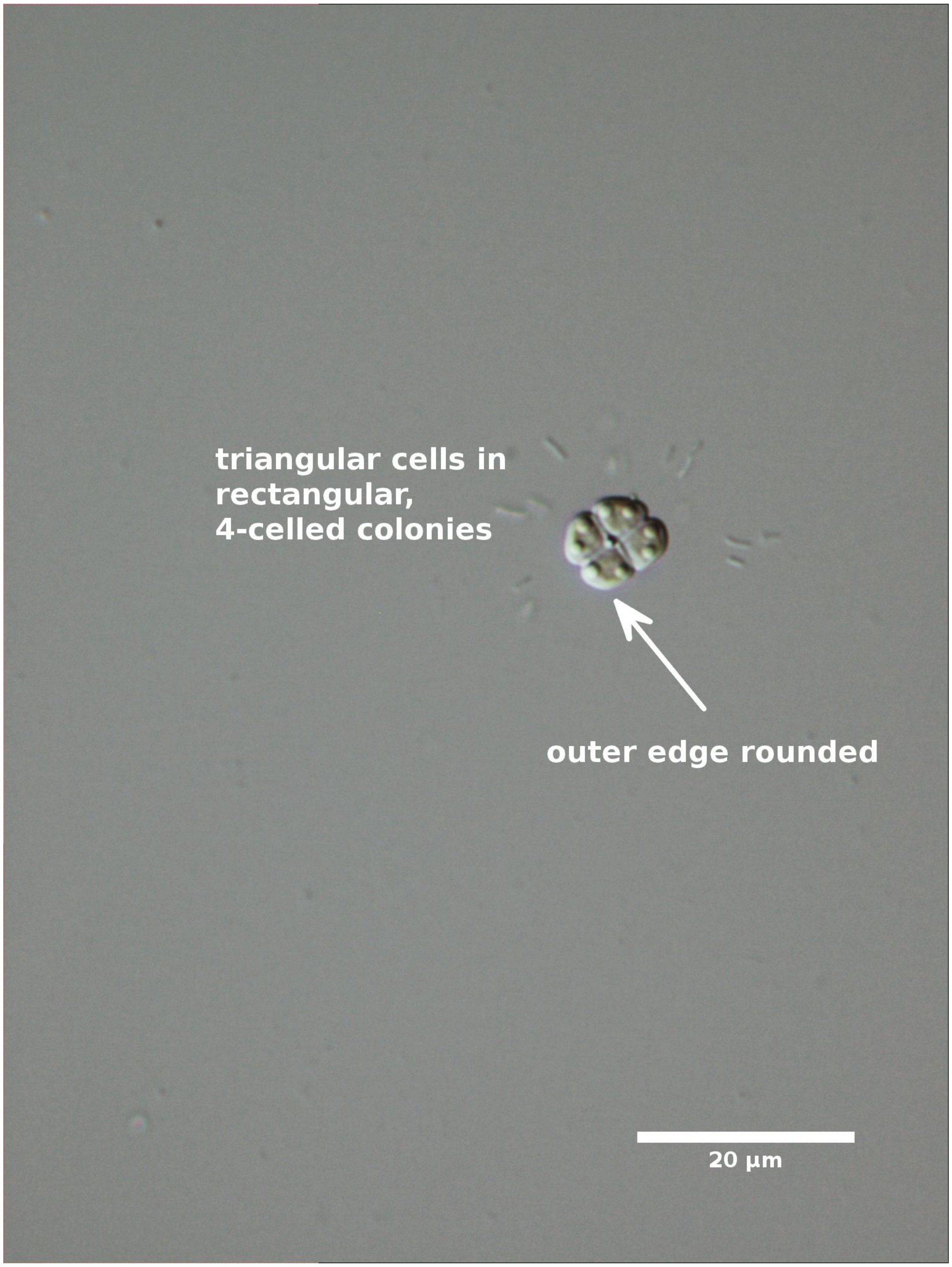

Figure 3.115: *Crucigenia quadrata* (600x DIC), Picture Lake, IWS water quality sampling site, Whatcom County, August 26, 2008.

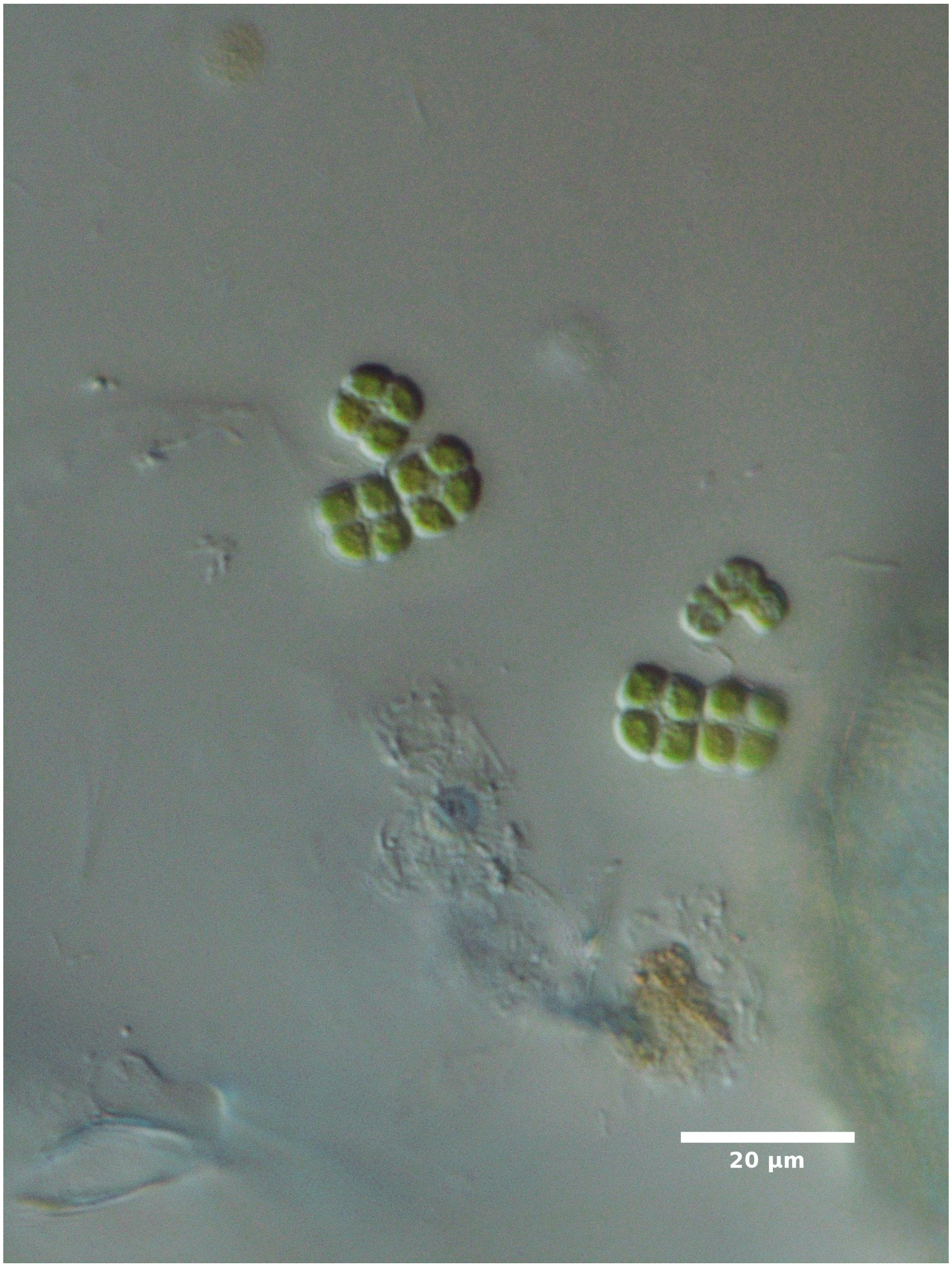

Figure 3.116: *Crucigenia quadrata* (600x DIC), Waughop Lake, Pierce County, April 7, 2014.

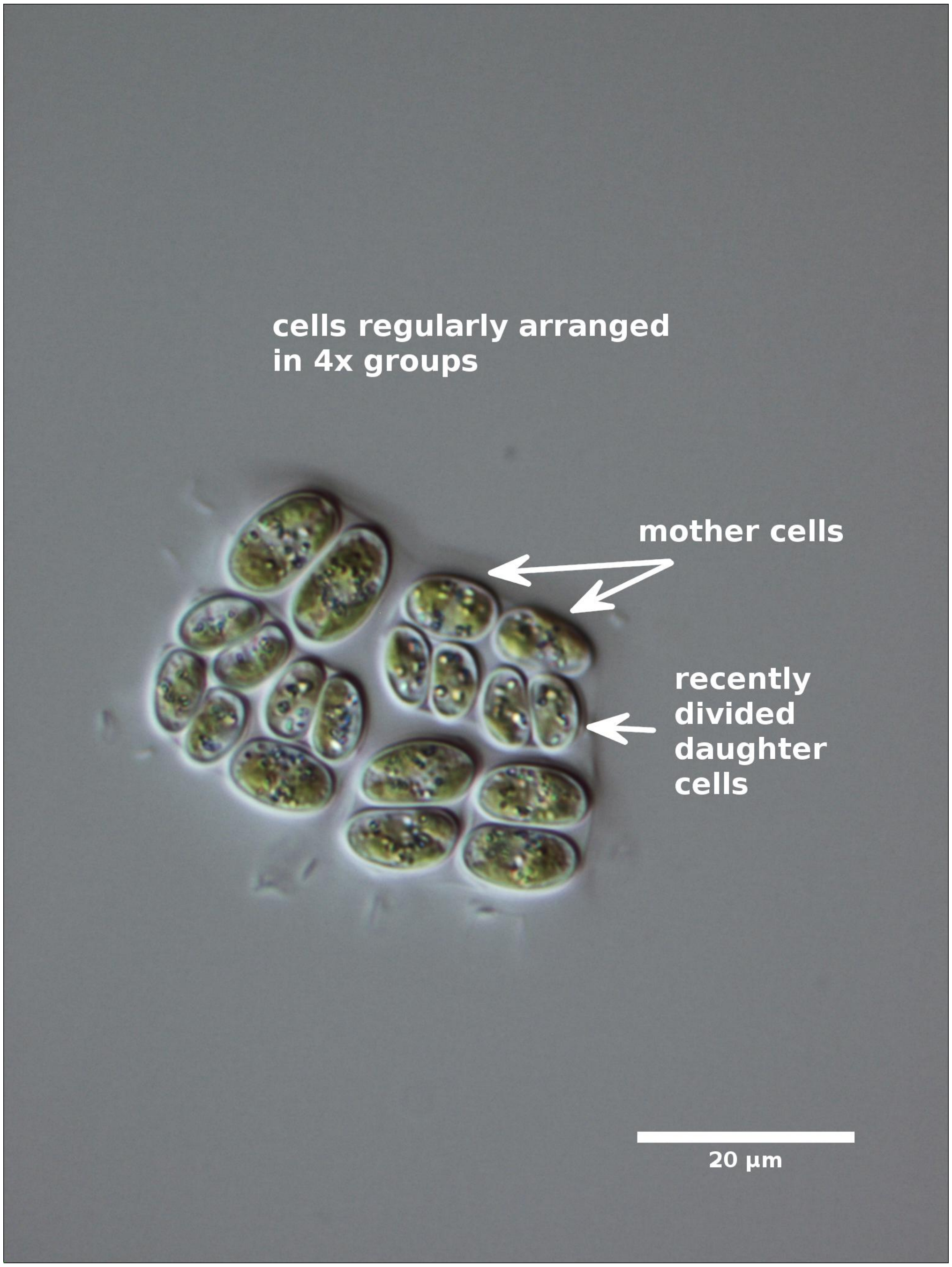

Figure 3.117: *Crucigenia rectangularis* (600x DIC), Silver Lake, IWS water quality sampling site, Whatcom County, August 20, 2007.

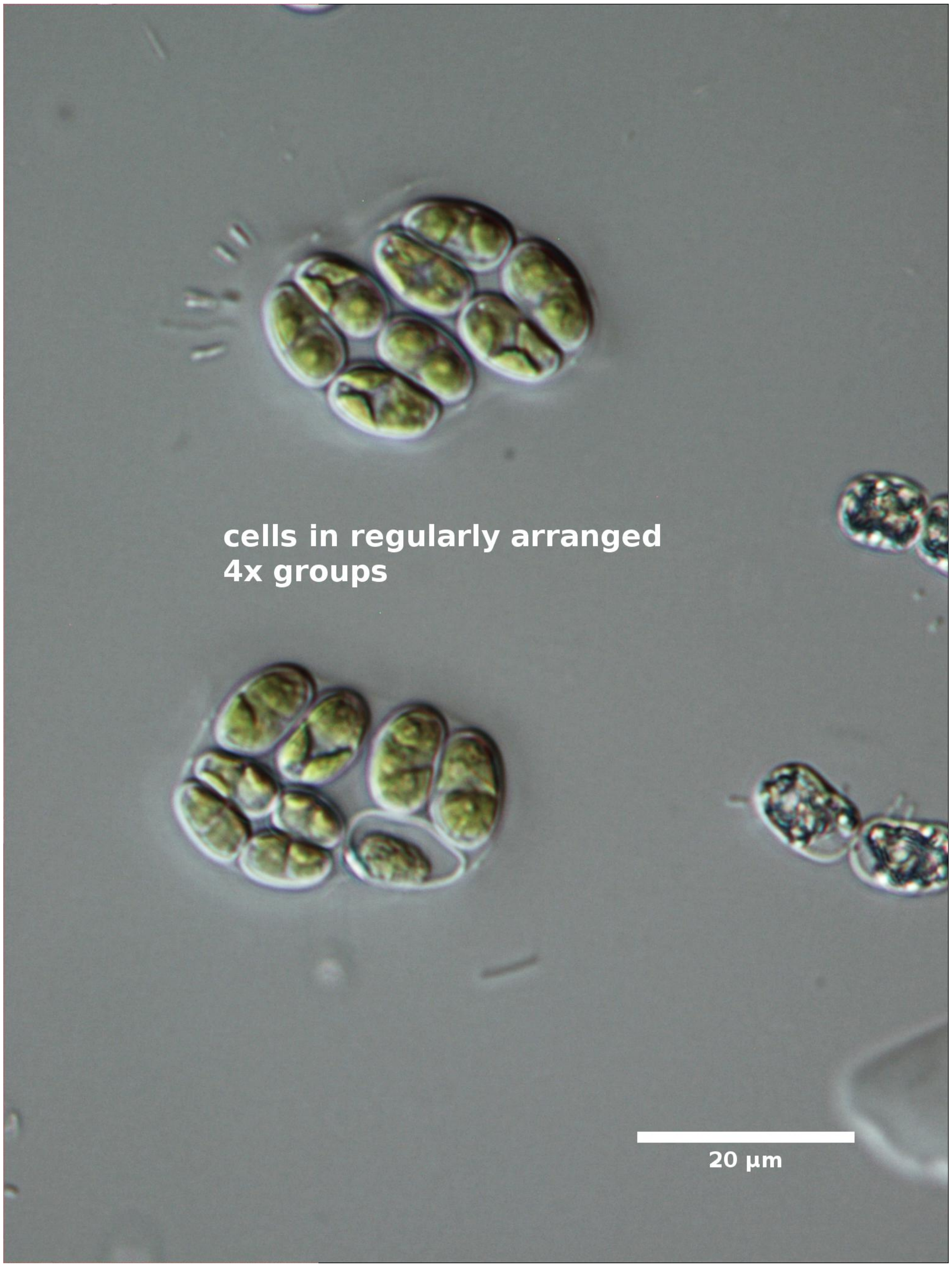

Figure 3.118: *Crucigenia rectangularis* (600x DIC), Deer Lake, IWS water quality sampling site, Island County, October 30, 2009.

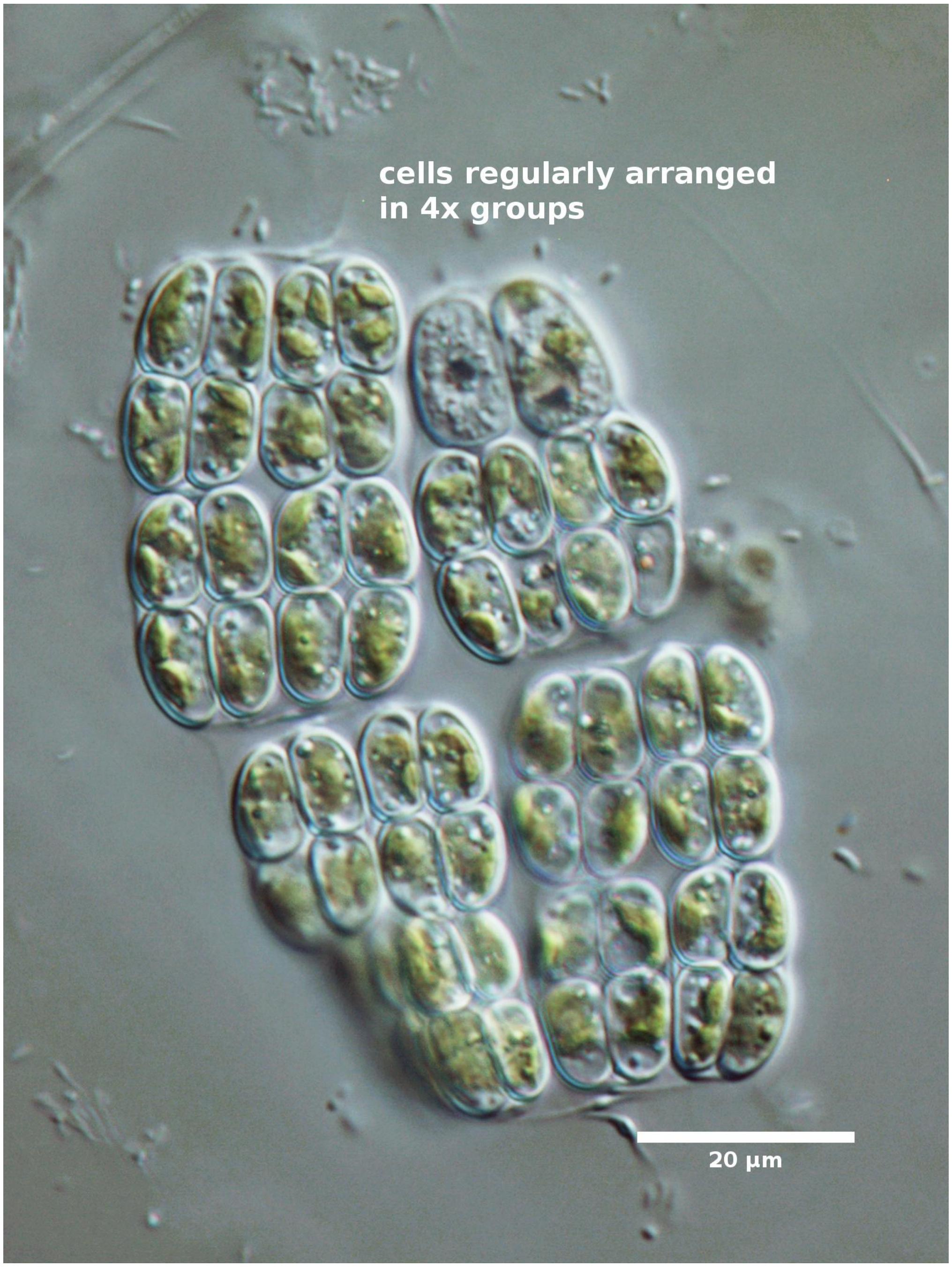

Figure 3.119: *Crucigenia rectangularis* stained with methylene blue (600x DIC), Silver Lake, IWS water quality sampling site, Whatcom County, August 29, 2012.

Figure 3.120: *Crucigenia tetrapedia* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, August 29, 2011.

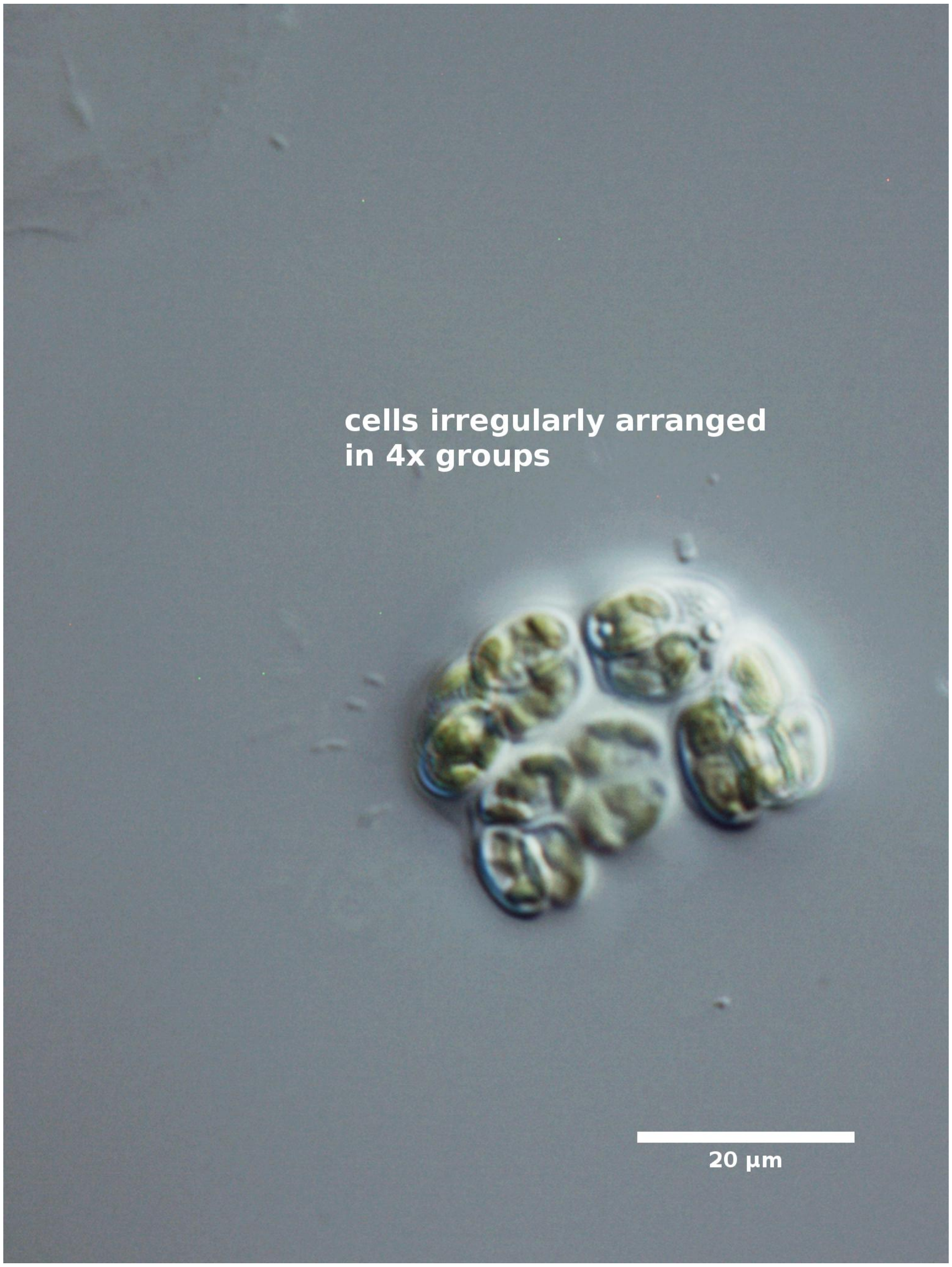

Figure 3.121: *Crucigeniella irregularis*? (600x DIC), Lake Howard, IWS water quality sampling site, Snohomish County, August 7, 2012.

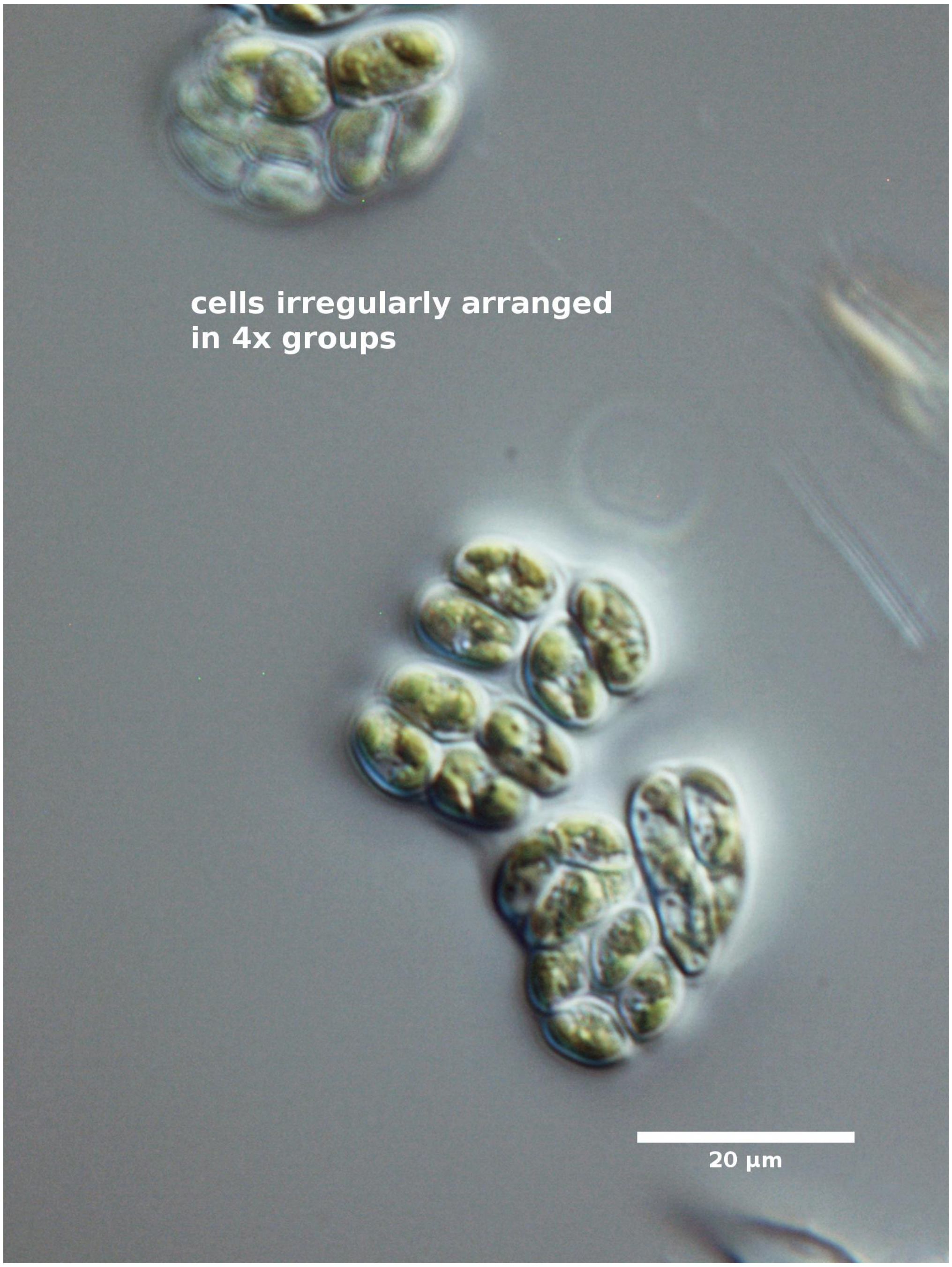

Figure 3.122: *Crucigeniella irregularis*? (600x DIC), Lake Howard, IWS water quality sampling site, Snohomish County, August 7, 2012.

3.12 *Dictyosphaerium* Nägeli

Local taxa

Dictyosphaerium chlorelloides (Naumann) Komárek & Perman?;
Dictyosphaerium pulchellum H. C. Wood
(=*Mucidosphaerium pulchellum* [H. C. Wood] C. Bock, Proschoid & Krientz)

Abundance

Dictyosphaerium pulchellum is moderately common and may be present in large numbers; *Dictyosphaerium chlorelloides* is infrequently collected.

Local measurements		Width	Length	Biovolume†
Dictyosphaerium	min	4.4 μm	4.8 μm	48.7 μm^3
chlorelloides?	med	5.0 μm	6.1 μm	79.2 μm^3
cells (spheroid)	max	6.5 μm	6.7 μm	148 μm^3
Dictyosphaerium	min	4.1 μm	5.5 μm	48.4 μm^3
pulchellum	med	6.2 μm	6.8 μm	131 μm^3
cells (spheroid)	max	9.1 μm	10.1 μm	438 μm^3

†Calculated using original measurements, not summary values.

Description

Dictyosphaerium cells are spherical or oval. The colonies contain cells in groups of 2–4 located at the ends of mucilaginous strands that radiate from the colony center. The cells are usually widely separated, so the radiating strands are clearly visible. Each cell contains a cup-shaped chloroplast with a single pyrenoid.

Dictyosphaerium chlorelloides colonies contain only 2–4 cells (Figure 3.123). The cells are attached to the remnants of the old mother cell, which is curved into a cup-like shape. The identification of the specimen in Figure 3.123 is uncertain because of the poor image quality.

Dictyosphaerium pulchellum colonies are relatively large and may contain >32 cells (Figures 3.124–3.128). The cells are in groups of 4 at the end of branching mucilaginous strands. The cells in old colonies are usually spherical, but young cells may be oval, elliptical, or even fusiform. The colonies often contain parasitic fungi (Figure 3.128).

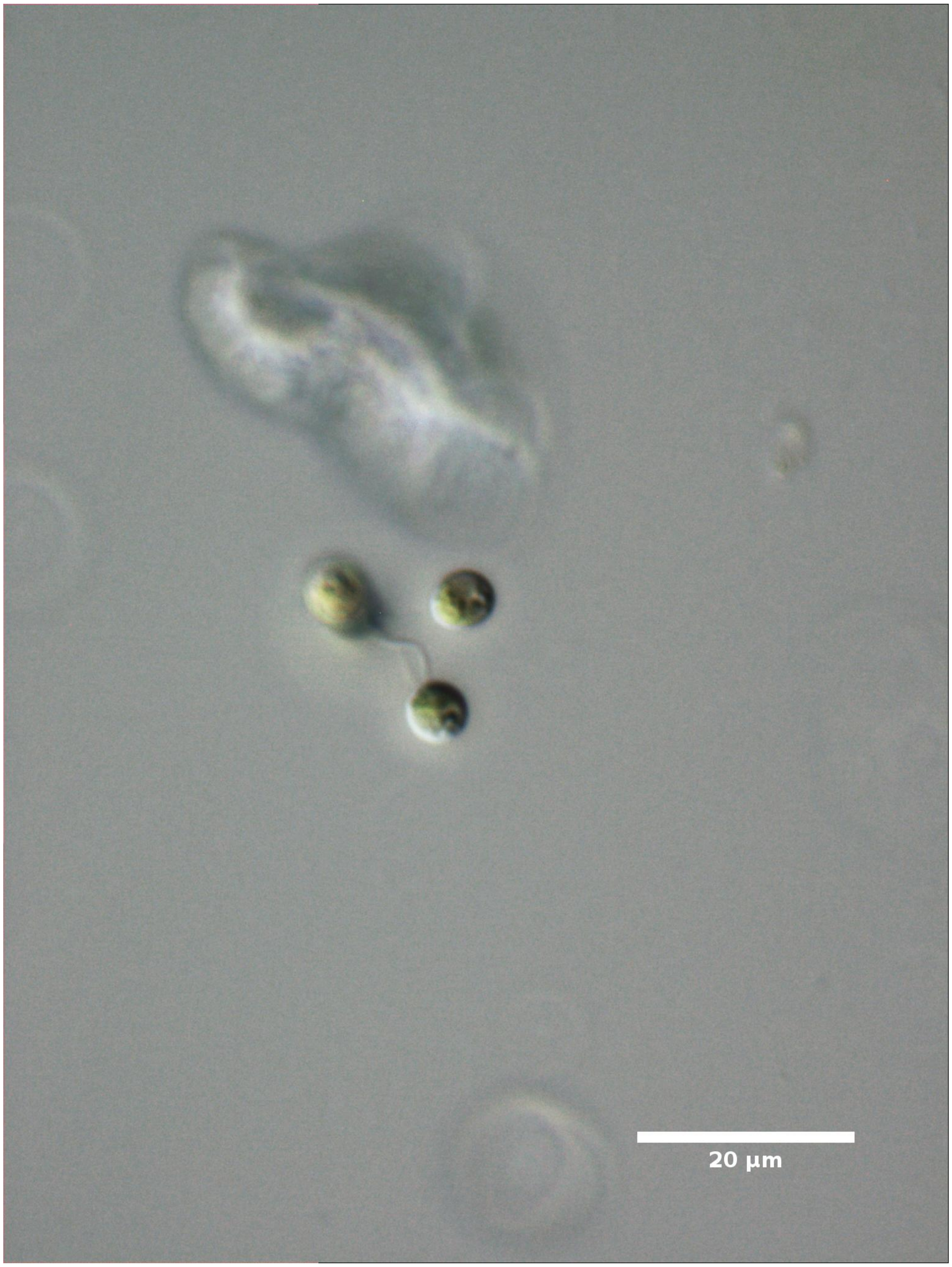

Figure 3.123: *Dictyosphaerium chlorelloides*? (600x DIC), Lake Geneva, IWS water quality sampling site, Whatcom County, July 12, 2011.

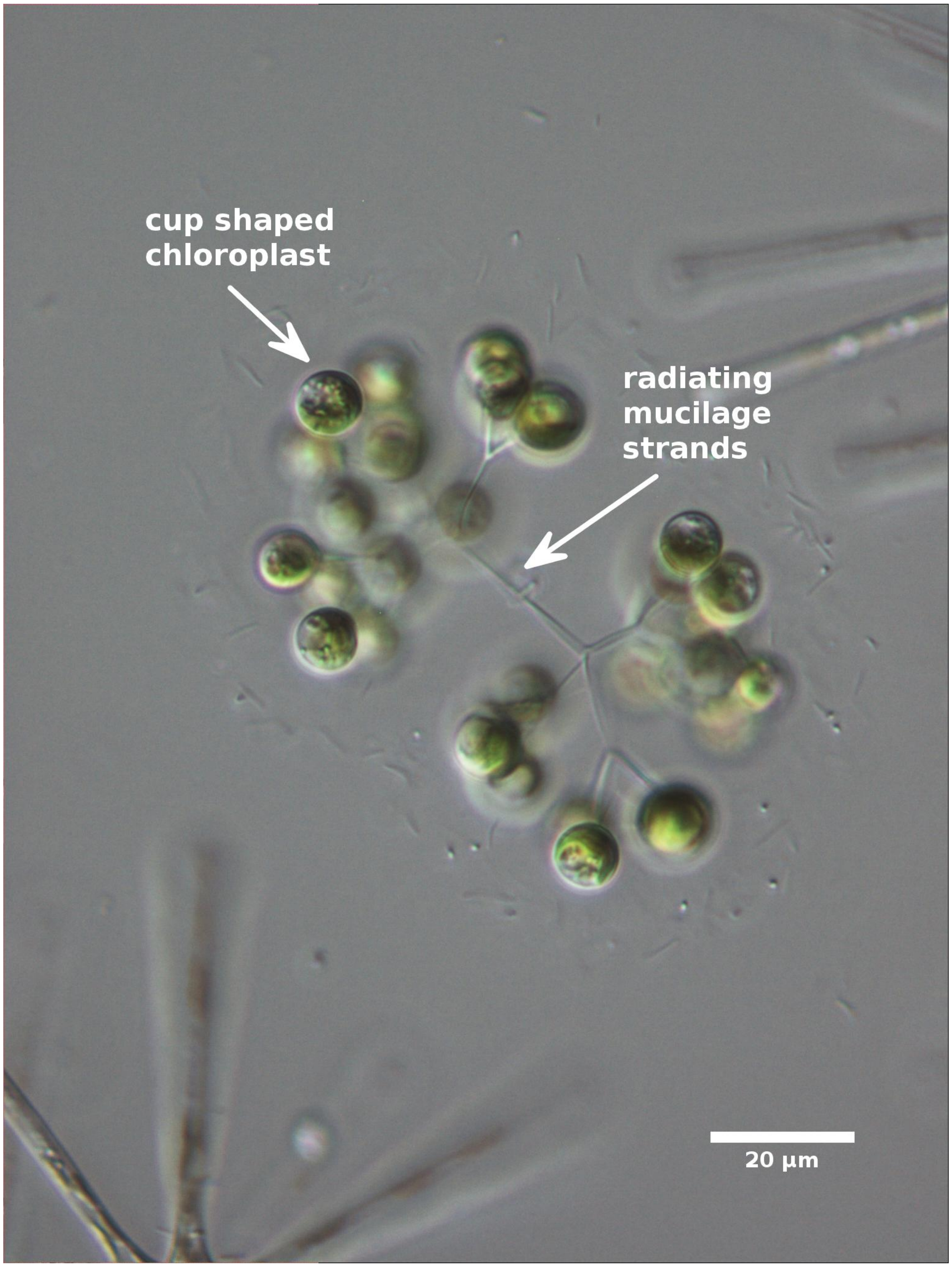

Figure 3.124: *Dictyosphaerium pulchellum* (400x DIC), Lake Padden, IWS water quality sampling site, Whatcom County, April 21, 2009.

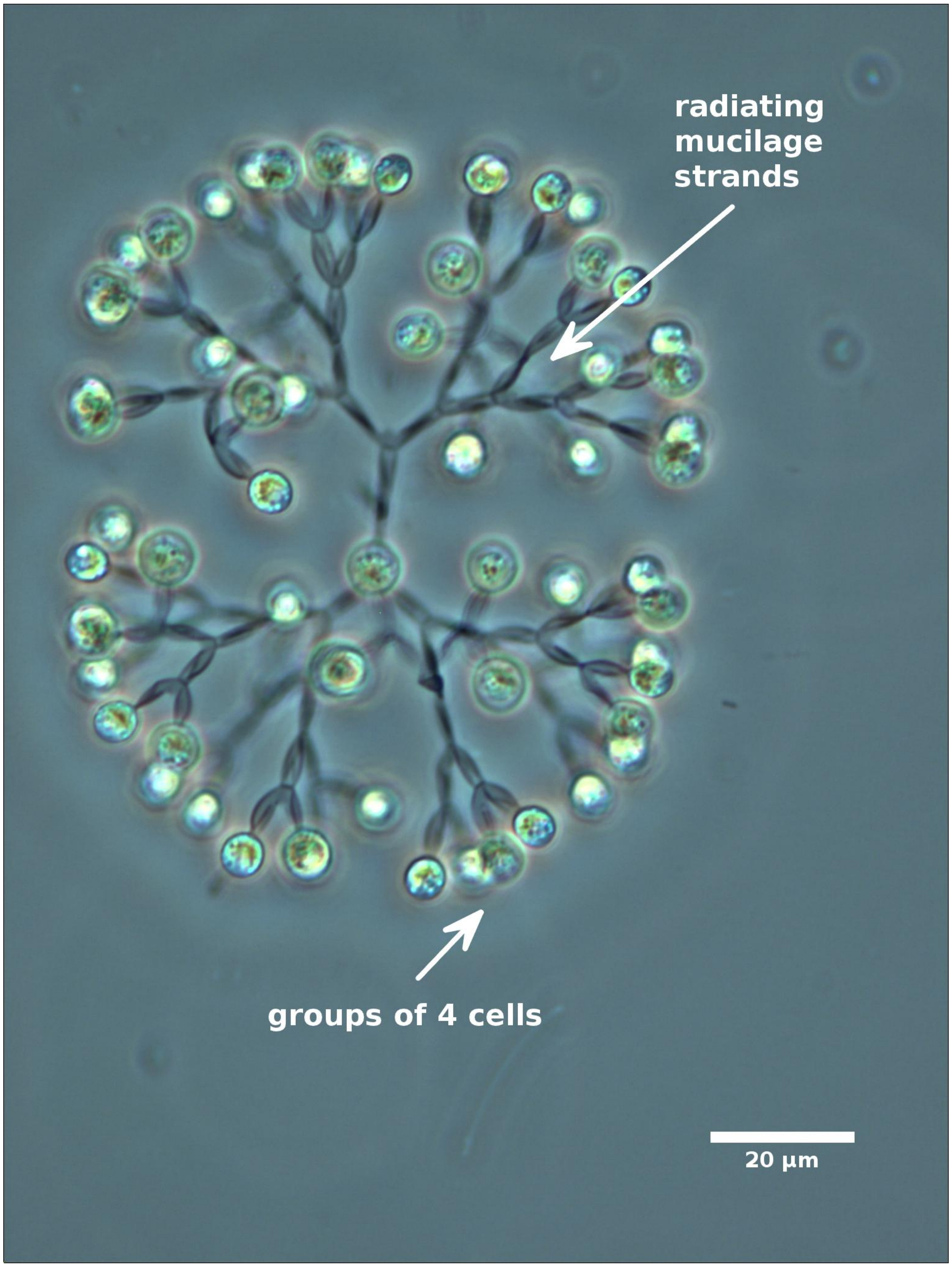

Figure 3.125: *Dictyosphaerium pulchellum* (400x phase contrast), Lake Erie, IWS water quality sampling site, Skagit County, March 30, 2007.

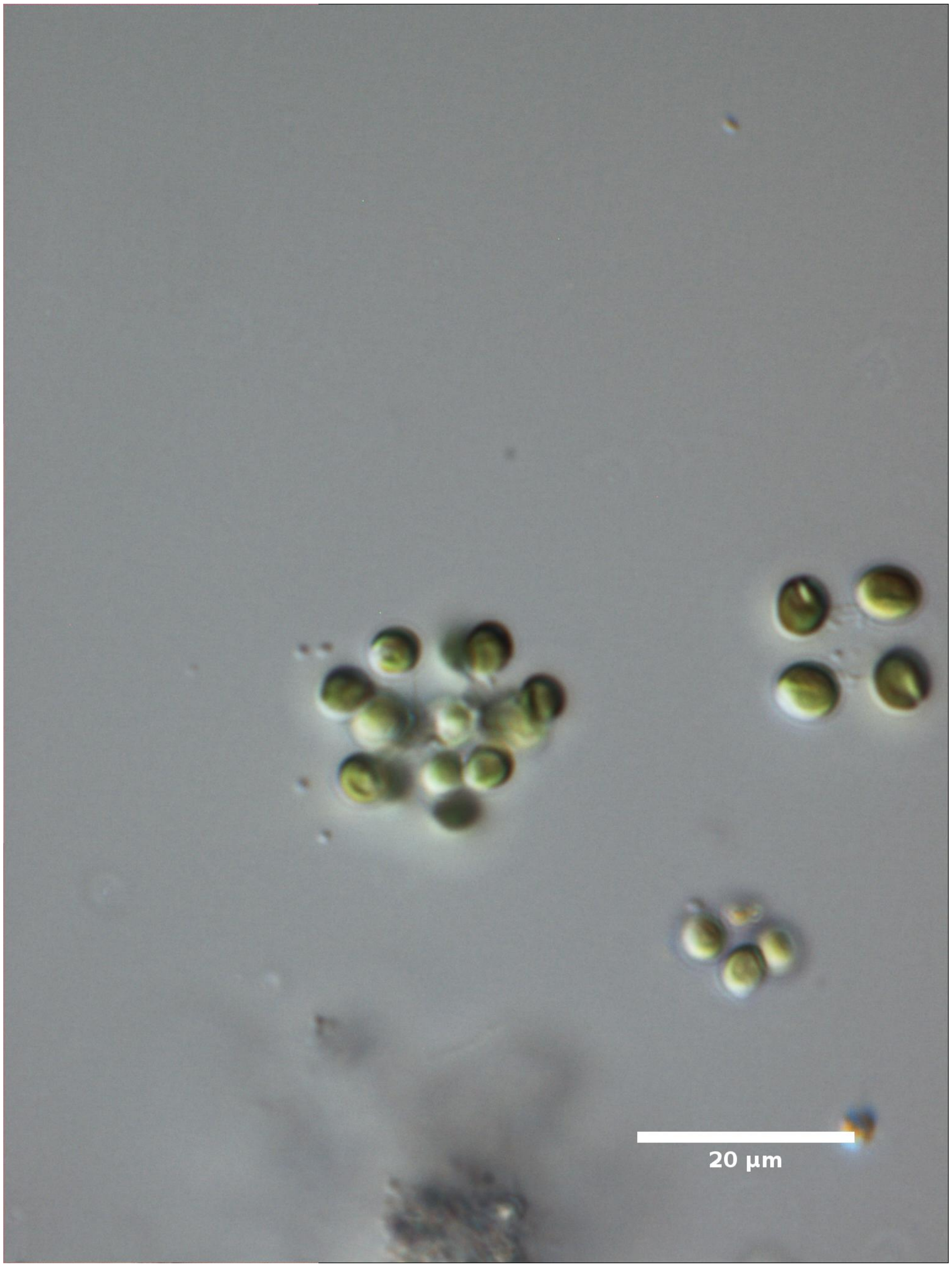

Figure 3.126: *Dictyosphaerium pulchellum* (600x DIC), freshwater pond uphill from Mud Bay, Whatcom County, May 7, 2009.

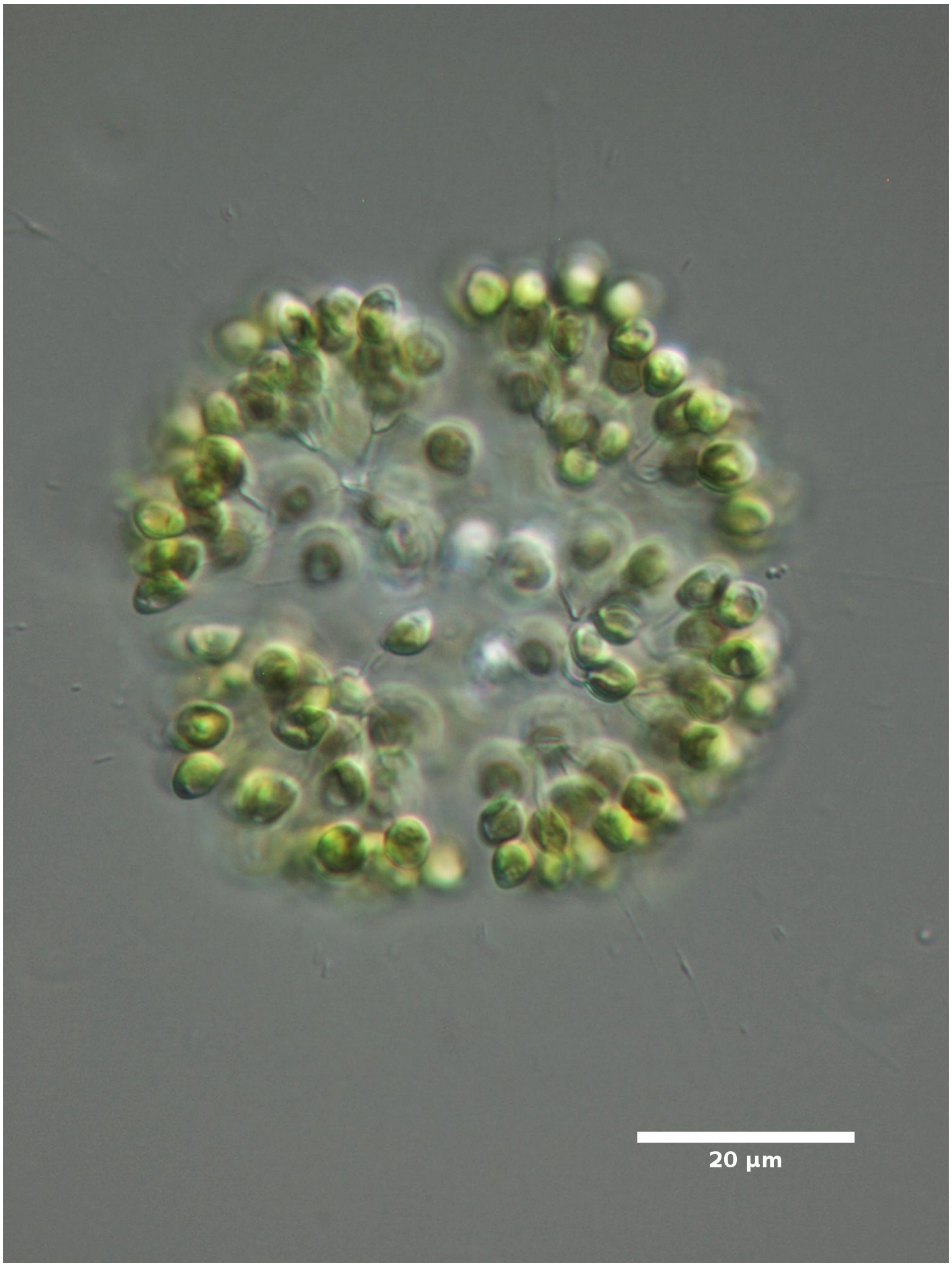

Figure 3.127: *Dictyosphaerium pulchellum* (600x DIC), Lake Padden, IWS water quality sampling site, Whatcom County, October 26, 2012.

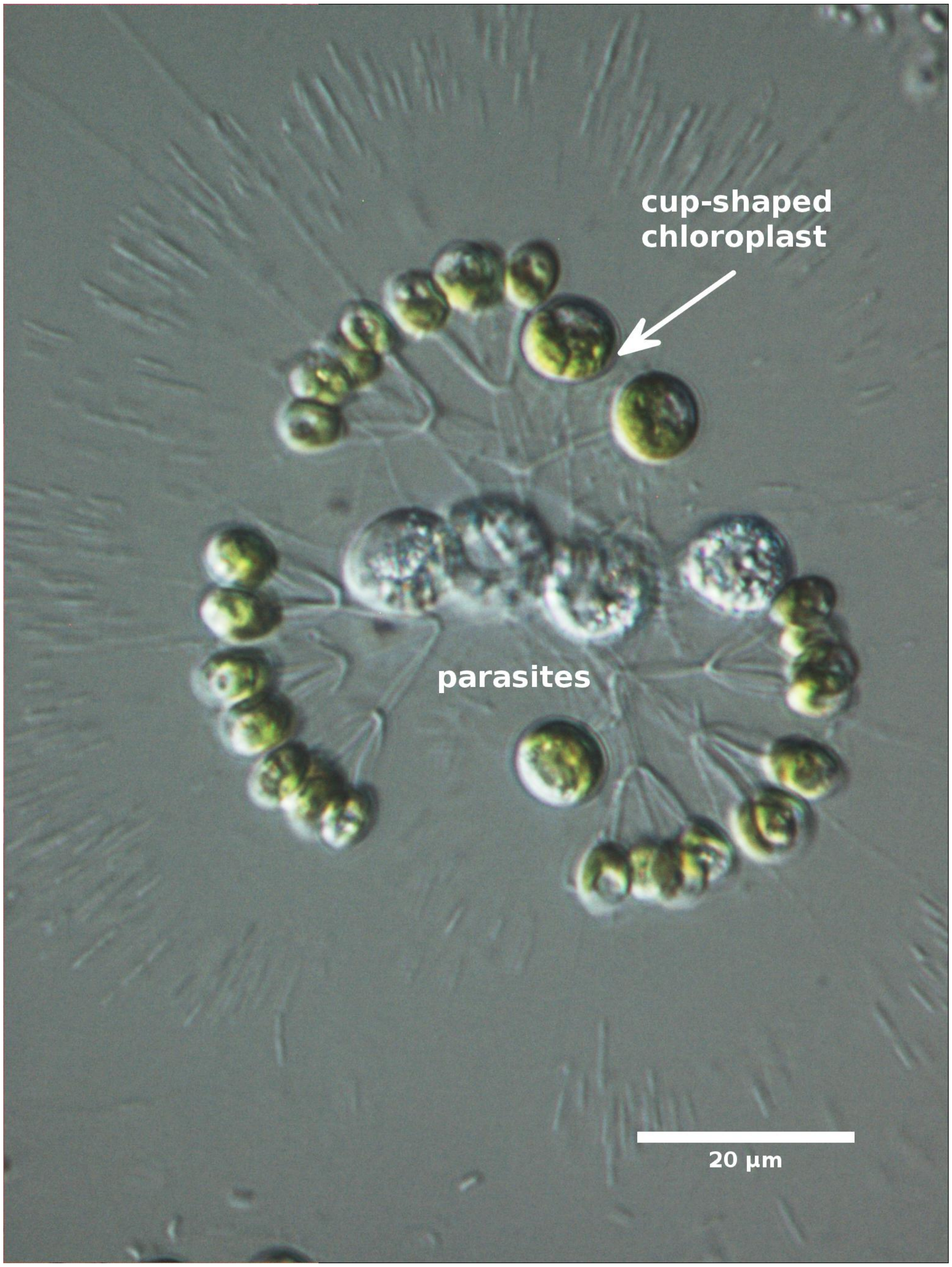

Figure 3.128: *Dictyosphaerium pulchellum* with parasitic fungi (600x DIC), Lake Whatcom, IWS water quality sampling site, October 12, 2010.

3.13 *Dimorphococcus* A. Braun

Local taxon
Dimorphococcus lunatus A. Braun

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Dimorphococcus lunatus	min	5.5 μm	12.8 μm	275 μm^3
cells (spheroid)	med	6.4 μm	15.4 μm	373 μm^3
	max	6.8 μm	26.1 μm	434 μm^3

†Calculated using original measurements, not summary values; biovolume estimates are approximate due to the irregular cell shape.

Description
Dimorphococcus cells may be elliptical, bluntly crescent-shaped, or heart-shaped. The cells form small colonies of irregularly shaped cells in groups of 4 attached to mucilaginous strands that are the remnants of the old mother cell wall (Figures 3.129–3.130). *Dimorphococcus lunatus* has cells groups with two more-or-less straight, elliptical inner cells and two curved, crescent-shaped or heart-shaped outer cells.

Figure 3.129: *Dimorphococcus lunatus* (200x DIC), Sunday Lake, IWS water quality sampling site, Snohomish County, September 2, 2009.

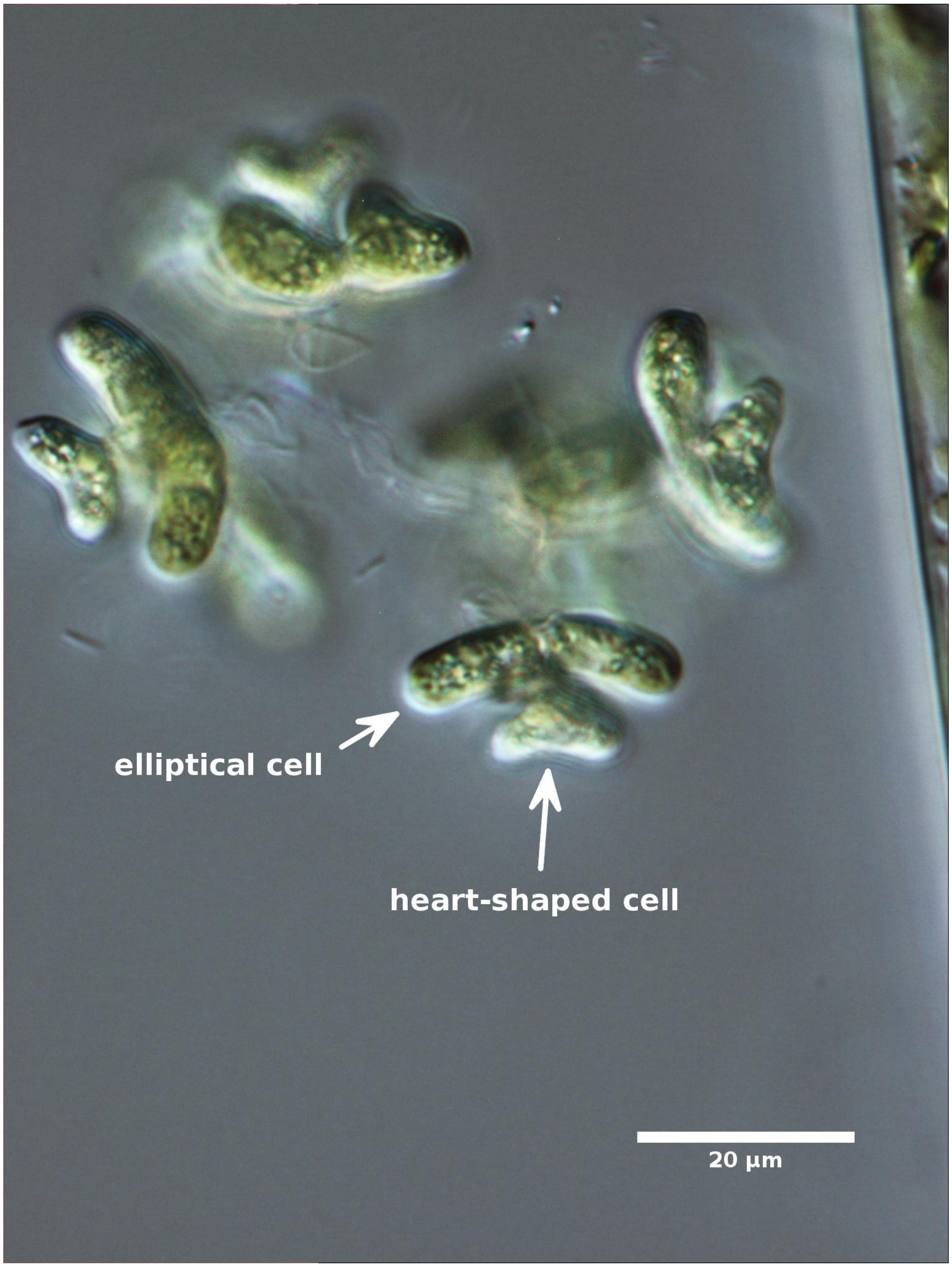

Figure 3.130: *Dimorphococcus lunatus* (600x DIC), Sunday Lake, IWS water quality sampling site, Snohomish County, September 2, 2009.

3.14 *Elakatothrix* Wille

Local taxa
Elakatothrix gelatinosa Wille;
Elakatothrix viridis (Snow) Printz (=*Fusola viridis* Snow);
Elakatothrix sp.

Abundance
Moderately common; rarely present in large numbers.

Local measurements		Width	Length	Biovolume[†]
Elakatothrix gelatinosa	min	3.6 μm	22.2 μm	83.9 μm^3
cells (fusiform)	med	4.8 μm	34.3 μm	221 μm^3
	max	5.7 μm	52.1 μm	427 μm^3
Elakatothrix viridis	min	8.5 μm	43.7 μm	827 μm^3
cells (fusiform)	med	10.8 μm	49.3 μm	1,560 μm^3
	max	11.2 μm	52.9 μm	1,650 μm^3
Elakatothrix sp.1[‡]	min	2.7 μm	10.2 μm	88.6 μm^3
cells (cyl + two $\frac{1}{2}$ spheres)	med	4.4 μm	18.9 μm	212 μm^3
	max	5.2 μm	33.4 μm	534 μm^3

[†]Calculated using original measurements, not summary values.
[‡]Biovolume based on cylinder length (< cell length).

Description
Elakatothrix cells are fusiform, elliptical, or asymmetric and spindle-shaped (Figures 3.131–3.139). Each cell contains a single chloroplast with one or more pyrenoids. The cell shape is quite variable due to the transverse mode of cellular division, which often creates short, asymmetric daughter cells. *Elakatothrix* is closely related to the filamentous genus *Klebsormidium* (Section 4.12, page 630), and is often grouped with filamentous algae because some of the taxa (e.g., *Elakatothrix* sp.1) have cells that are oriented end-to-end inside a mucilaginous sheath to form pseudofilaments. But the most common local species, *Elakatothrix gelatinosa*, forms lens-shaped colonies and the cells do not exhibit any obvious filamentous structure, so the genus description is included in this chapter.

Elakatothrix gelatinosa cells may be solitary, but usually form small colonies (2–32 cells) enclosed in a distinctive, lens-shaped colonial mucilage (Figures 3.131–3.134). The narrow, fusiform or spindle-shaped cells are oriented with their long axis parallel to the long axis of the colonial mucilage. The colonial mucilage may be faint, but will be visible using phase contrast or when stained with methylene blue.

Elakatothrix viridis is included in this section because of its morphological similarity *Elakatothrix gelatinosa*. *Elakatothrix viridis* cells are broadly fusiform (not spindle-shaped), with a large chloroplast the fills the entire cells (Figures 3.135–3.136). Solitary cells may be occur, but the cells are usually arranged parallel to each other in small colonies that are enclosed in a lens-shaped colonial mucilage. Although it is listed in most taxonomic keys as a species of *Elakatothrix*, AlgaeBase lists this species as *Fusola viridis* (`www.algaebase.org`, downloaded March 16, 2016). Furthermore, the taxonomic hierarchy on AlgaeBase suggests that, despite visible similarities, this species may not be closely related to other species of *Elakatothrix*.

Elakatothrix sp.1 is characterized by small elliptical or cylindrical cells that form distinct pseudofilaments (Figures 3.137–3.139). The cells are surrounded by a wide mucilage layer that is difficult to see unless stained or viewed using phase contrast illumination. When stained, the mucilage follows the shape of the pseudofilaments rather than forming a lens-shaped colony. Although this species is encountered less frequently than *Elakatothrix gelatinosa*, it can be quite abundant when present.

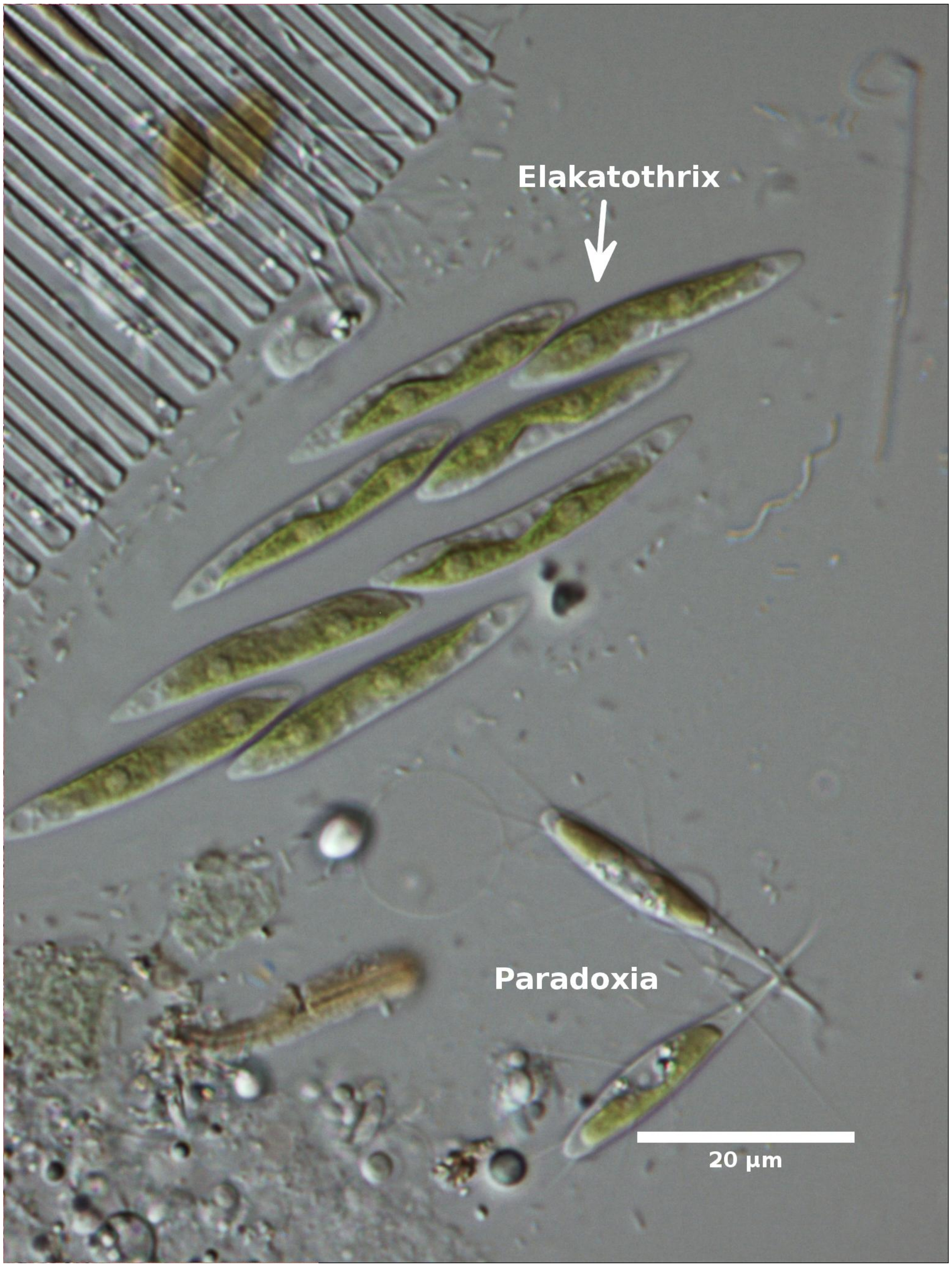

Figure 3.131: *Elakatothrix gelatinosa* (600x DIC), Cranberry Lake, IWS water quality sampling site, Island County, September 1, 2008.

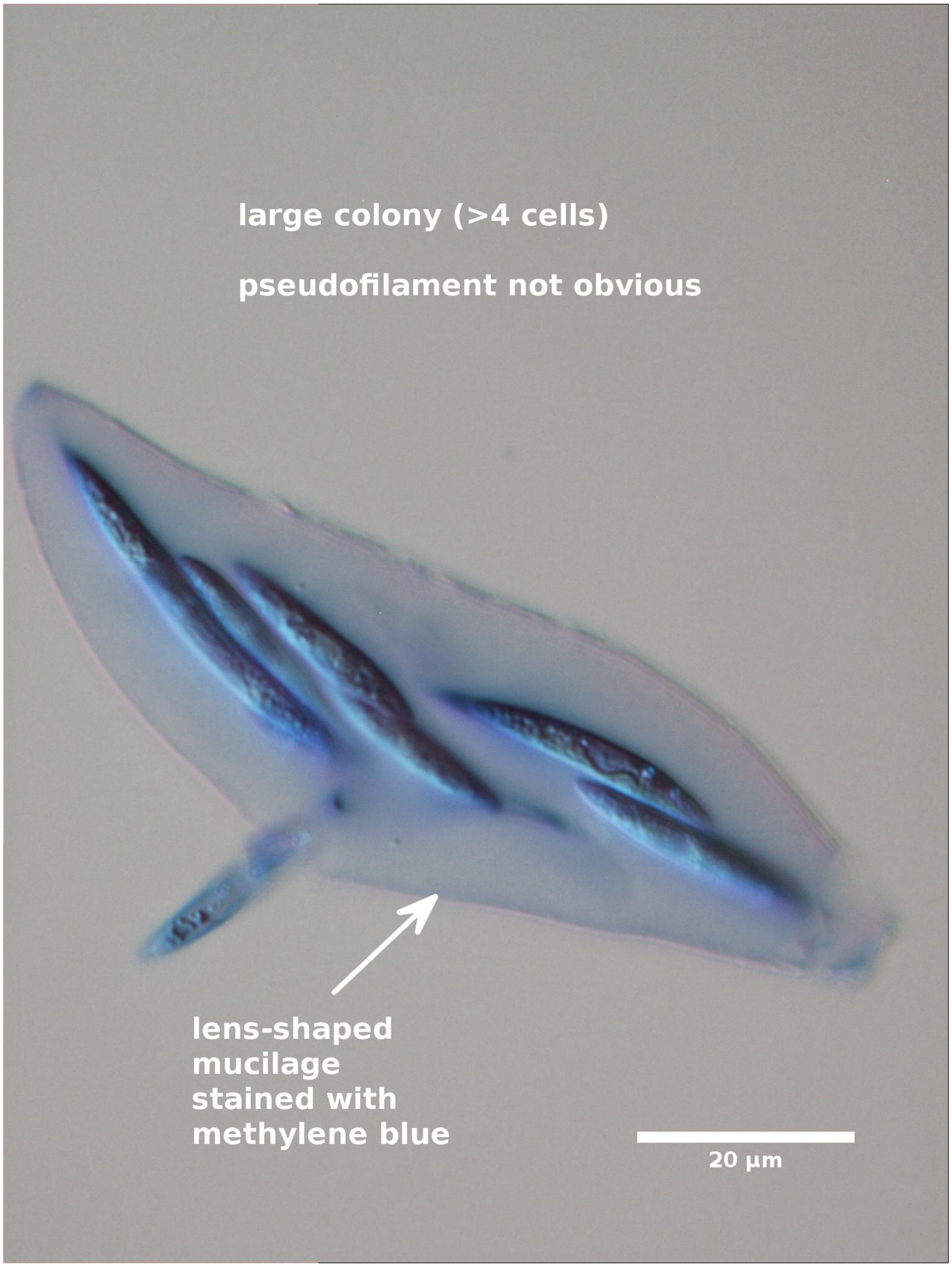

Figure 3.132: *Elakatothrix gelatinosa* stained with methylene blue (600x DIC), Toad Lake, IWS water quality sampling site, Whatcom County, June 27, 2011.

Figure 3.133: *Elakatothrix gelatinosa* (600x DIC), Lake Ketchum, IWS water quality sampling site, Snohomish County, August 2, 2012.

Figure 3.134: *Elakatothrix gelatinosa* stained with methylene blue (400x phase contrast), Silver Lake, IWS water quality sampling site, Whatcom County, August 28, 2012.

Figure 3.135: *Elakatothrix viridis* (600x DIC), small lake north of Sultan, Snohomish County, April 27, 2015.

Figure 3.136: *Elakatothrix viridis* (600x DIC), small lake north of Sultan, Snohomish County, April 27, 2015.

Figure 3.137: *Elakatothrix* sp.1 (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 5, 2011.

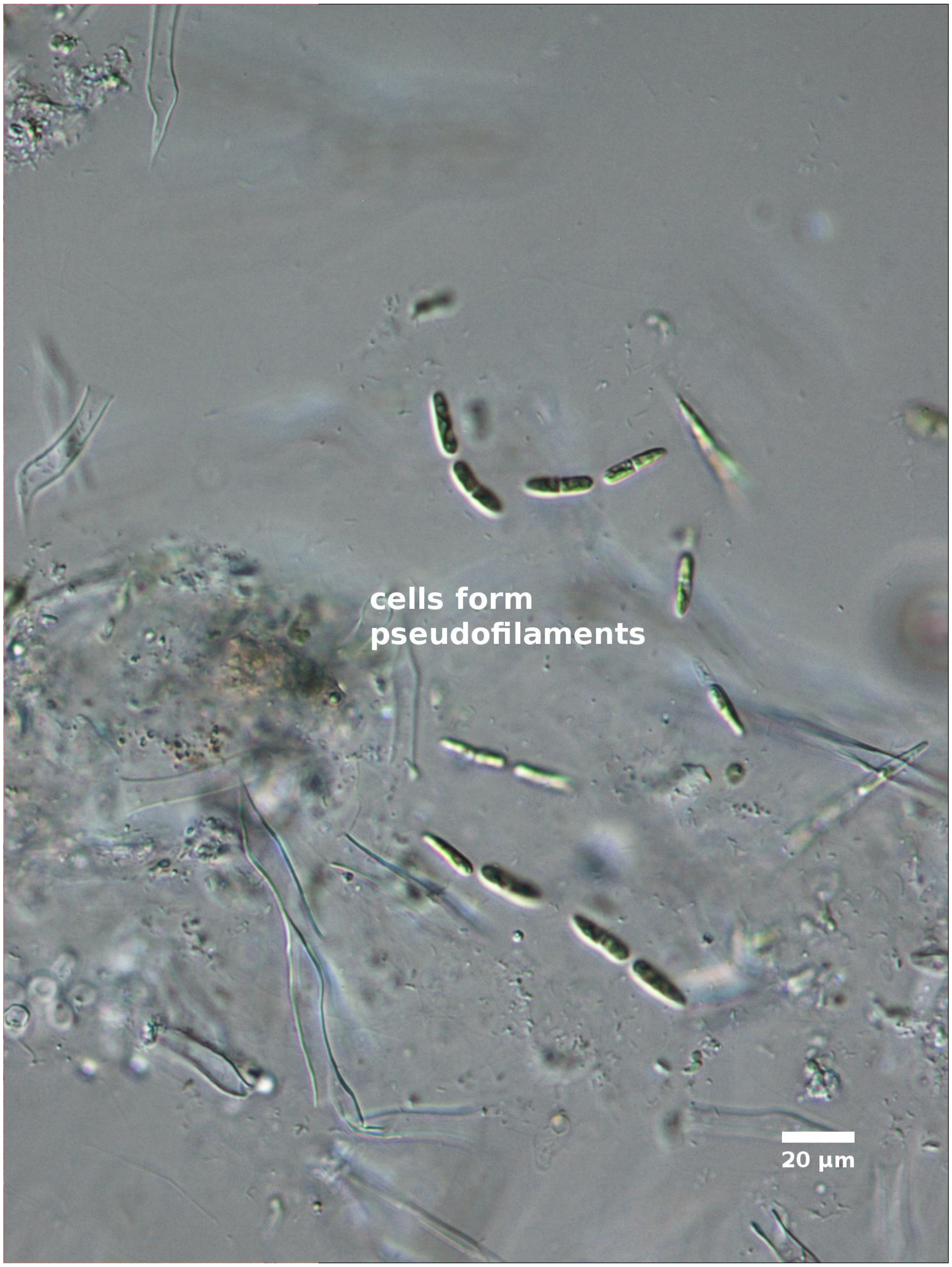

Figure 3.138: *Elakatothrix* sp.1 (200x DIC), Lake Goodwin, IWS water quality sampling site, Snohomish County, April 1, 2010.

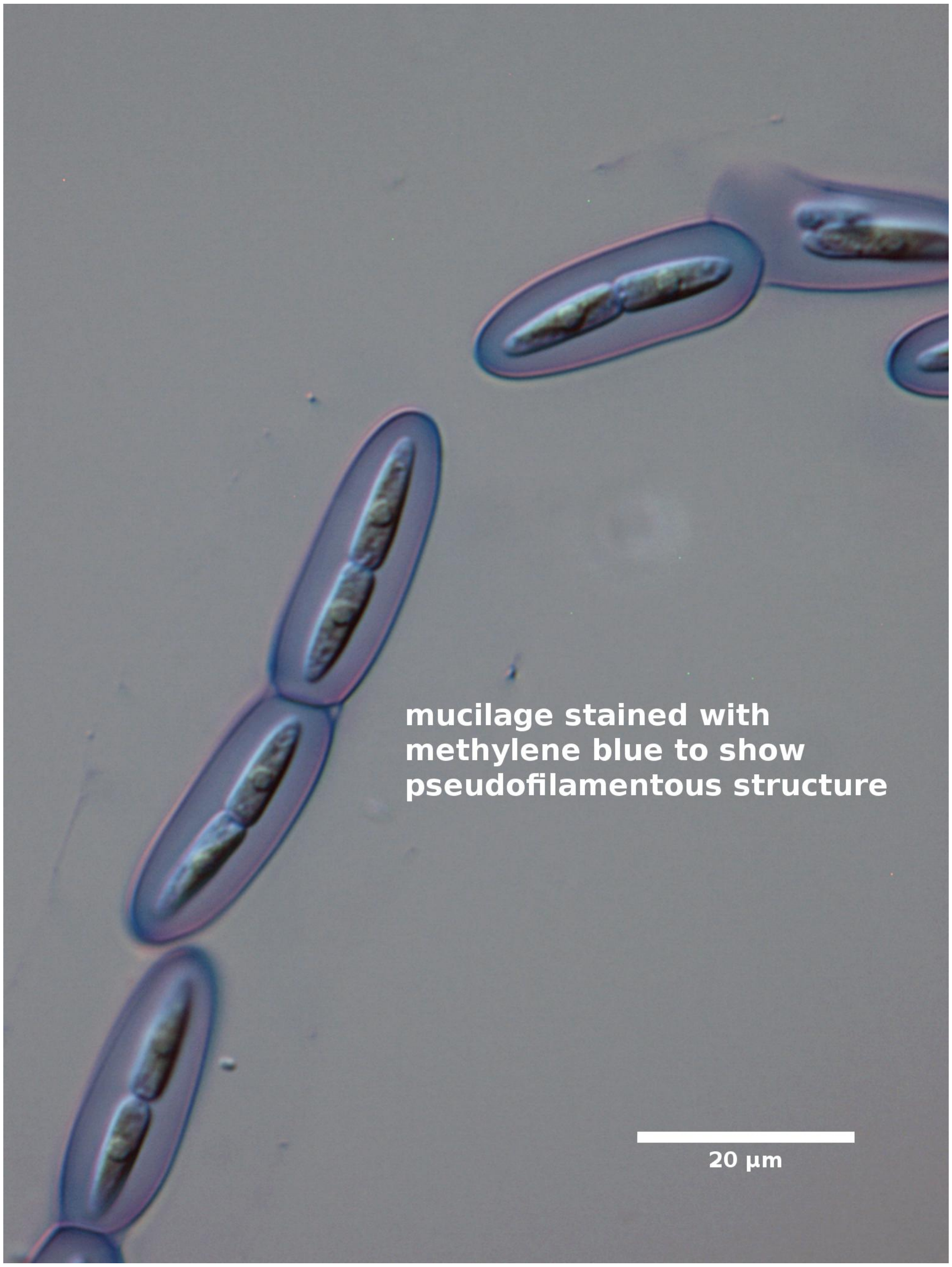

Figure 3.139: *Elakatothrix* sp.1 stained with methylene blue (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, July 11, 2013.

3.15 *Eremosphaera* De Bary

Local taxon
Eremosphaera viridis de Bary

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Eremosphaera viridis	min	146.1 μm	–	1,630,000 μm^3
cells (sphere)	med	167.9 μm	–	2,480,000 μm^3
	max	195.0 μm	–	3,880,000 μm^3

†Calculated using original measurements, not summary values.

Description
Eremosphaera viridis cells are solitary, spherical, and very large (Figures 3.140–3.143). The cells have a large interior vacuole with a central nucleus connected to the periphery by long radiating strands of mucilage. Wrinkled, irregularly shaped chloroplasts cover the surface of the cell and may also be embedded in the mucilaginous strands. Oil droplets are often visible, especially on the surface of the cell (Figure 3.143). This species is associated with acidic water and *Sphagnum* bogs; most of the local specimens were collected in Highwood Lake and Picture Lake, two small, high elevation lakes near Mt. Baker.

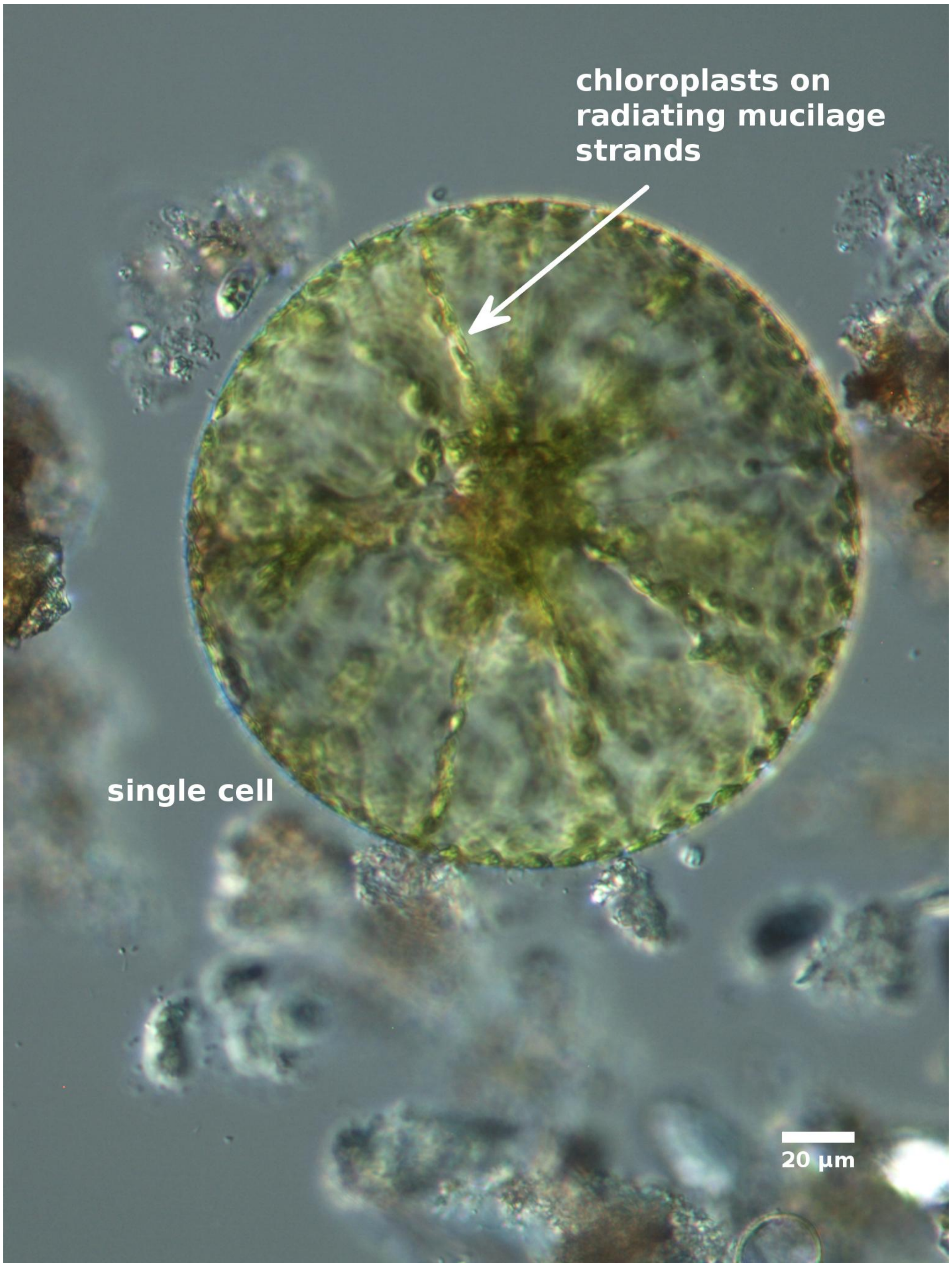

Figure 3.140: *Eremosphaera viridis* (200x DIC), Highwood Lake, IWS water quality sampling site, Whatcom County, August 19, 2013.

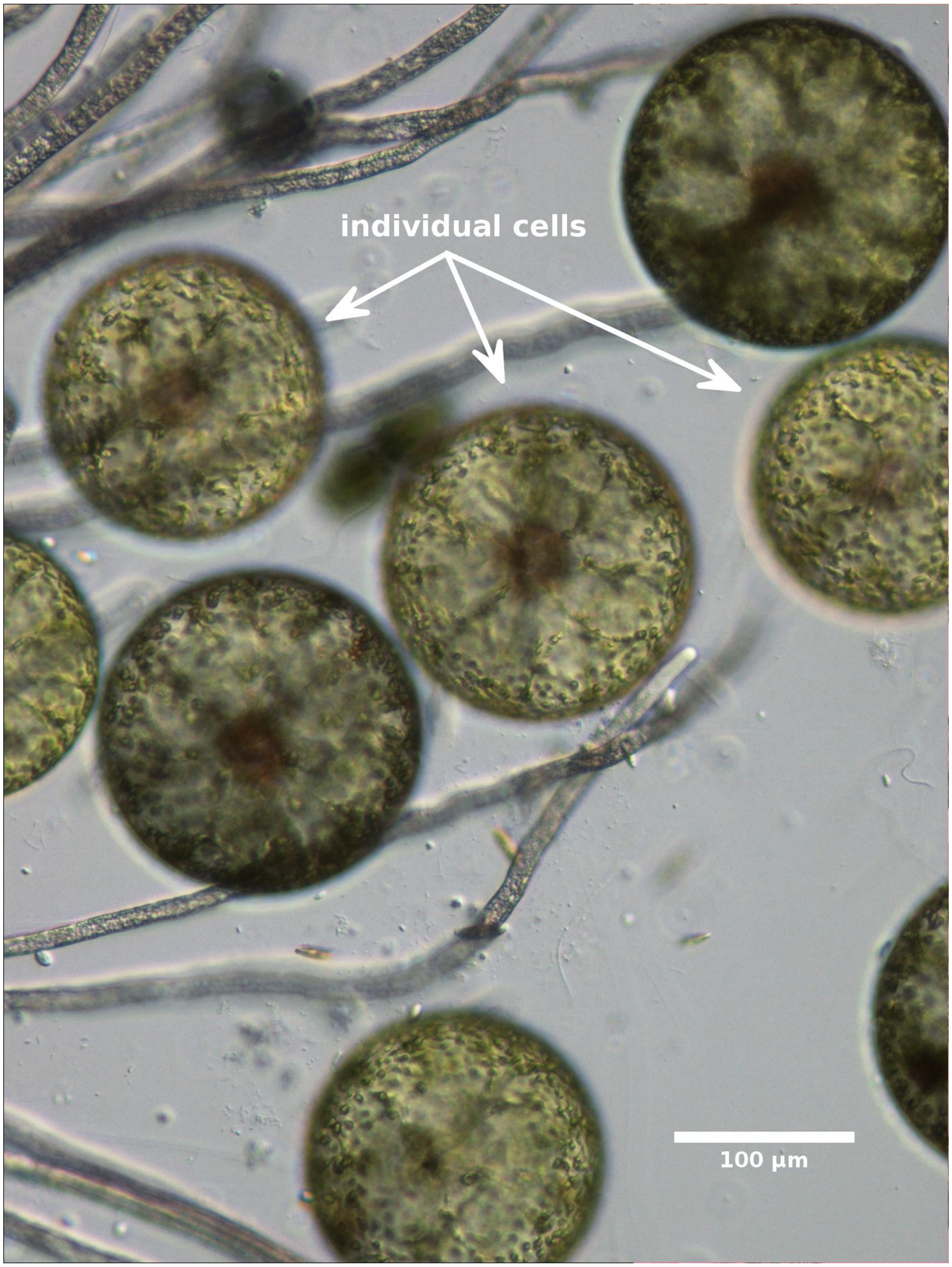

Figure 3.141: *Eremosphaera viridis* (100x DIC), Highwood Lake, IWS water quality sampling site, Whatcom County, September 29, 2010.

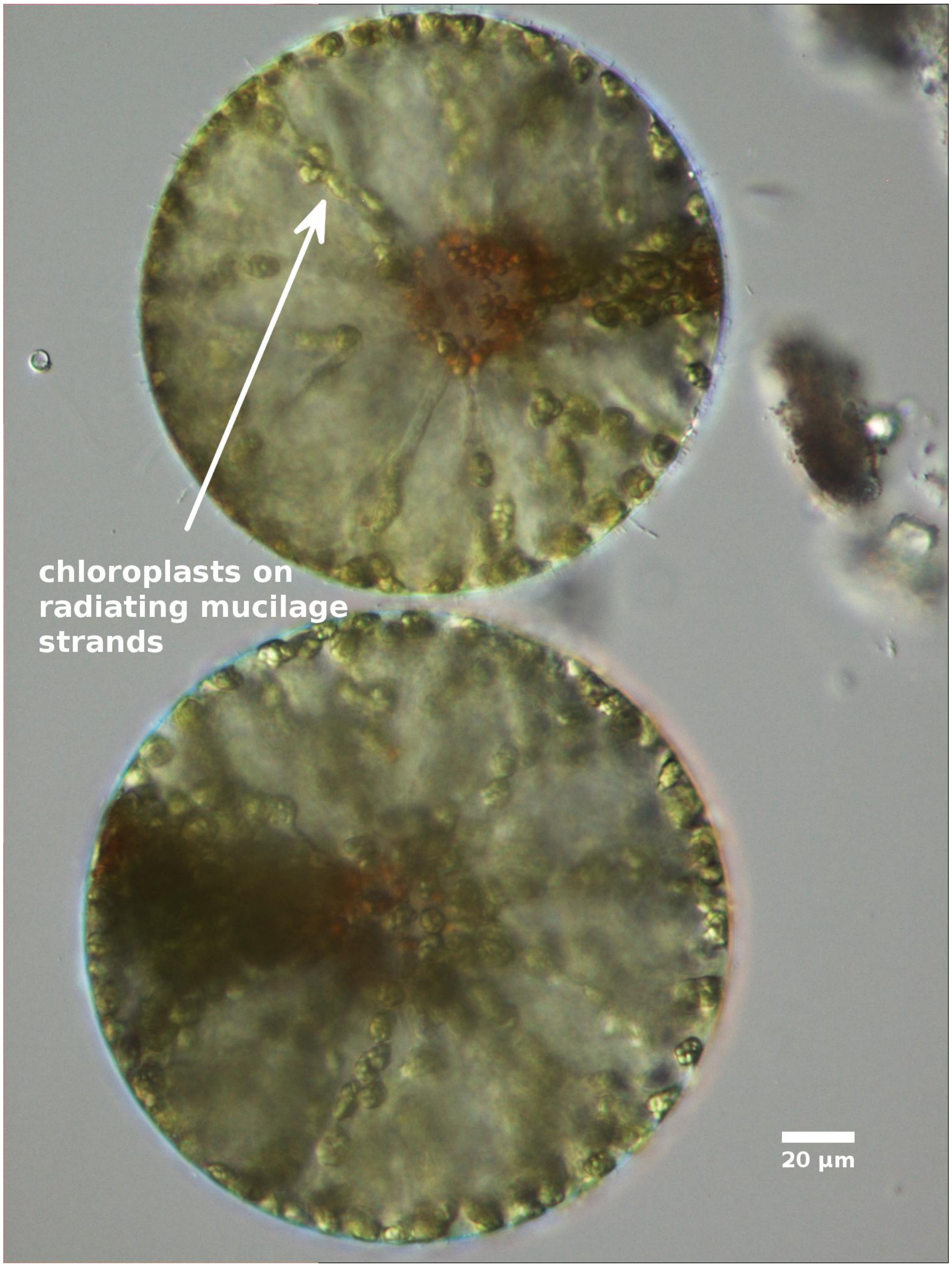

Figure 3.142: *Eremosphaera viridis* (200x DIC), Highwood Lake, IWS water quality sampling site, Whatcom County, August 29, 2011.

Figure 3.143: *Eremosphaera viridis* (600x DIC), Highwood Lake, IWS water quality sampling site, Whatcom County, September 16, 2010.

3.16 *Gloeocystis* Nägeli (and similar taxa)

Local taxa

Gloeocystis spp.

Abundance

Moderately common; may be present in large numbers but rarely forms blooms.

Local measurements		Width	Length	Biovolume†
Gloeocystis sp.1	min	7.4 μm	11.0 μm	315 μm^3
cells (spheroid)	med	10.3 μm	14.1 μm	762 μm^3
	max	12.1 μm	15.1 μm	1,160 μm^3
Gloeocystis sp.2	min	9.8 μm	11.5 μm	664 μm^3
cells (spheroid)	med	10.8 μm	13.2 μm	778 μm^3
	max	12.6 μm	14.3 μm	1,190 μm^3
Gloeocystis sp.3	min	7.1 μm	13.6 μm	370 μm^3
cells (spheroid)	med	8.3 μm	14.6 μm	545 μm^3
	max	14.4 μm	18.8 μm	2,040 μm^3
Gloeocystis sp.4	min	19.4 μm	20.0 μm	3,940 μm^3
cells (spheroid)	med	20.1 μm	21.3 μm	4,630 μm^3
	max	20.3 μm	21.9 μm	4,600 μm^3

†Calculated using original measurements, not summary values.

Description

Gloeocystis species are difficult to identify, and John, et al. (2011) indicate that some of the common species are “doubtful records” that may be nonmotile forms of other green algae. For practical purposes, this section will include all spherical or slightly elliptical, nonmotile Chlorophyta cells that fit the general description for *Gloeocystis* and can’t be assigned to any other genus, but the local lakes and streams almost certainly include additional genera.

Gloeocystis cells are solitary or form small colonies, and may be spherical, oval, or broadly elliptical (Figures 3.144–3.150). Each cell has a cup-shaped chloroplast

(⇒not stellate), with a single pyrenoid. In older cells the chloroplast becomes dense, very dark, and often fills the entire cell. The chloroplast may appear granular due to the accumulation of starch. The cells and colonies are surrounded by a thick mucilage layer that is often layered or stratified, sometimes forming concentric rings.

Compare *Gloeocystis* to *Chlorella* (Section 3.9, page 282), which does not form distinct colonies and has little if any mucilage surrounding the cells. Also compare specimens to *Asterococcus* (Section 3.6, page 245), which has stellate chloroplasts and stratified mucilage surrounding the cells and colony; *Planktosphaeria* (Section 3.29, page 451), which is characterized by solitary cells surrounded by a firm, unstratified mucilage; and *Sphaerocystis* (Section 3.35, page 493), which forms irregular colonies containing large and small cells surrounded by a diffuse, unstriated colonial mucilage.

Gloeocystis sp.1 is characterized by small, oval or broadly elliptical cells with a distinct central pyrenoid (Figures 3.144–3.145). The cells may be solitary or in small, 2-cell or 4-cell colonies. The cells and colonies are surrounded by a distinctly striated mucilage.

Gloeocystis sp.2 cells are small, oval or broadly elliptical, and form medium sized colonies that may contain >16 cells (Figures 3.146–3.147). Within the colonies, smaller subgroups of 1, 2 or 4 cells are visible. The cell groups and colony are enclosed in thick mucilage that may be slightly layered, but will not have concentric striations.

Gloeocystis sp.3 forms small colonies of 4–8 broadly oval cells (Figure 3.148). The cells and colony are enclosed in a thick mucilage that may be slightly layered, but does not form concentric striations and does not enclose individual cells. This taxon resembles *Gloeocystis* sp.4 (below), but the cells are smaller and the specimens were collected from a moderately eutrophic, low elevation lake.

Gloeocystis sp.4 resembles online descriptions and images for *Gloeocystis gigas* (Kützing) Lagerheim (=*Chlamydocapsa planctonica* (West & G. S. West) Fott), which is characterized by large, broadly oval cells that are either solitary or form 4-cell tetrahedral groups (Figures 3.149–3.150). The cells or cell groups are surrounded by a distinct mucilage layer. This taxon resembles *Gloeocystis* sp.3, but the cells are considerably larger and the specimens were collected from boggy mountain lakes. John, et al. (2011) state that there is "considerable debate" about the validity of the genus *Chlamydocapsa* and the species *Gloeocystis gigas*.

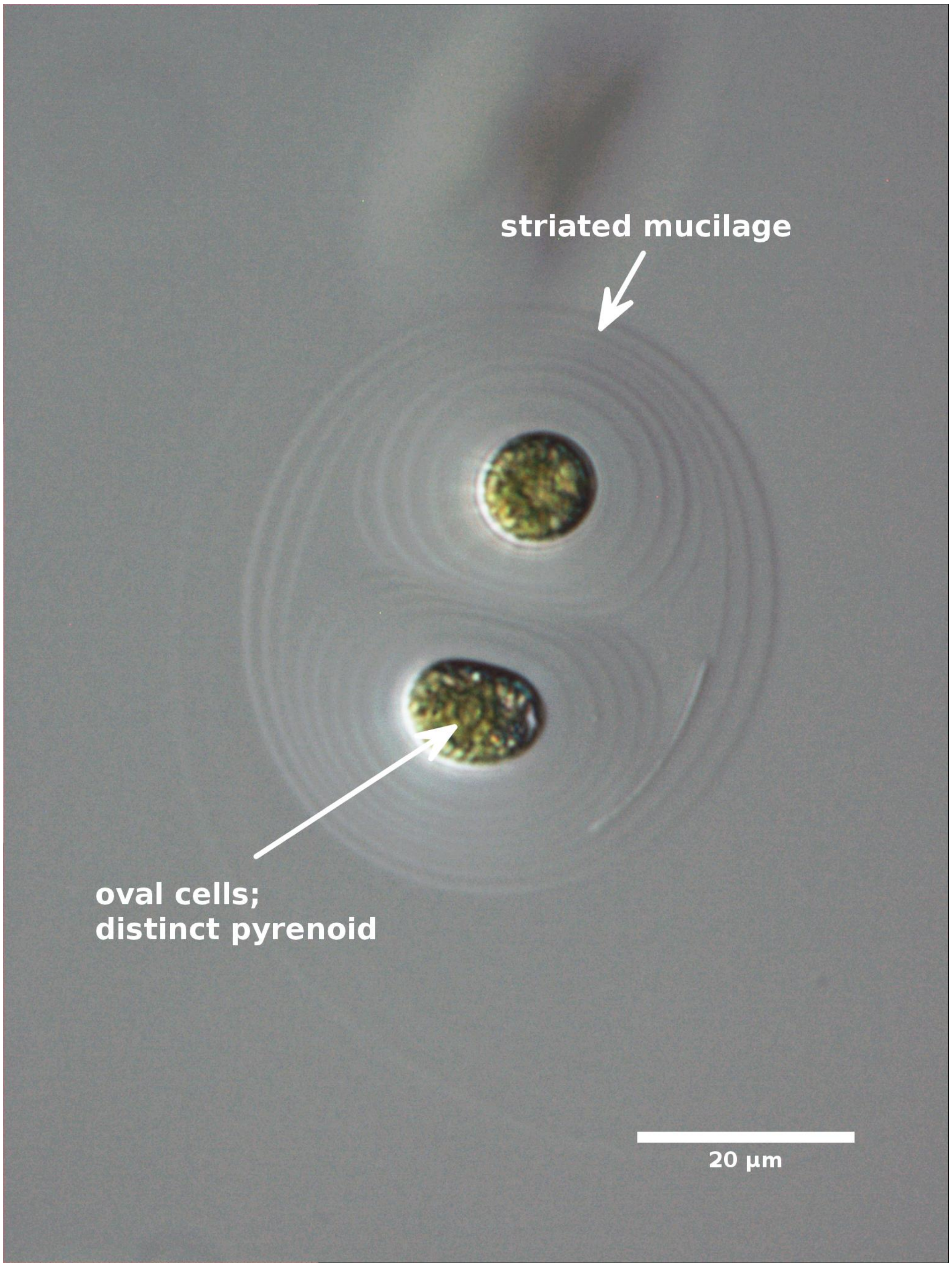

Figure 3.144: *Gloeocystis* sp.1 (600x DIC), Lake Ki, IWS water quality sampling site, Snohomish County, July 26, 2011.

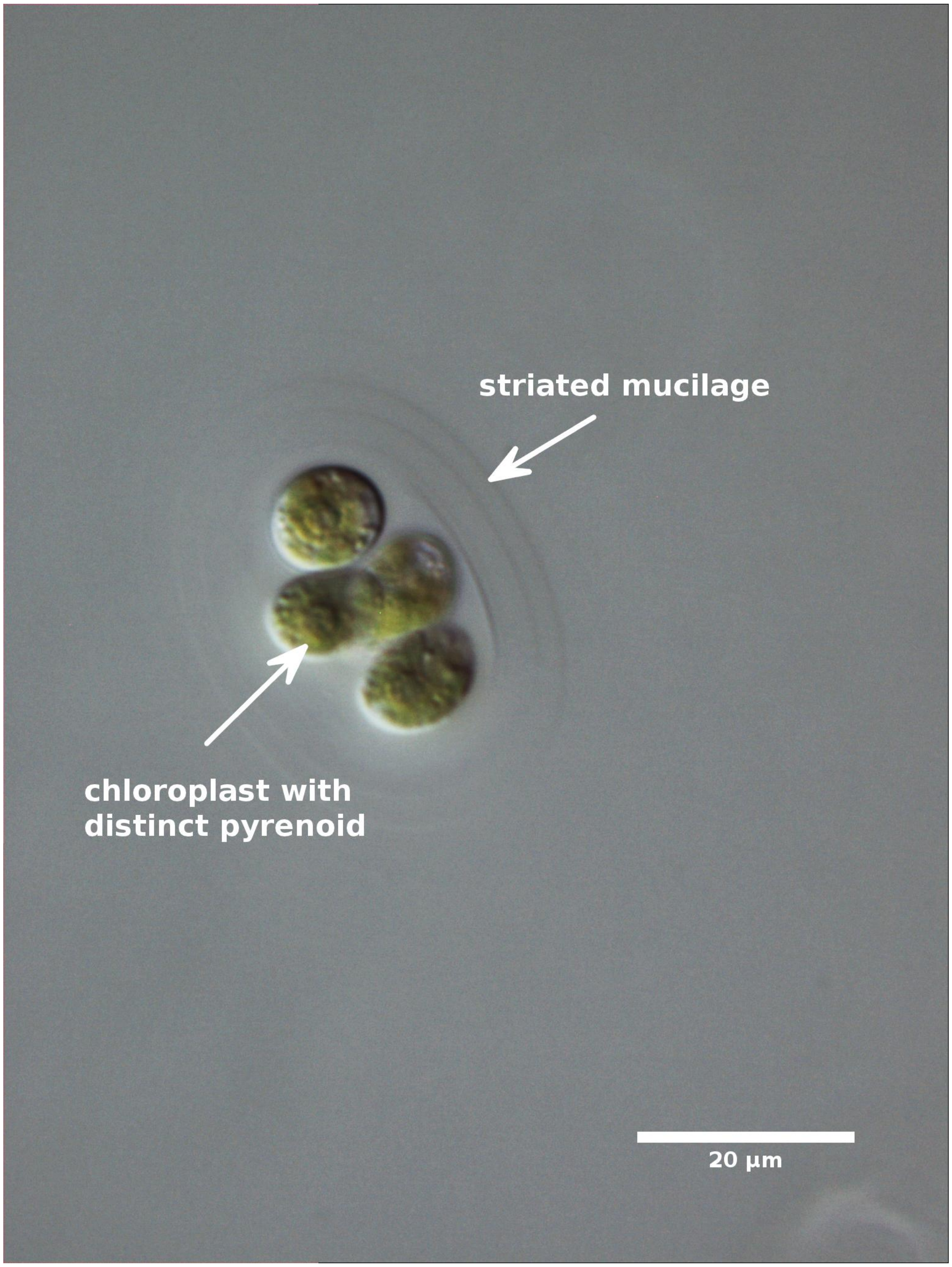

Figure 3.145: *Gloeocystis* sp.1 (600x DIC), Cain Lake, IWS water quality sampling site, Whatcom County, August 14, 2008.

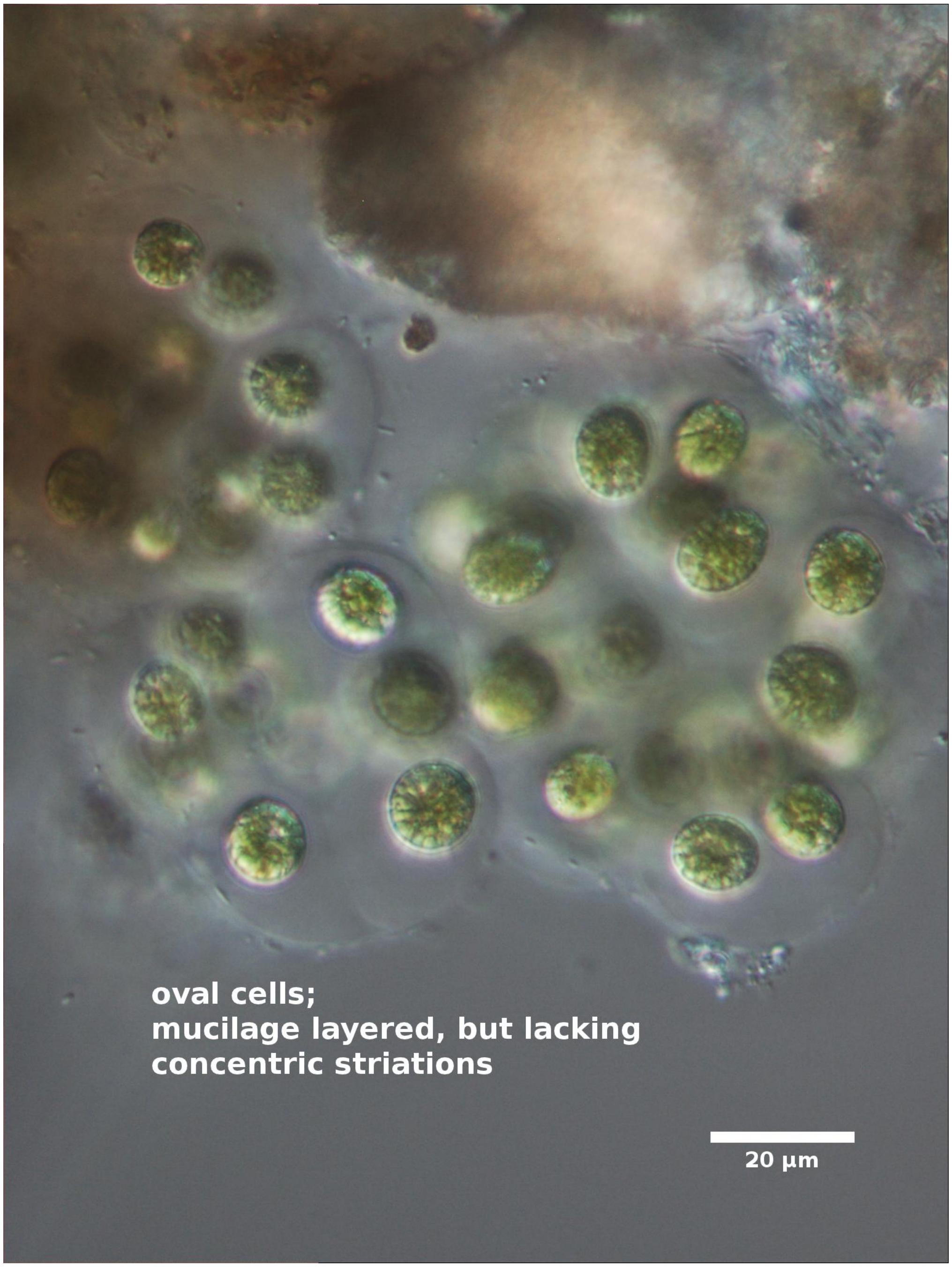

Figure 3.146: *Gloeocystis* sp.2 (400x DIC), Toad Lake, IWS water quality sampling site, Whatcom County, August 19, 2009.

Figure 3.147: *Gloeocystis* sp.2 (200x DIC), Ross Lake, Ross Lake National Recreation Area, September 27, 2010.

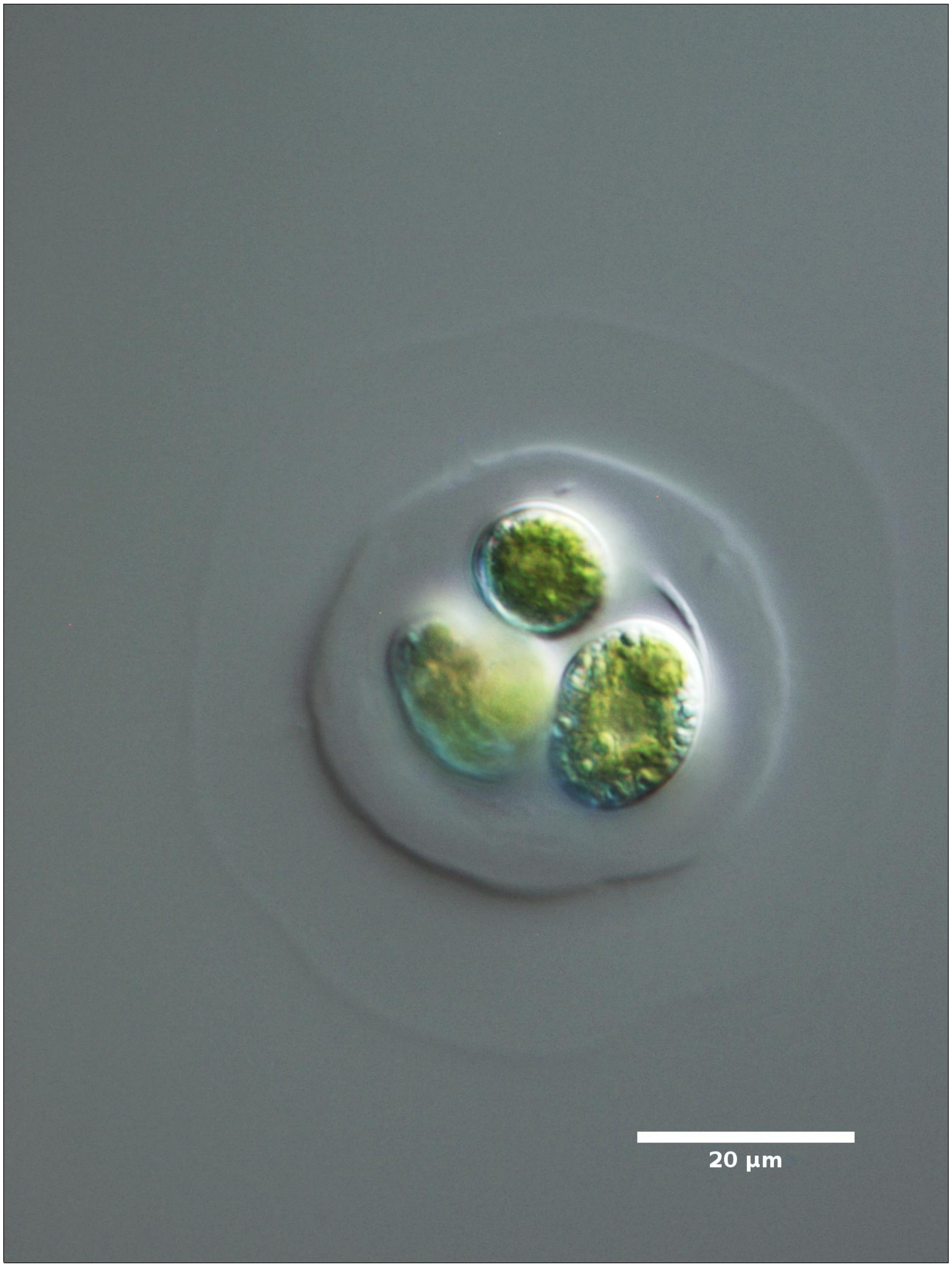

Figure 3.148: *Gloeocystis* sp.3 (600x DIC), Lake Samish, IWS water quality sampling site, Whatcom County, June 22, 2007.

Figure 3.149: *Gloeocystis* sp.4 (600x DIC), Myrtle Lake, IWS water quality sampling site, Snohomish County, May 21, 2014.

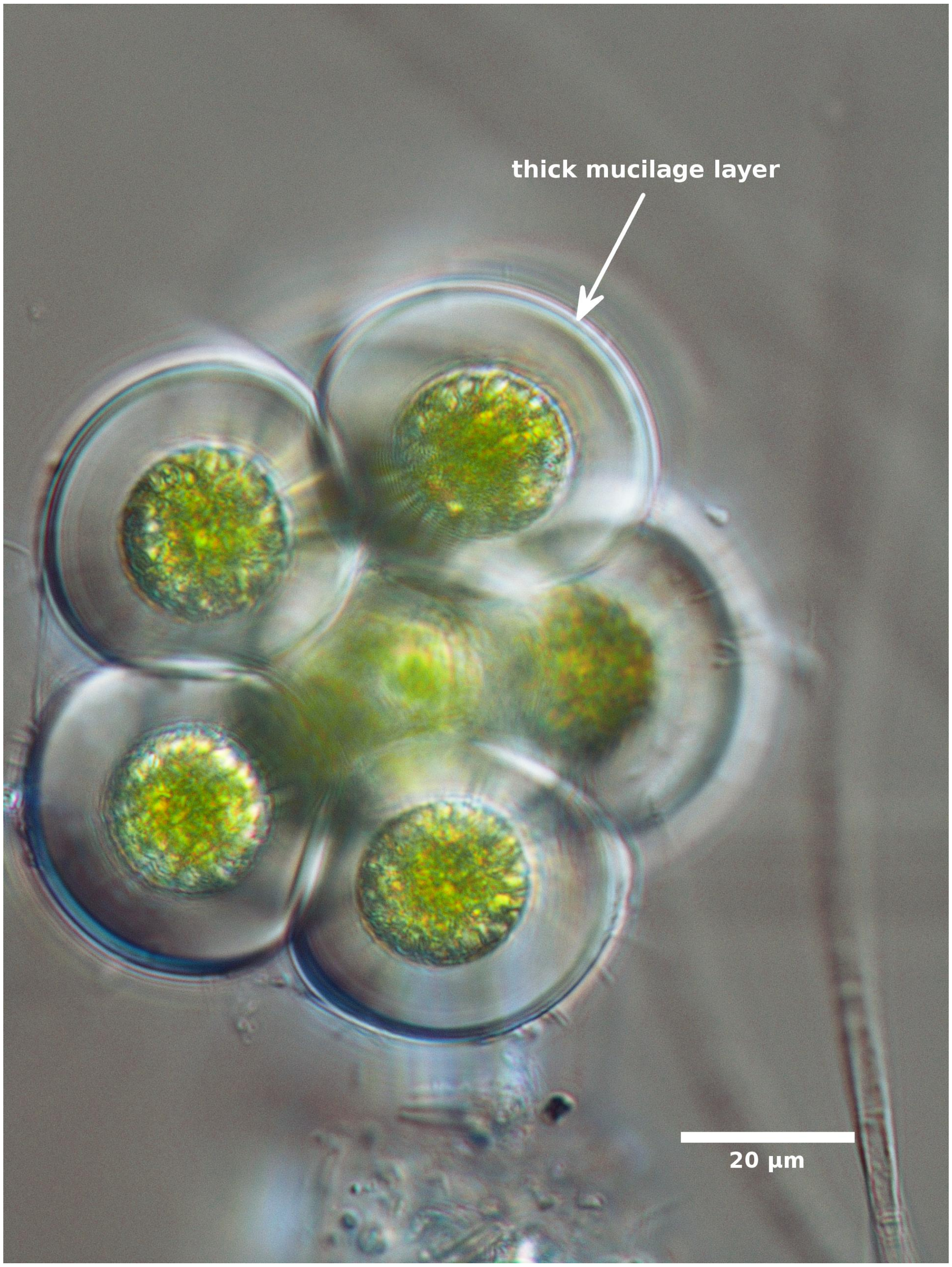

Figure 3.150: *Gloeocystis* sp.4 (600x DIC), Coal Lake, IWS water quality sampling site, Snohomish County, August 1, 2014.

3.17 *Golenkinia* Chodat

Local taxon
Golenkinia radiata Chodat

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Golenkinia radiata	min	9.8 μm	–	493 μm^3
cells (sphere)	med	15.1 μm	–	1,780 μm^3
	max	17.4 μm	–	2,760 μm^3

†Calculated using original measurements, not summary values.

Description
Golenkinia radiata cells are spherical and solitary, with long, narrow spines extending out in all directions (Figures 3.151–3.153). *Golenkinia radiata* spines are considerably longer than the cell width. Each cell has a cup-shaped chloroplast that contains a large pyrenoid. Compare *Golenkinia radiata* cells to *Micractinium* (Section 3.21, page 377), which has smaller cells that form small colonies. This species is uncommon in most lakes, but is moderately abundant in Lake Terrell and Tennant Lake, two small, shallow, nutrient-rich lakes in northern Whatcom County.

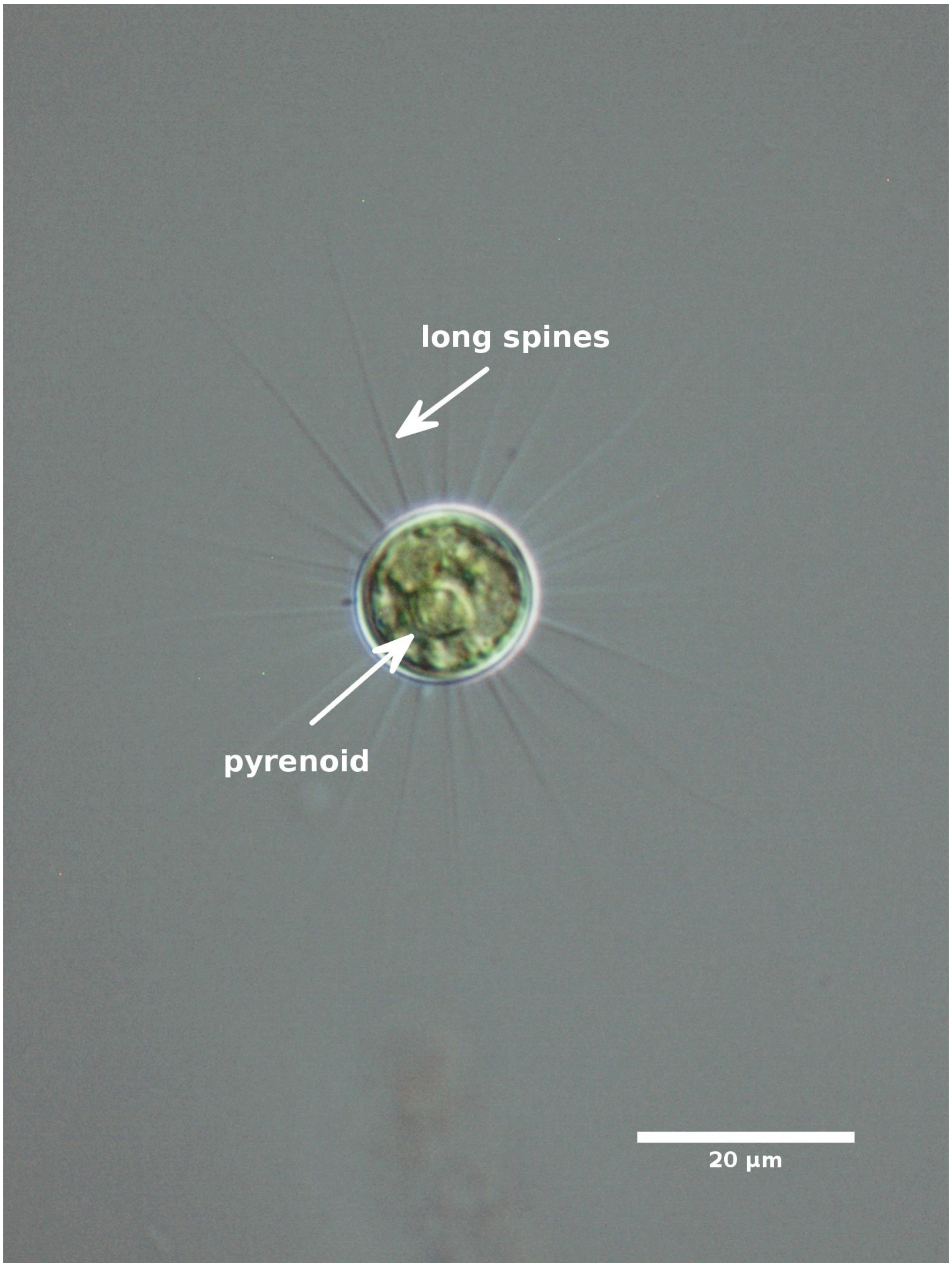

Figure 3.151: *Golenkinia radiata* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 29, 2013.

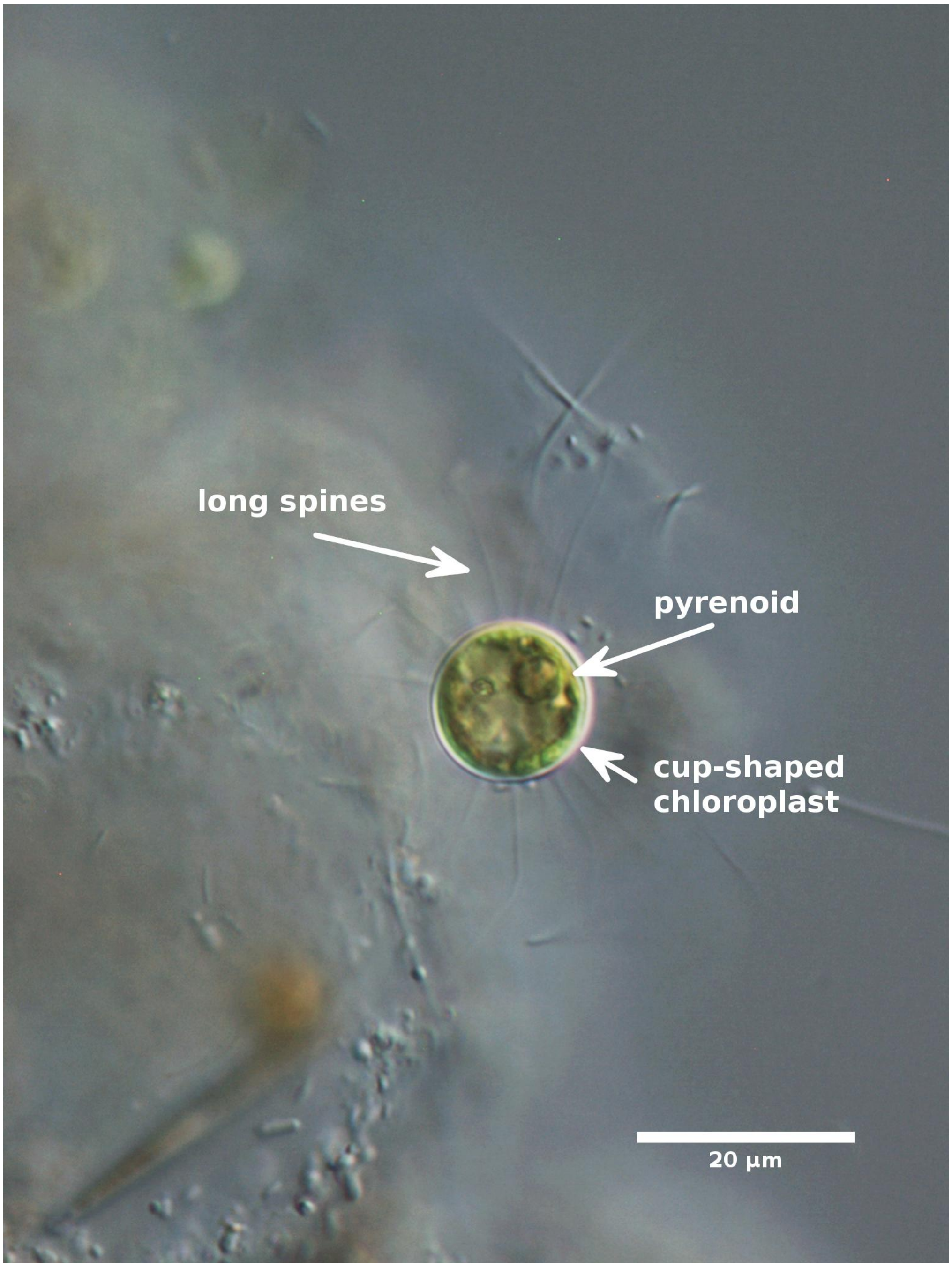

Figure 3.152: *Golenkinia radiata* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 30, 2013.

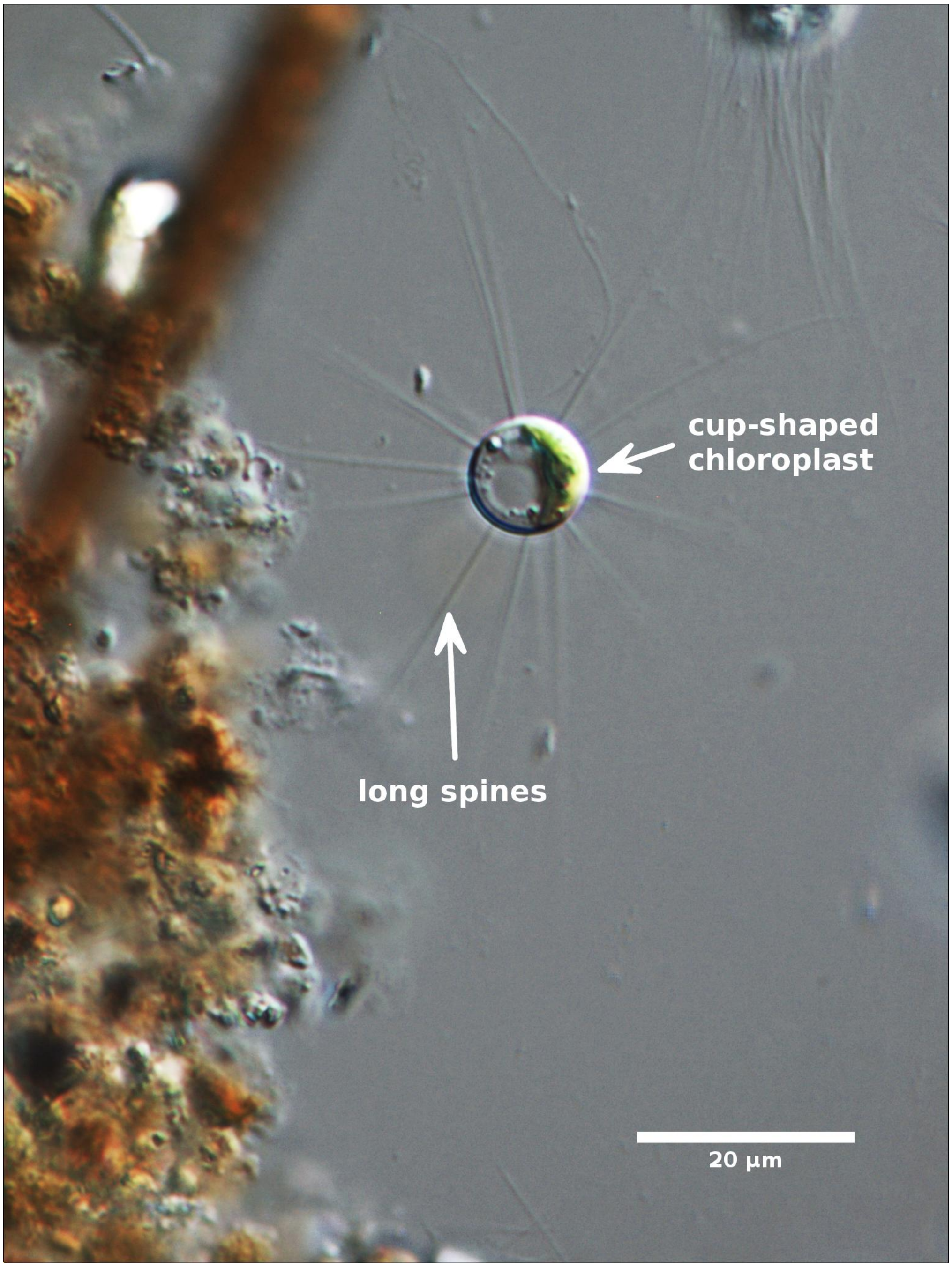

Figure 3.153: *Golenkinia radiata* (600x DIC), Tennant Lake, IWS water quality sampling site, Whatcom County, April 13, 2007.

3.18 *Kirchneriella* Schmidle

Local taxa

Kirchneriella irregularis (G. M. Smith) Korshikov;
Kirchneriella lunaris (Kirchner) K. Möbius?;
Kirchneriella obesa (West) West & G. S. West

Abundance

Moderately common; rarely present in large numbers.

Local measurements		Width	Length	Biovolume†
Kirchneriella irregularis	min	3.4 μm	15.8 μm	56.9 μm^3
cells (fusiform)	med	4.4 μm	20.1 μm	96.5 μm^3
	max	5.4 μm	27.2 μm	208 μm^3
Kirchneriella lunaris?	min	2.3 μm	11.0 μm	16.6 μm^3
cells (fusiform)	med	2.6 μm	12.8 μm	23.3 μm^3
	max	3.6 μm	16.0 μm	54.3 μm^3
Kirchneriella obesa	min	3.5 μm	12.8 μm	48.4 μm^3
cells (fusiform)	med	3.9 μm	14.9 μm	59.1 μm^3
	max	5.0 μm	18.0 μm	118 μm^3

†Calculated using original measurements, not summary values.

Description

Kirchneriella cells are strongly curved and crescent-shaped, occasionally solitary, but usually in irregular masses surrounded by a diffuse colonial mucilage (Figures 3.154–3.160). The colonial mucilage may not be visible except under phase contrast or DIC illumination. Most species exhibit a large amount of morphological variability, making identification difficult.

Kirchneriella cells and colonies closely resemble some species of *Selenastrum* (Section 3.33, page 477). *Selenastrum* cells are narrower, sharply pointed, and joined to other cells in the colony by their dorsal edge; *Kirchneriella* cells are thicker, may be sharply pointed or have bluntly rounded ends, and are loosely arranged in the colonial mucilage.

Kirchneriella irregularis has crescent-shaped cells that are so strongly curved that they appear nearly round, with the apices nearly touching each other (Figures 3.154–3.157). The cells may be sharply pointed or very slightly rounded, and are twisted so that the ends of the cell are not in the same plane.

The specimens in Figure 3.158 were tentatively identified as *Kirchneriella lunaris*. *Kirchneriella lunaris* cells are crescent-shaped, sharply pointed or very slightly rounded, and so strongly curved that the apices nearly touch each other. The cells are similar to *Kirchneriella irregularis*, but are flattened, not twisted.

Kirchneriella obesa cells are crescent-shaped and strongly curved, with rounded or bluntly pointed apices (Figures 3.159–3.160). The cells appear U-shaped because the inner cell walls are nearly parallel.

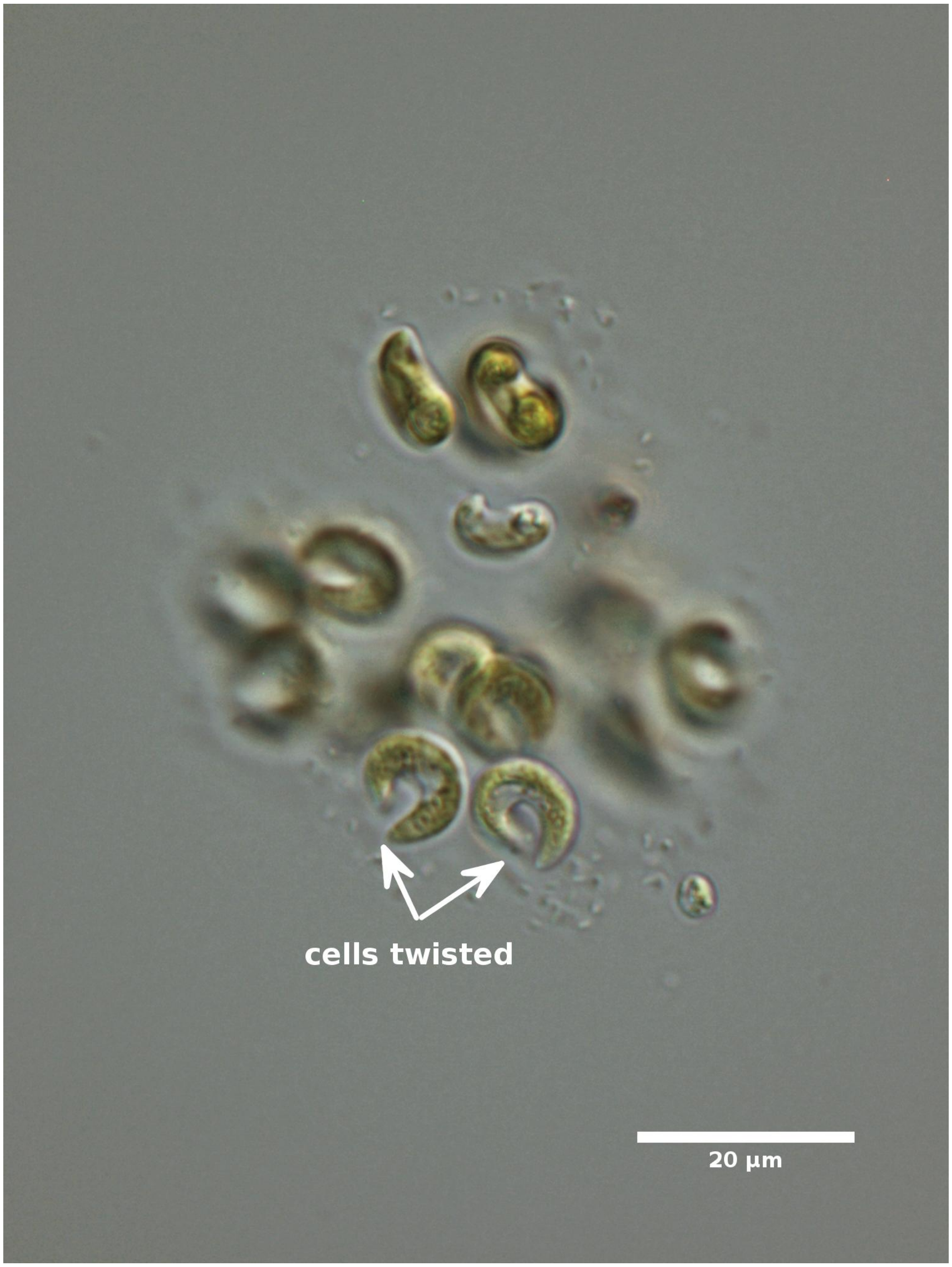

Figure 3.154: *Kirchneriella irregularis* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, September 5, 2012.

Figure 3.155: *Kirchneriella irregularis* (600x DIC), Big Lake, IWS water quality sampling site, Skagit County, August 21, 2008.

Figure 3.156: *Kirchneriella irregularis* stained with methylene blue (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 30, 2013.

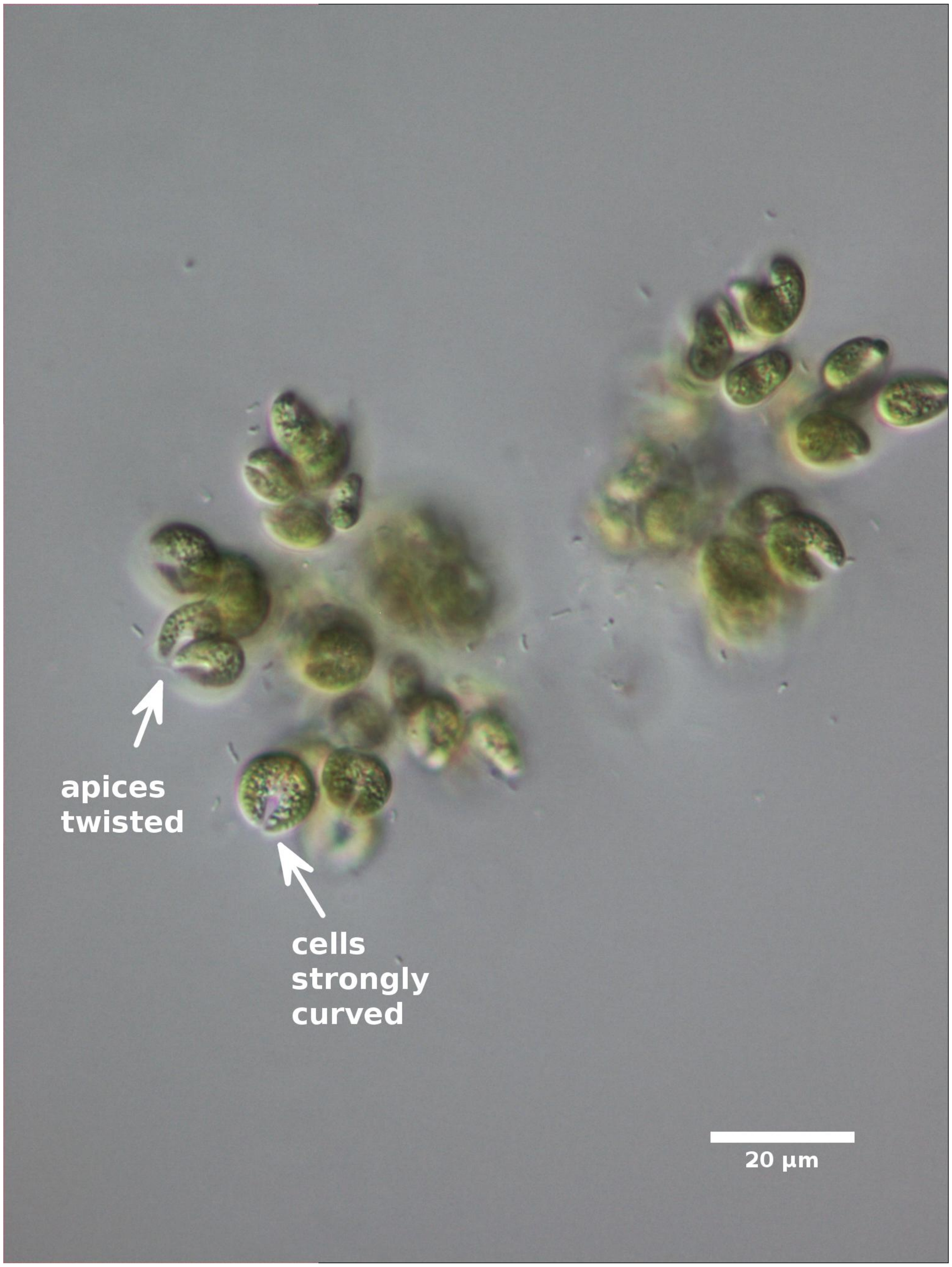

Figure 3.157: *Kirchneriella irregularis* (400x DIC), Big Lake, IWS water quality sampling site, Skagit County, August 21, 2008.

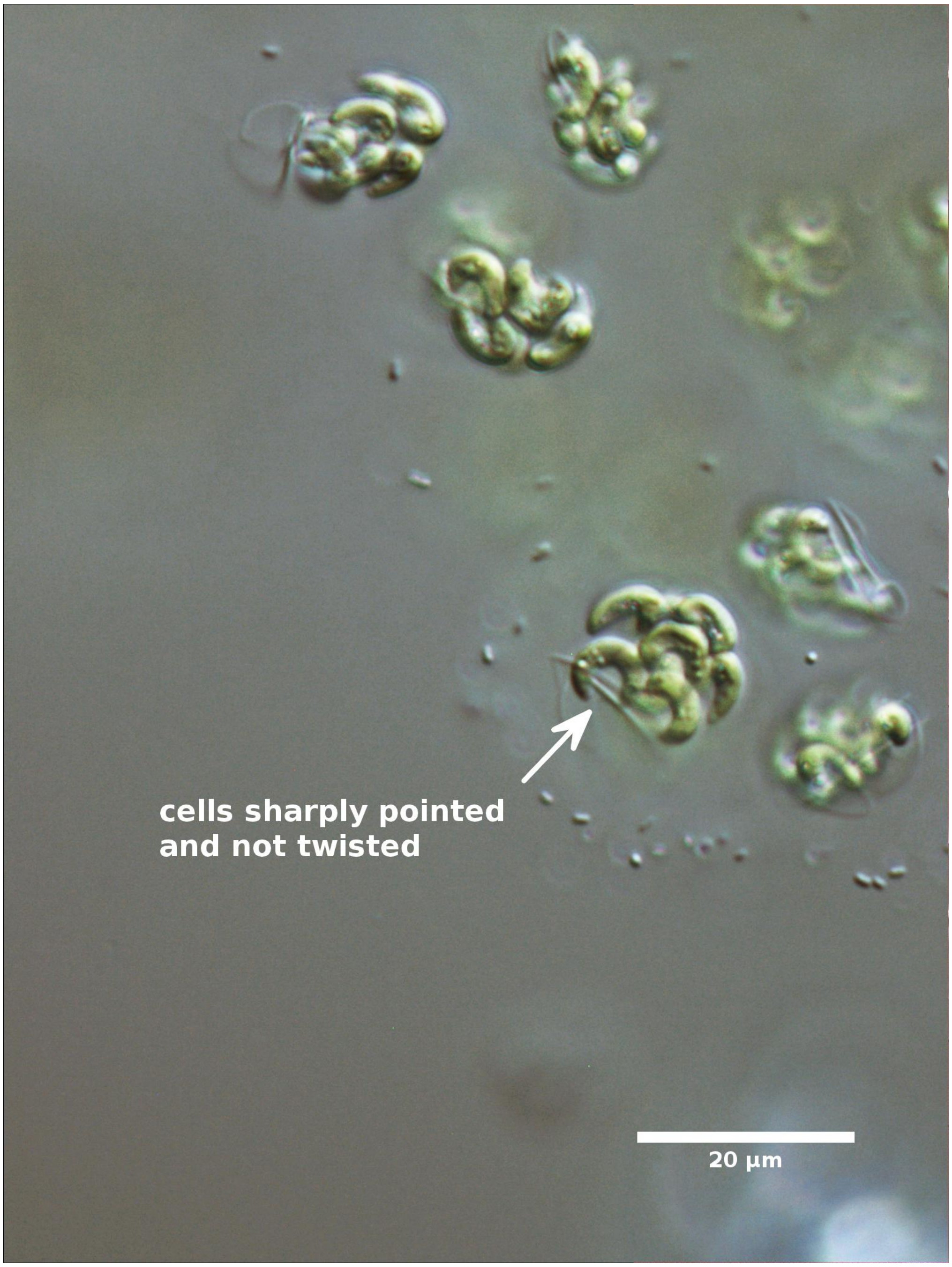

Figure 3.158: *Kirchneriella lunaris*? (600x DIC), Sunday Lake, IWS water quality sampling site, Snohomish County, September 2, 2009.

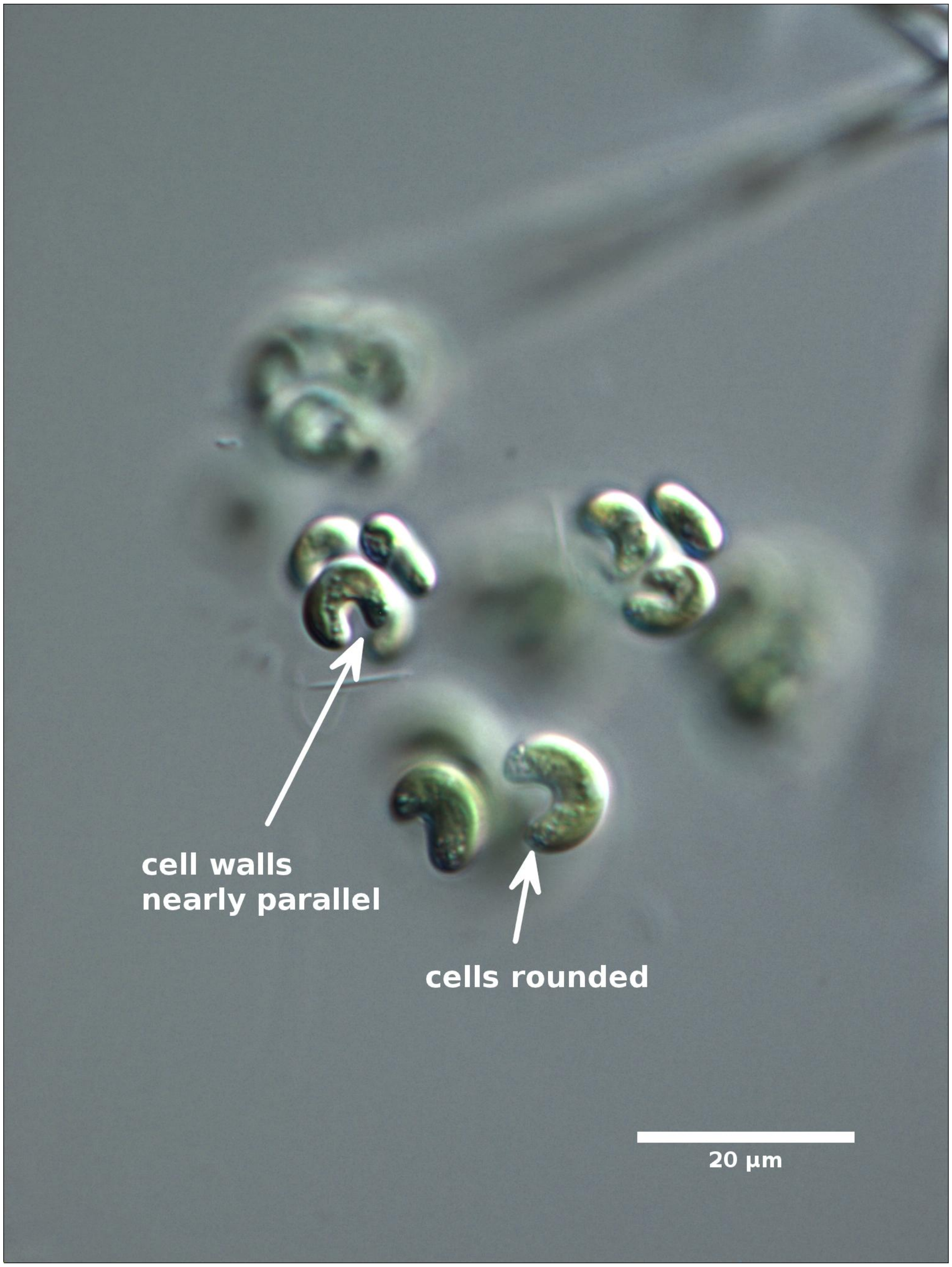

Figure 3.159: *Kirchneriella obesa* (600x DIC), Lake Erie, IWS water quality sampling site, Skagit County, March 30, 2007.

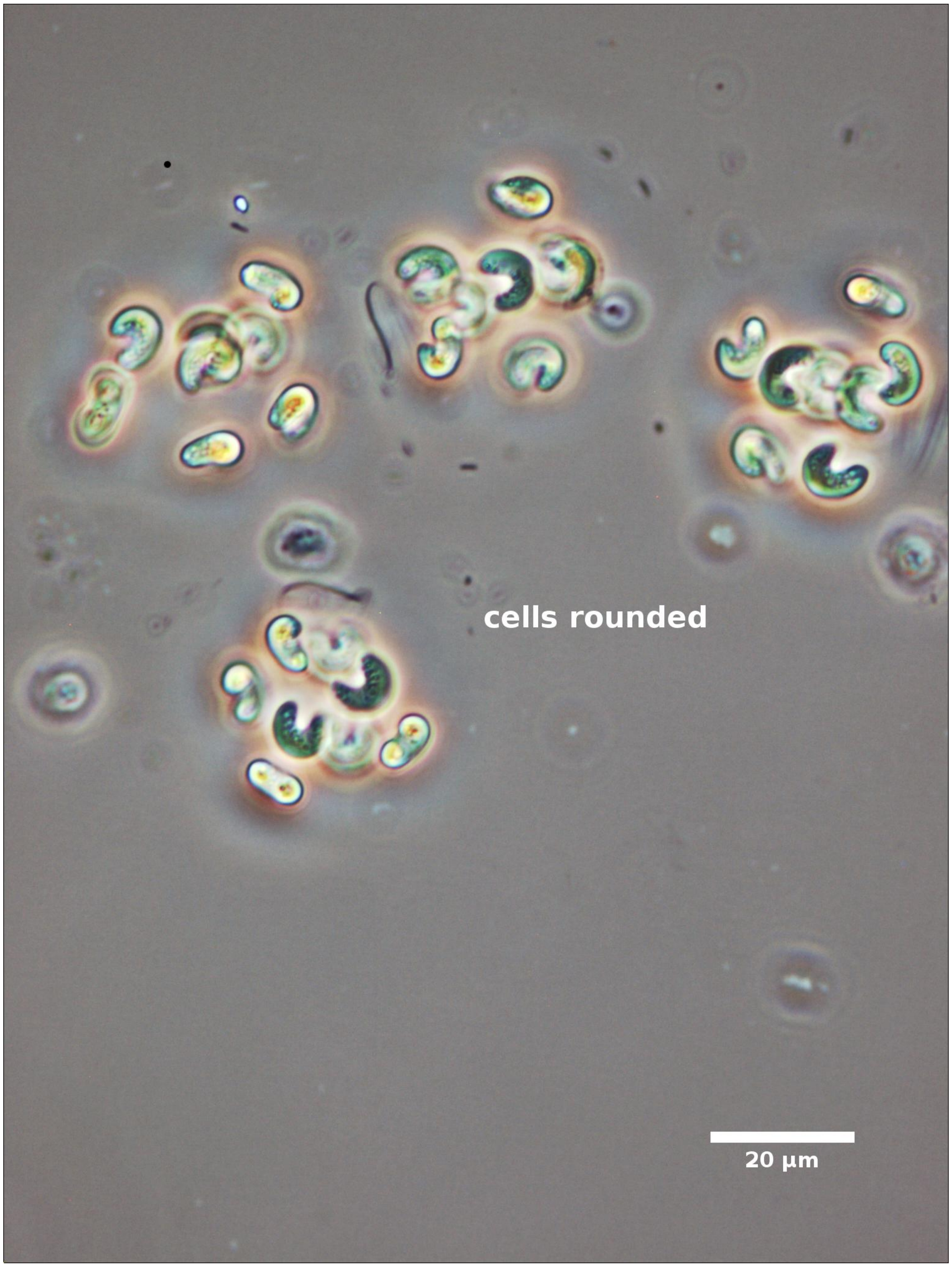

Figure 3.160: *Kirchneriella obesa* (400x phase contrast), Lake Terrell, IWS water quality sampling site, Whatcom County, April 13, 2007.

3.19 *Koliella* Hindák

Local taxa
Koliella longiseta (Vischer) Hindák;
Koliella sp.

Abundance
Infrequently collected; easily overlooked.

Local measurements		Width	Length	Biovolume†
Koliella longiseta	min	1.7 μm	41.0 μm	39.6 μm^3
cells (fusiform)	med	2.1 μm	52.4 μm	59.2 μm^3
	max	2.9 μm	73.3 μm	133 μm^3
Koliella sp.1‡	min	2.5 μm	45.5 μm	83.8 μm^3
cells (fusiform)	med	4.1 μm	49.3 μm	215 μm^3
	max	4.4 μm	52.6 μm	243 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume estimate based on <5 cells.

Description
Koliella cells are very long, fusiform, and often curved or twisted (Figures 3.161–3.164). The cells contain a single parietal chloroplast and numerous oil droplets. The cells are usually solitary, but may be joined briefly during division. Cell division is transverse, and the recently divided cells may appear spindle-shaped. Fully developed *Koliella* cells resemble *Ankistrodesmus* (Section 3.3, page 220), *Monoraphidium* (Section 3.22, page 383), and *Schroederia* (Section 3.32, page 470), but these genera have longitudinal cell division. Recently divided *Koliella* and *Elakatothrix gelatinosa* (Section 3.14, page 327) cells may appear similar (both have transverse division), but *Koliella* lacks the lens-shaped mucilage layer.

Koliella longiseta cells are fusiform, with long, hair-like extensions at each end of the cell (Figures 3.161–3.162). The cells showed evidence of transverse division (Figure 3.162). The chloroplast is straight, not spiraling, which distinguishes this species from *Koliella spirotaenia* (no image available). The specimens in Figures 3.163–3.164 displayed transverse division, but could not be identified to species.

Figure 3.161: *Koliella longiseta* (600x DIC), small eutrophic farm pond, Whatcom County, June 3, 2014.

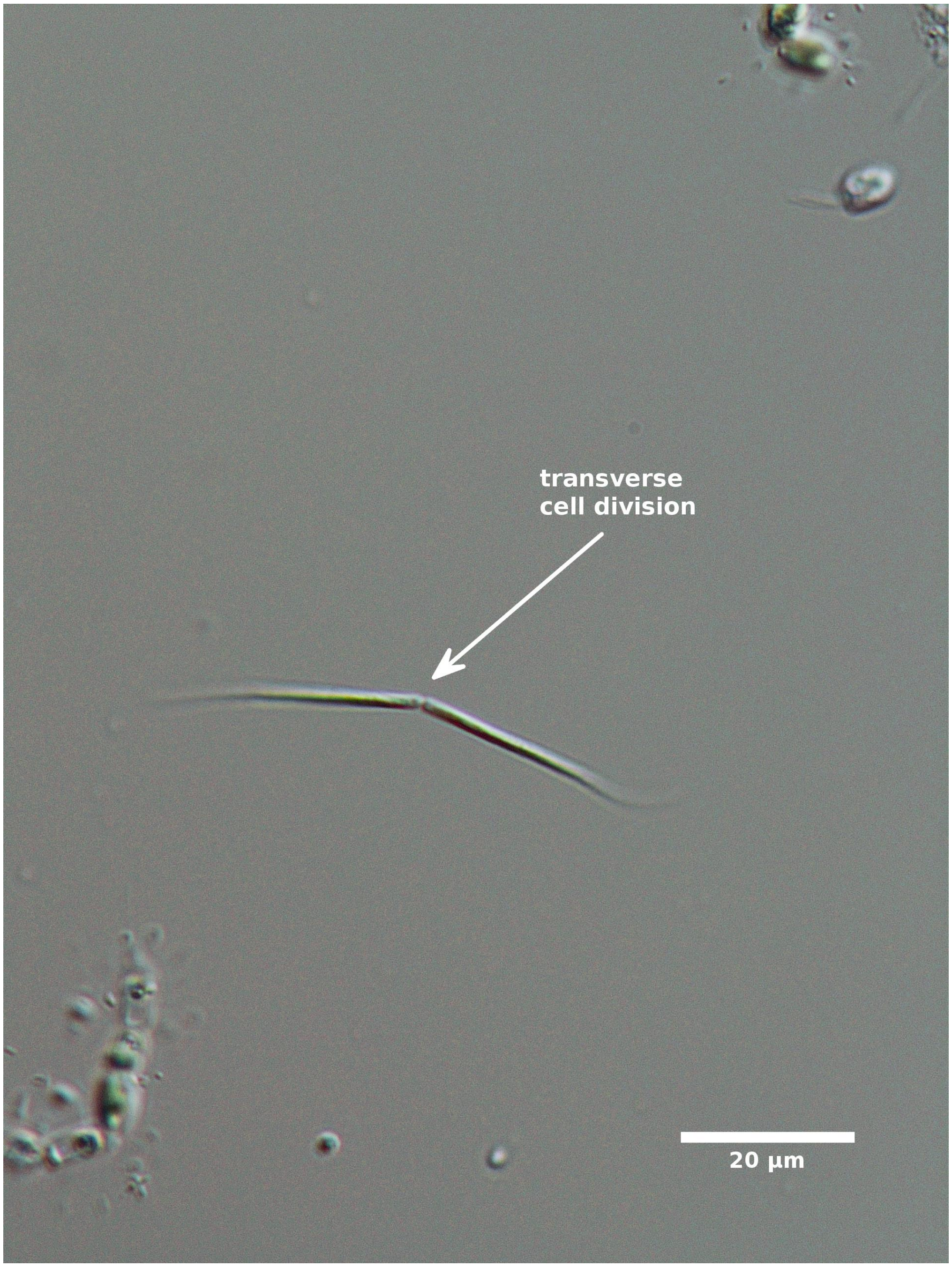

Figure 3.162: *Koliella longiseta* (600x DIC), small eutrophic farm pond, Whatcom County, June 3, 2014.

Figure 3.163: *Koliella* sp.1 (600x DIC), Ross Lake, Ross Lake National Recreation Area, September 27, 2010.

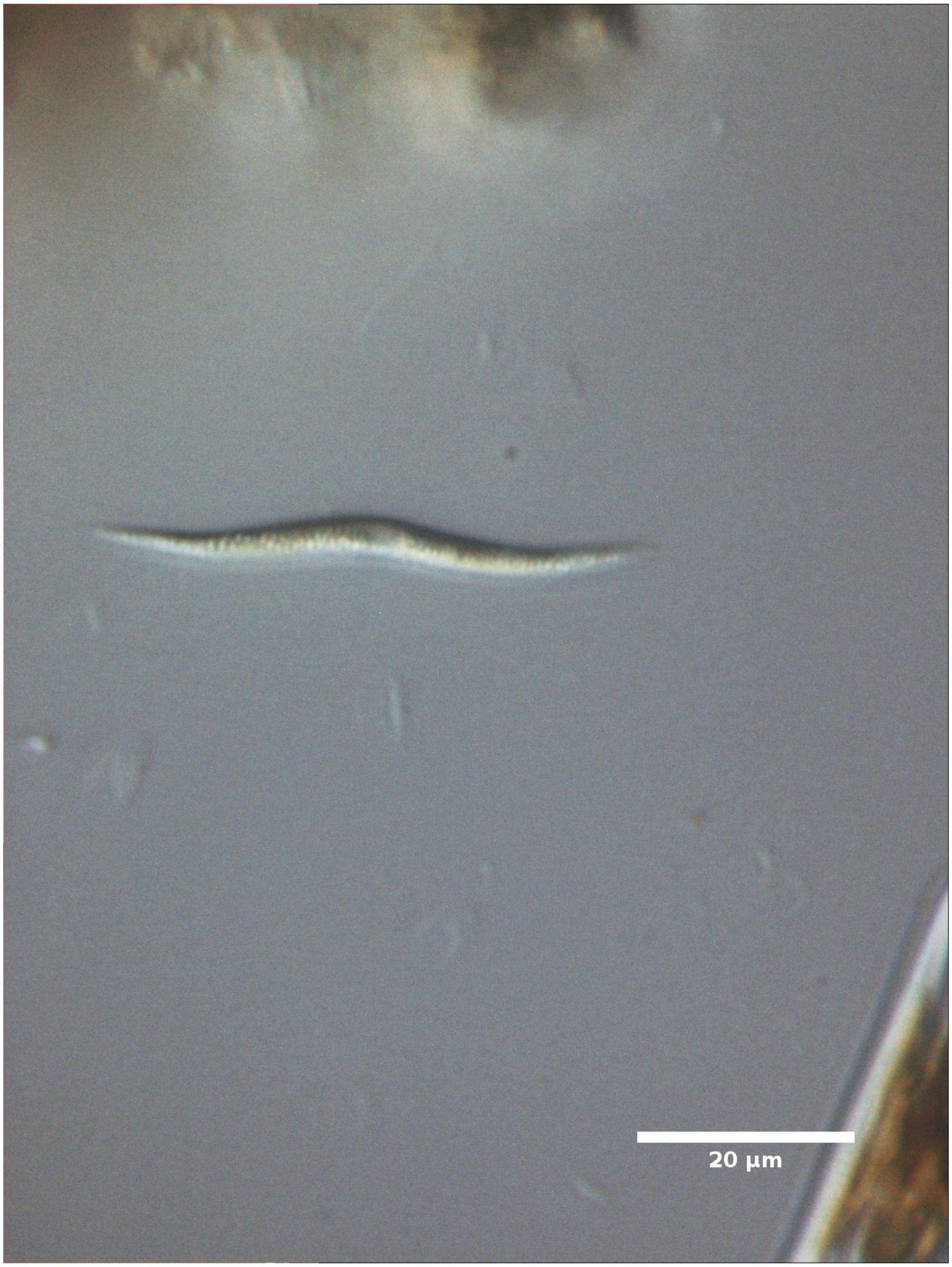

Figure 3.164: *Koliella* sp.1 (600x DIC), Ross Lake, Ross Lake National Recreation Area, September 27, 2010.

3.20 *Lagerheimia* Chodat

Local taxa
Lagerheimia ciliata (Lagerheim) Chodat;
Lagerheimia genevensis (Chodat) Chodat

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Lagerheimia ciliata	min	5.0 μm	8.8 μm	125 μm^3
cells (spheroid)	med	9.8 μm	14.8 μm	734 μm^3
	max	12.6μm	16.4 μm	1,360 μm^3
Lagerheimia genevensis	min	6.0 μm	11.0 μm	207 μm^3
cells (spheroid)	med	6.2 μm	11.8 μm	238 μm^3
	max	7.5 μm	12.5 μm	368 μm^3

†Calculated using original measurements, not summary values.

Description
Lagerheimia cells are usually solitary, but may also form small groups of 4–8 daughter cells enclosed inside the old mother cell wall (Figures 3.165–3.169). Individual cells are usually spherical, oval, or elliptical, with distinctive spines. Young cells contain a single chloroplast with one pyrenoid, but the number of chloroplasts increases prior to cell division. *Lagerheimia* cells should be compared to *Desmodesmus* (Section 3.2, page 174), which usually forms linear colonies containing 4–8 spiny, elliptical cells, but may also be solitary.

Lagerheimia ciliata cells are solitary, oval, and have numerous long, thin, subapical spines extending from both ends of the cell (Figures 3.165–3.167). The spines are about the same length or slightly longer than the cell. *Lagerheimia ciliata* forms daughter cells that are retained inside the mother cell wall. Except for the distinctive spines, *Lagerheimia ciliata* cells resemble *Oocystis* (Section 3.24, page 401).

Lagerheimia genevensis cells are solitary, elliptical or cylindrical, with two stout spines extending from opposite ends of the cell (Figures 3.168–3.169). The spines may or may not be thickened at the base. *Lagerheimia genevensis* cells may resemble solitary *Desmodesmus* cells (Section 3.2, page 174), but often when there are solitary *Desmodesmus* cells present, there are also the easily recognizable, linear, 4-cell colonies in the same sample.

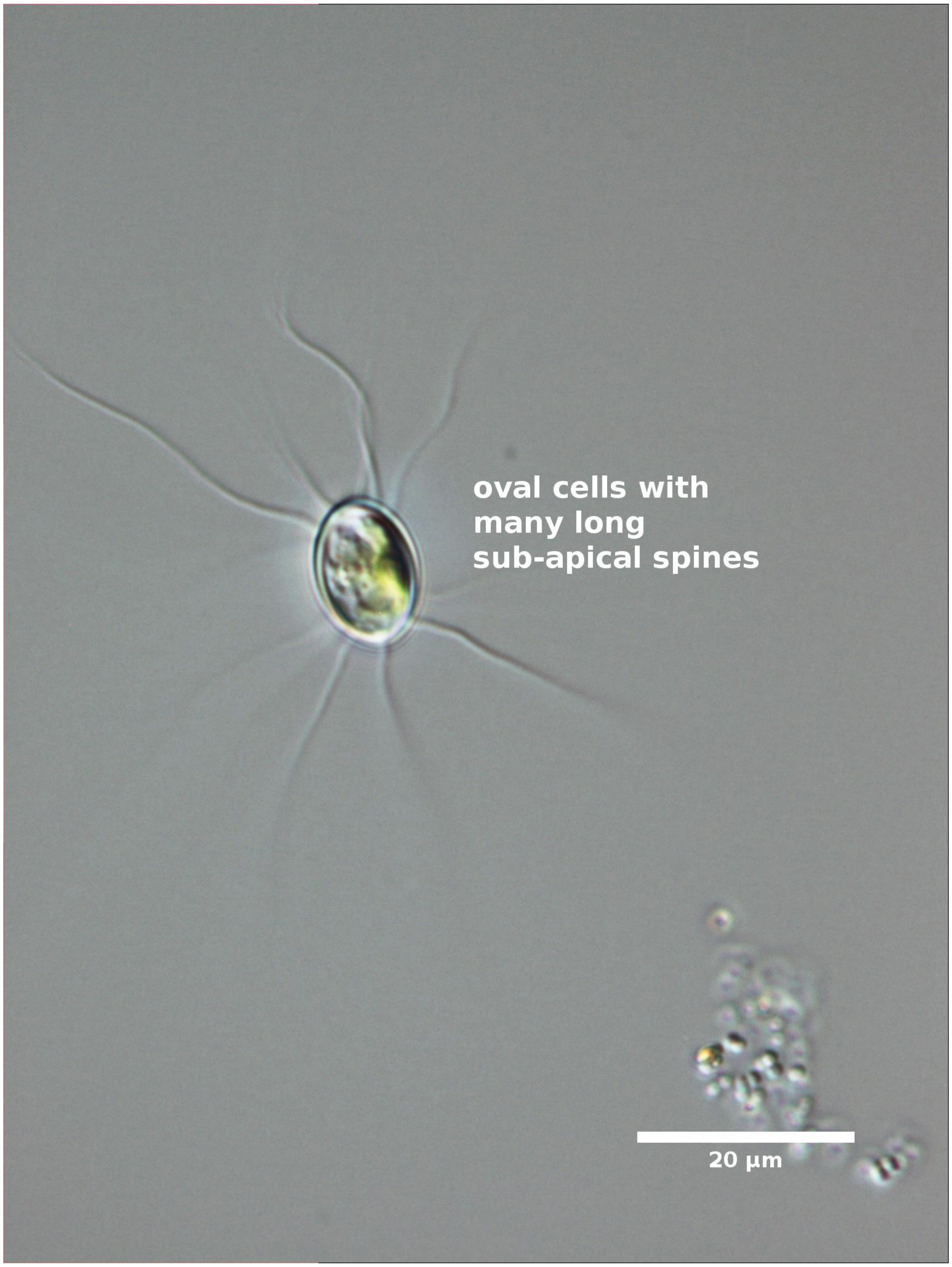

Figure 3.165: *Lagerheimia ciliata* (600x DIC), Lake Erie, IWS water quality sampling site, Skagit County, September 1, 2008.

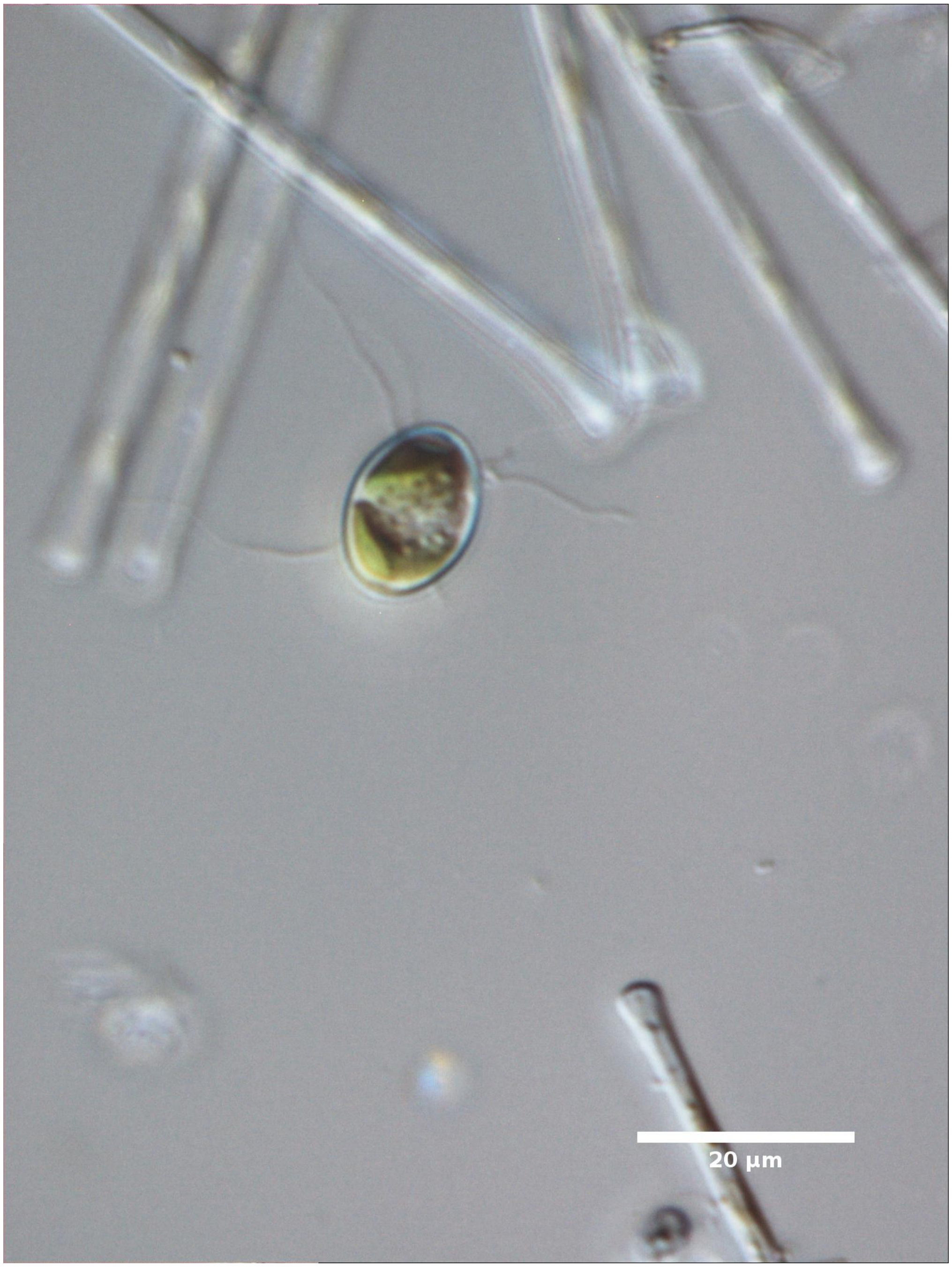

Figure 3.166: *Lagerheimia ciliata* (600x DIC), Lake Campbell, IWS water quality sampling site, Skagit County, August 25, 2009.

Figure 3.167: *Lagerheimia ciliata* (600x DIC), Lake Erie, IWS water quality sampling site, Skagit County, September 1, 2008.

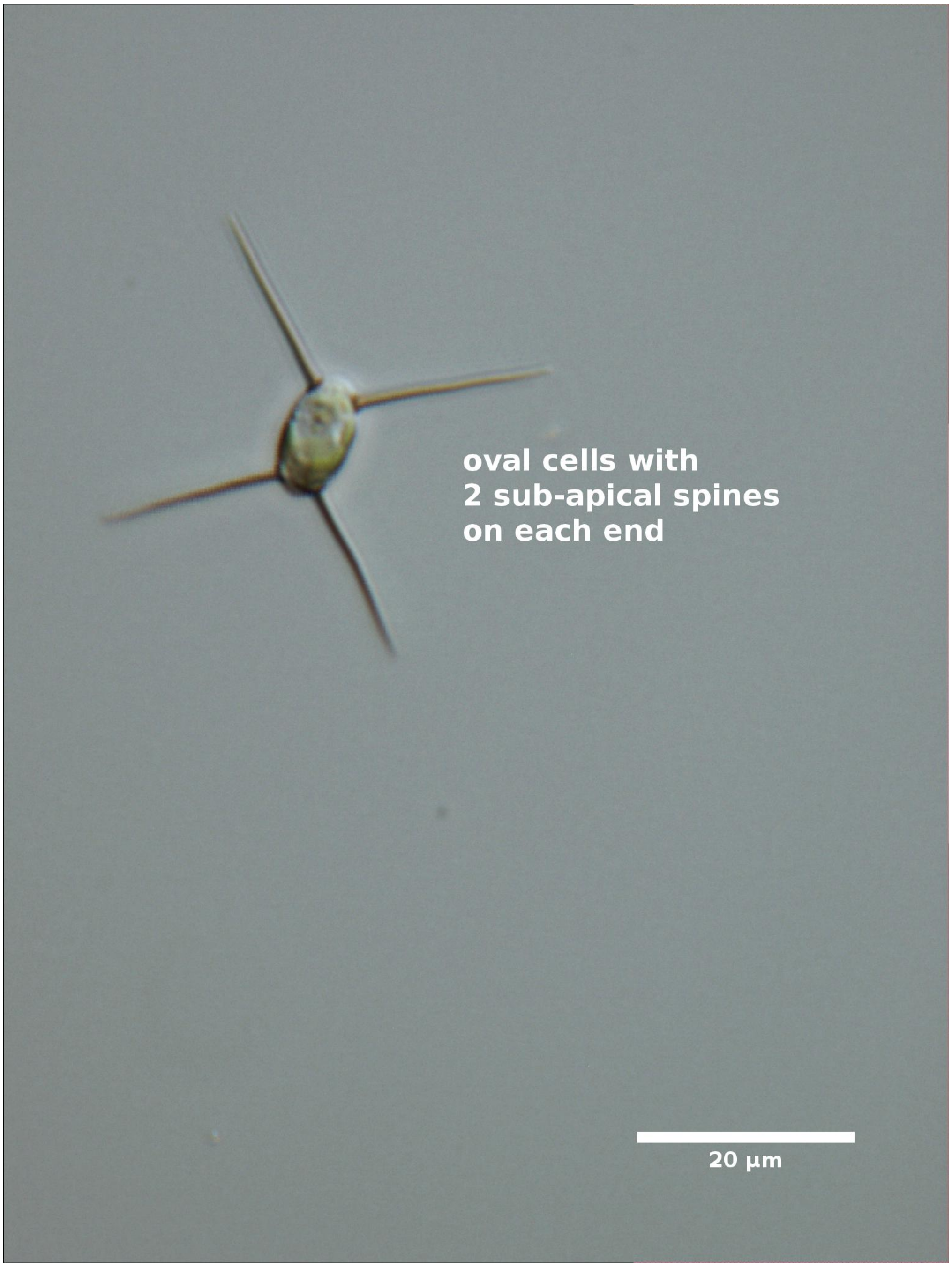

Figure 3.168: *Lagerheimia genevensis* (600x DIC), Thunderbird Lake, IWS water quality sampling site, Whatcom County, April 27, 2009.

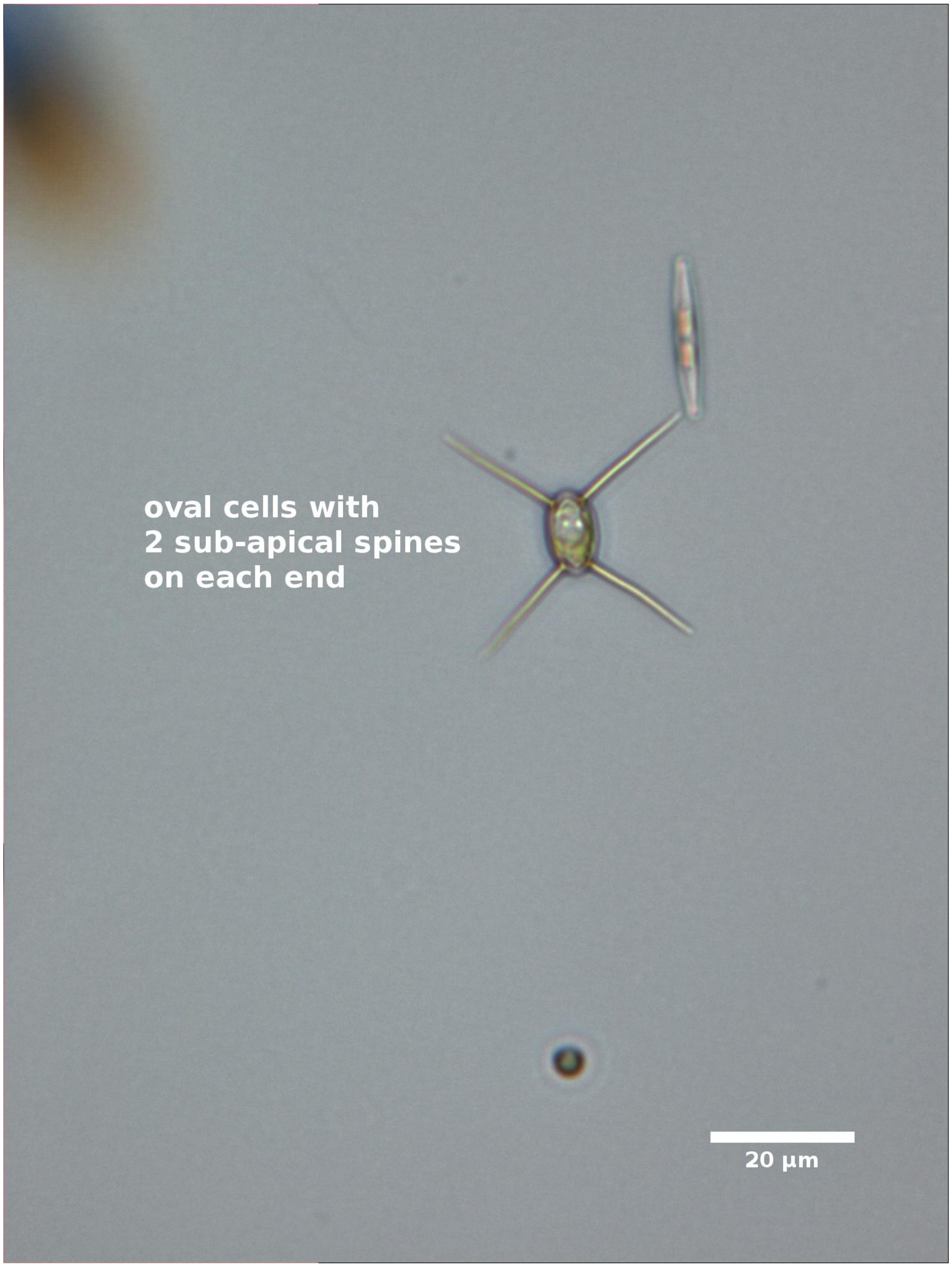

Figure 3.169: *Lagerheimia genevensis* (400x brightfield), Thunderbird Lake, IWS water quality sampling site, Whatcom County, April 27, 2009.

3.21 *Micractinium* Fresenius

Local taxa

Micractinium pusillum Fresenius;
Micractinium quadrisetum (Lemmermann) G. M. Smith?

Abundance

Infrequently collected.

Local measurements		Width	Length	Biovolume†
Micractinium pusillum	min	4.5 μm	4.9 μm	54.3 μm^3
cells (spheroid)	med	5.1 μm	5.9 μm	75.0 μm^3
	max	7.1 μm	7.6 μm	201 μm^3
Micractinium quadrisetum?	min	3.2 μm	4.0 μm	21.4 μm^3
cells (spheroid)	med	4.8 μm	5.3 μm	66.3 μm^3
	max	5.7 μm	6.3 μm	102 μm^3

†Calculated using original measurements, not summary values.

Description

Individual *Micractinium* cells resemble the single-celled species *Golenkinia radiata* (Section 3.17, page 352), but *Micractinium* cells are grouped into small colonies of 4–16 cells. The cells are spherical, oval, or broadly elliptical. Each cell has a cup-shaped chloroplast, one pyrenoid, and long spines.

Micractinium pusillum cells are spherical and closely arranged in pyramidal groups of 4 that may join with additional groups for form larger polyhedral colonies (Figures 3.170–3.173). Individual cells have two or more long, hair-like setae; the setae may widen at the base. The sample from Thunderbird Lake (Figure 3.173) contained an interesting mixture of *Micractinium pusillum* and *Cyclotella*, a tiny diatom that extrudes thread-like filaments, forming a shape that closely resembled the structure of *Micractinium* cells.

The specimen in Figure 3.174 was tentatively identified as *Micractinium quadrisetum*, which forms 16-cell colonies with the cells in groups of 4 arranged around a central opening to form a flattened, wreath. The individual cells are oval or broadly elliptical and have 2–4 long spines that may widen slightly at the base.

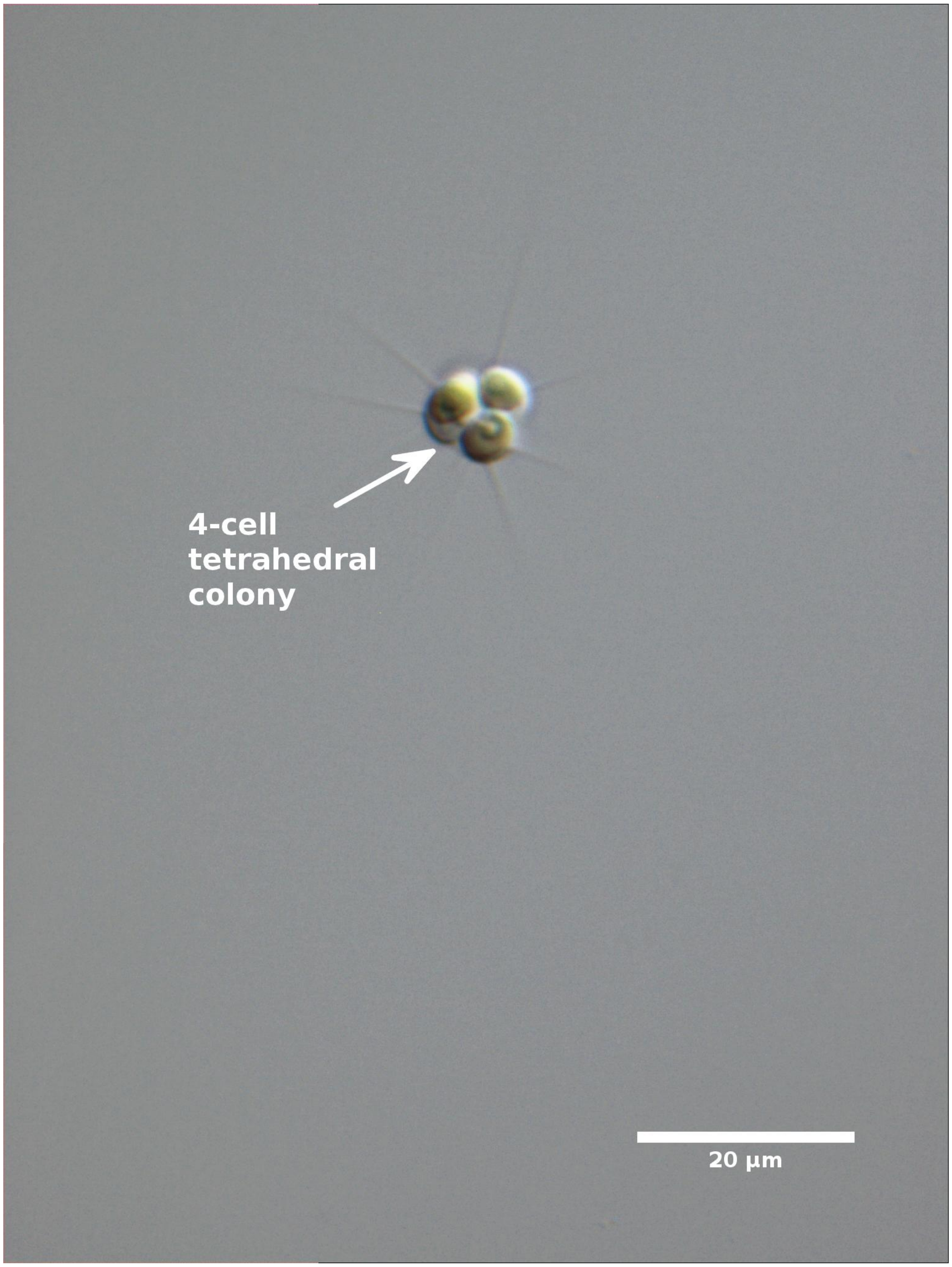

Figure 3.170: *Micractinium pusillum* (600x DIC), Sunset Pond, IWS water quality sampling site, Whatcom County, May 1, 2008.

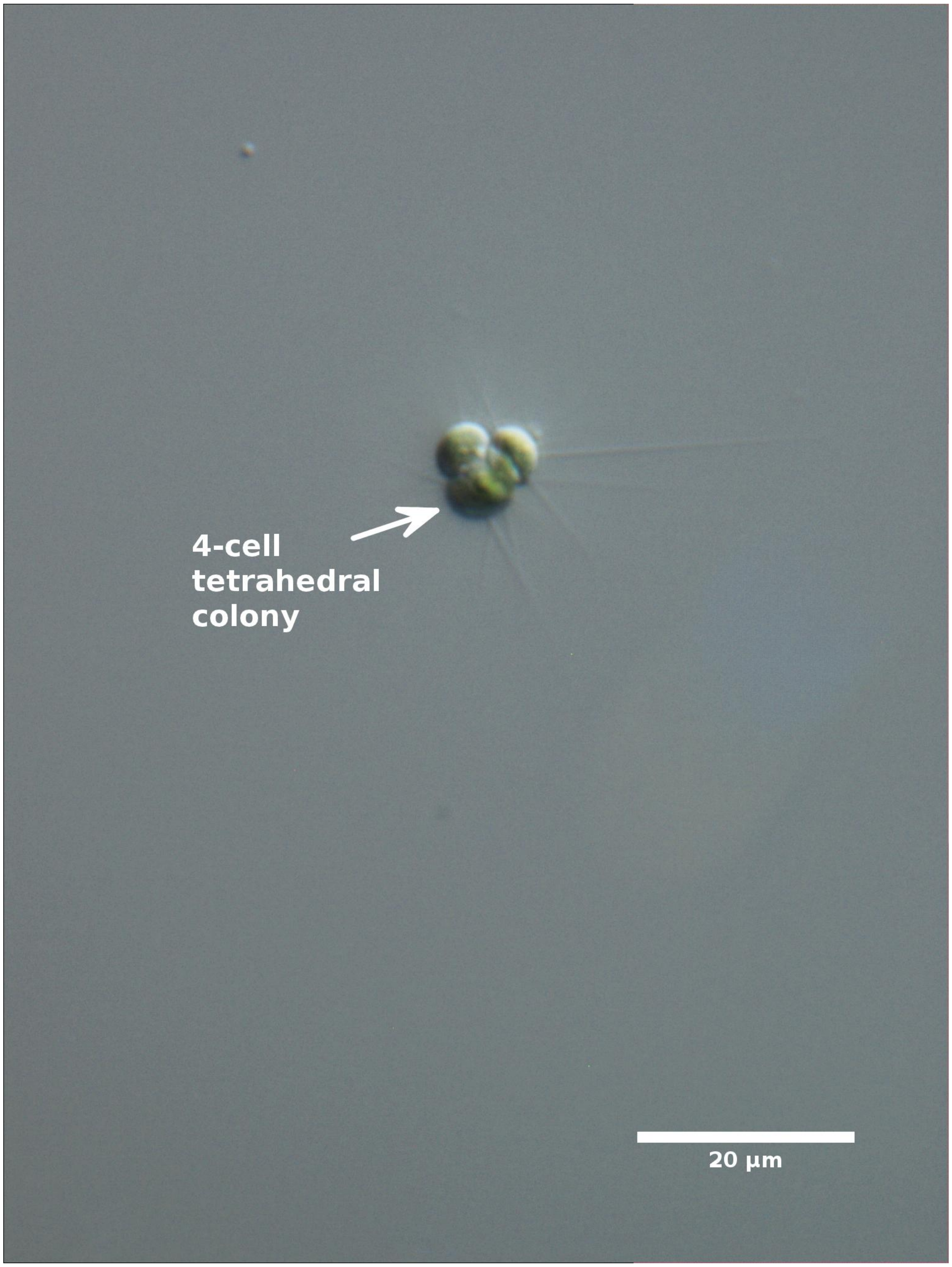

Figure 3.171: *Micractinium pusillum* (600x DIC), Squalicum Lake, IWS water quality sampling site, Whatcom County, April 21, 2009.

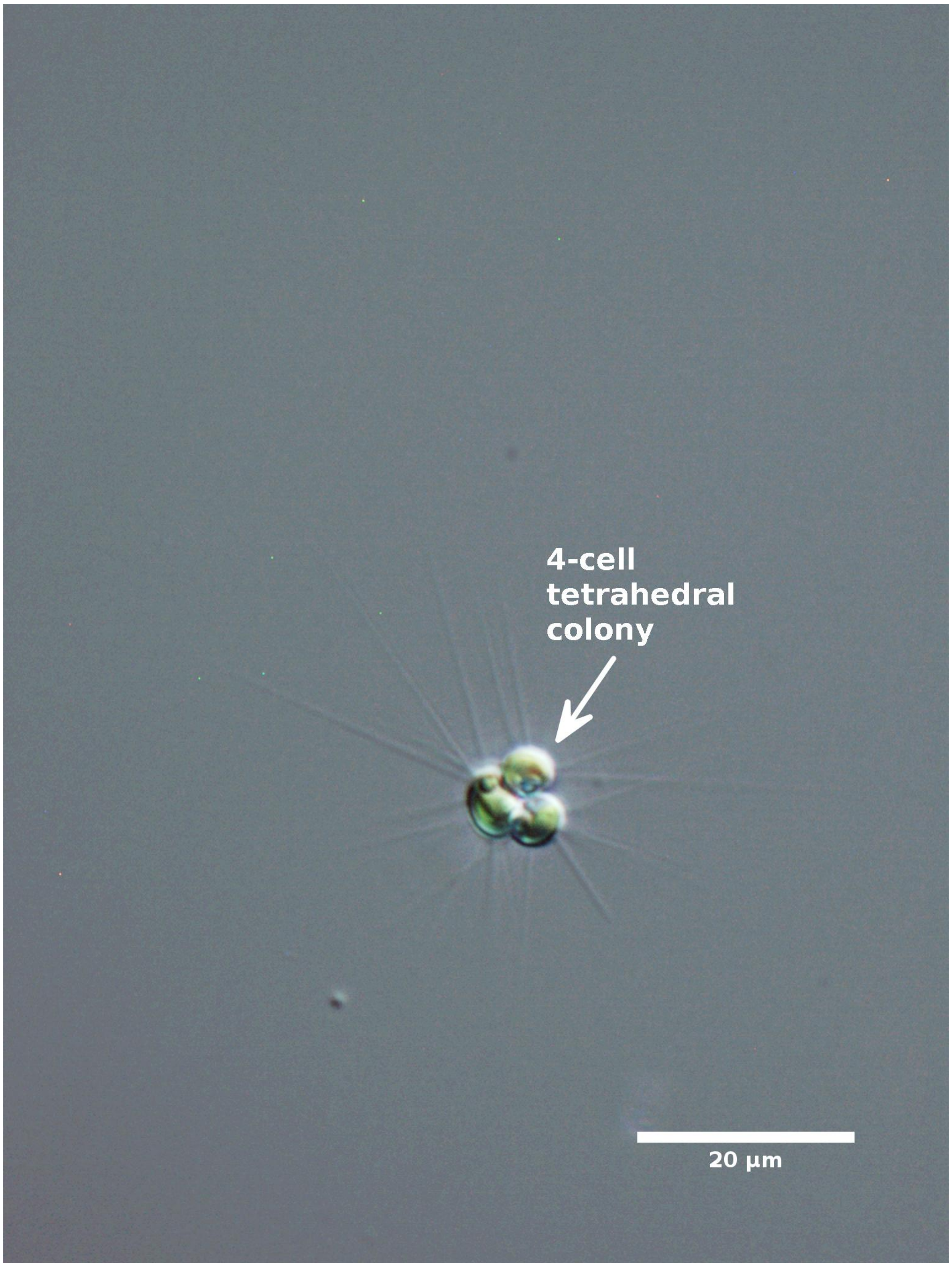

Figure 3.172: *Micractinium pusillum* (600x DIC), outdoor fish pond, Maple Valley, King County, May 8, 2013.

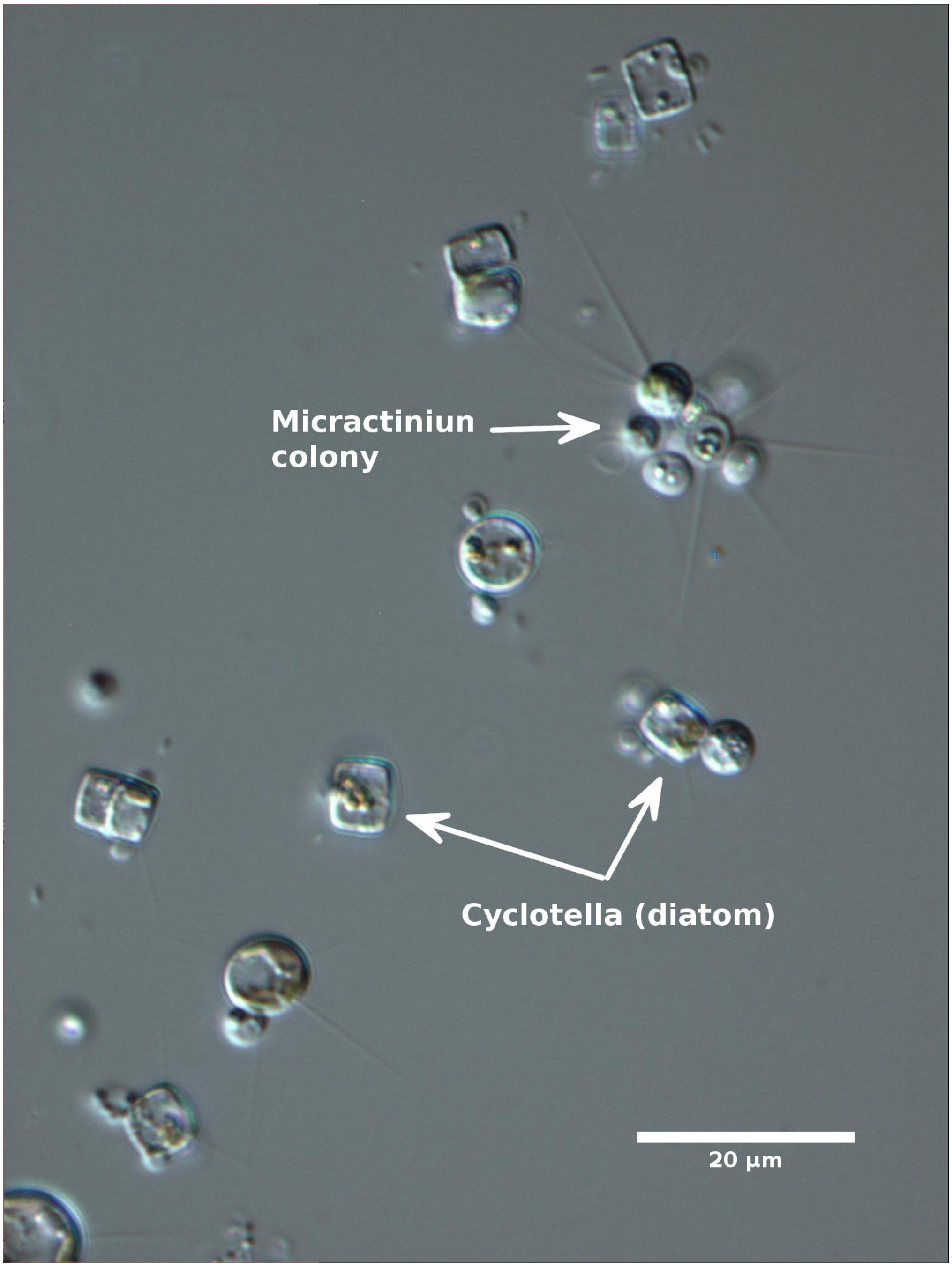

Figure 3.173: *Micractinium pusillum* and *Cyclotella* (600x DIC), Thunderbird Lake, IWS water quality sampling site, Whatcom County, August 24, 2009.

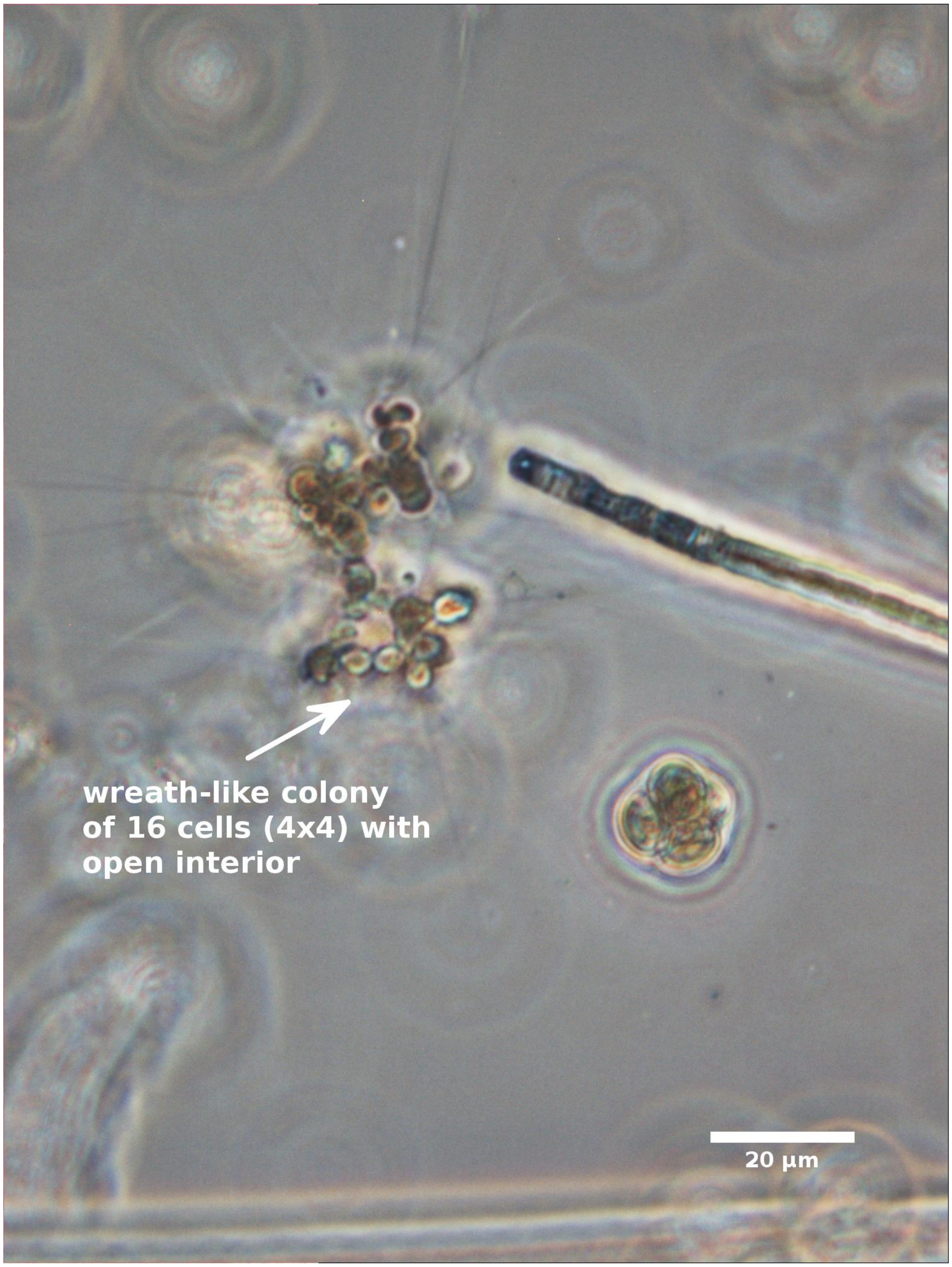

Figure 3.174: *Micractinium quadrisetum*? (400x phase contrast) in Lugol's iodine solution, Heart Lake, IWS water quality sampling site, Skagit County, August 27, 2009.

3.22 *Monoraphidium* Komárková-Legnerová

Local taxa

Monoraphidium contortum (Thuret) Komárková-Legnerová;
Monoraphidium griffithii (Berkeley) Komárková-Legnerová

Abundance

Moderately common; rarely present in large numbers; easily overlooked.

Local measurements		Width	Length	Biovolume†
Monoraphidium contortum	min	2.0 μm	27.7 μm	33.9 μm^3
cells (fusiform)	med	2.2 μm	40.2 μm	53.5 μm^3
	max	3.9 μm	100.8 μm	401 μm^3
Monoraphidium griffithii	min	1.4 μm	52.5 μm	31.7 μm^3
cells (fusiform)	med	2.6 μm	62.1 μm	116 μm^3
	max	2.9 μm	109.5 μm	194 μm^3

†Calculated using original measurements, not summary values.

Description

Monoraphidium cells are solitary, fusiform, and straight, curved, or even helical (Figures 3.175–3.179). The cells contain a single parietal chloroplast that usually do not have a visible pyrenoid.[17] *Monoraphidium* closely resembles *Ankistrodesmus* (Section 3.3, page 220), and it is very difficult to distinguish from solitary *Ankistrodesmus* cells. But *Ankistrodesmus* will form clumped colonies, which are usually present in the same sample that contains solitary *Ankistrodesmus* cells. *Monoraphidium* cells remain solitary except briefly during cell division.

Monoraphidium cells also resemble *Koliella* (Section 3.19, page 365) and *Schroederia* (Section 3.32, page 470). *Schroederia* cells will have one or more clearly visible pyrenoids, which are usually not visible in *Monoraphidium* cells. *Koliella* cells divide transversely, and may form short pseudofilaments, while

[17]The absence of pyrenoids is not a particularly good taxonomic feature. Recent improvements in microscopy have revealed the presence of pyrenoids in species that were initially described as lacking this feature.

Monoraphidium divides longitudinally, and may briefly form bundles of parallel cells (see Figure 3.179). The presence of a transverse cross-wall in individual cells needs to be checked carefully. *Monoraphidium* division may start with transverse divisions of the chloroplast, but subsequent cell divisions will be longitudinal.

Monoraphidium contortum cells are very long and narrow, sharply pointed, and twisted into crescents or spirals (Figures 3.175–3.177). This species is common in local lakes, but very easy to overlook.

Monoraphidium griffithii cells are straight, narrowly fusiform, and sharply pointed (Figures 3.178–3.179). This species is also fairly common in local lakes. The cells are occasionally bent, but can be distinguished from *Monoraphidium contortum* by their greater width and length. Figure 3.179 shows the longitudinal cell division that is characteristic of this genus.

Figure 3.175: *Monoraphidium contortum* (600x DIC), Thunderbird Lake, IWS water quality sampling site, Whatcom County, May 7, 2009.

Figure 3.176: *Monoraphidium contortum* (600x DIC), Manito Park duck pond (Spokane area), eastern Washington, May 27, 2009.

Figure 3.177: *Monoraphidium contortum* (400x phase contrast), Kwan Lake, IWS water quality sampling site, Whatcom County, August 24, 2009.

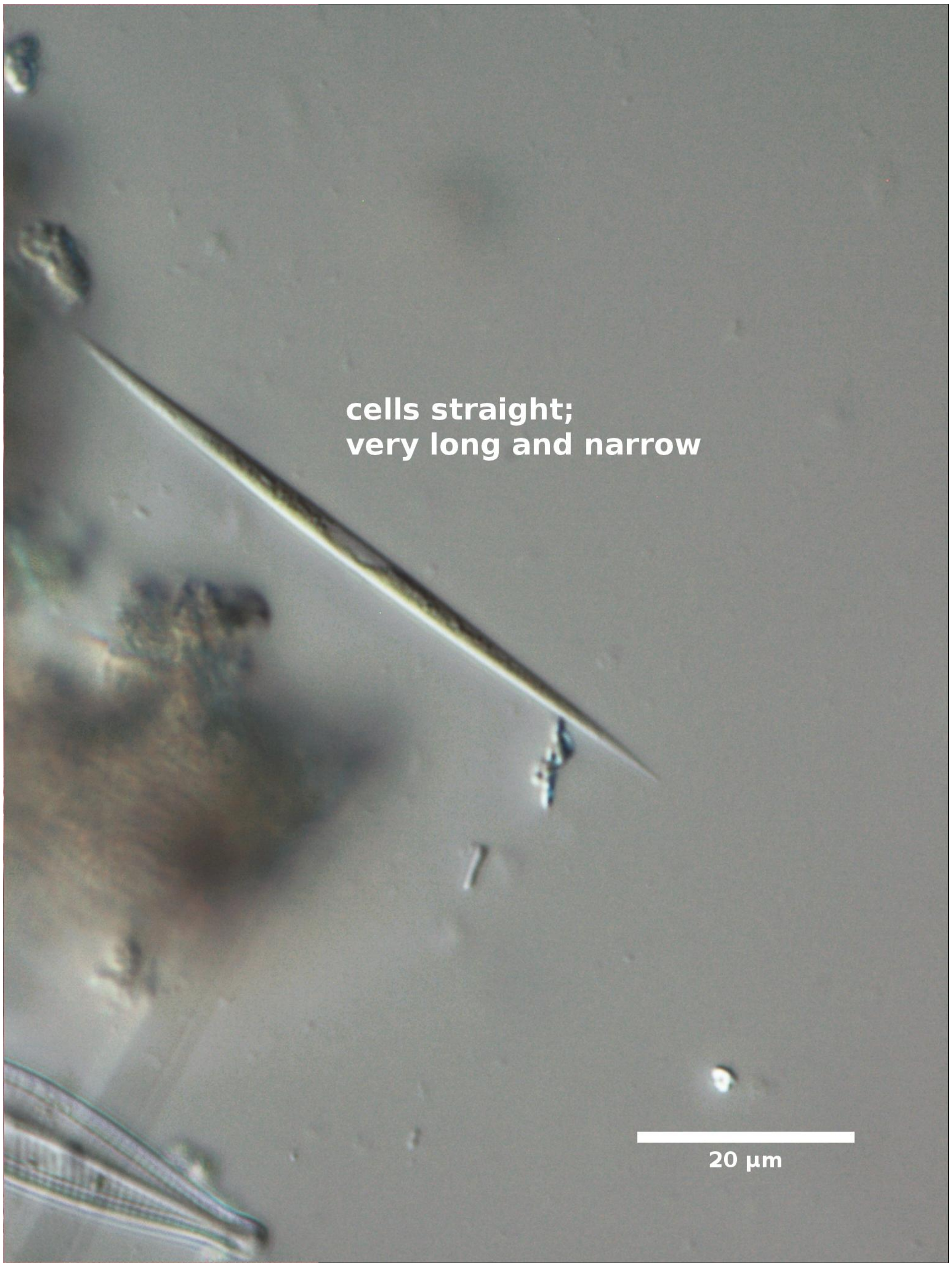

Figure 3.178: *Monoraphidium griffithii* (600x DIC), Lake Geneva, IWS water quality sampling site, Whatcom County, July 12, 2011.

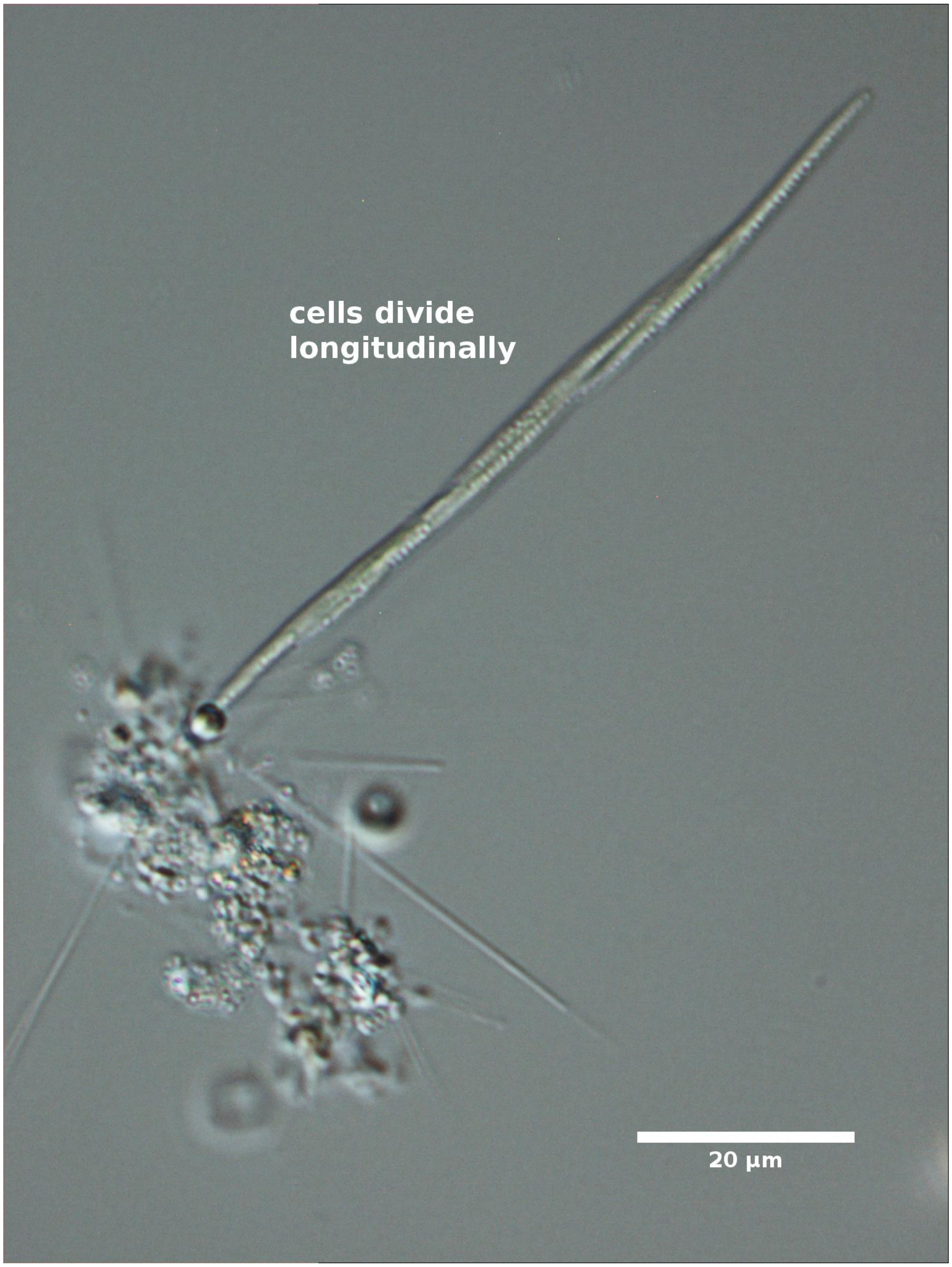

Figure 3.179: *Monoraphidium griffithii* (600x DIC), Kwan Lake, IWS water quality sampling site, Whatcom County, August 24, 2009.

3.23 *Nephrocytium* Nägeli and *Oonephris* Fott

Local taxa

Nephrocytium agardhianum Nägeli;
Nephrocytium limneticum (G. M. Smith) G. M. Smith;
Oonephris obesa (West & G. S. West) Fott

Abundance

Moderately common; rarely present in large numbers.

Local measurements		Width	Length	Biovolume†
Nephrocytium agardhianum	min	3.8 μm	9.8 μm	81.7 μm^3
cells (spheroid)	med	5.0 μm	12.1 μm	171 μm^3
	max	5.8 μm	14.7 μm	241 μm^3
Nephrocytium limneticum	min	4.3 μm	11.3 μm	122 μm^3
cells (spheroid)	med	5.2 μm	12.6 μm	187 μm^3
	max	9.5 μm	19.2 μm	907 μm^3
Oonephris obesa	min	8.5 μm	12.4 μm	469 μm^3
cells (spheroid)	med	13.4 μm	16.6 μm	1,540 μm^3
	max	16.7 μm	20.2 μm	2,950 μm^3

†Calculated using original measurements, not summary values.

Description

Nephrocytium and *Oonephris* colonies contain 4–8 oval, elliptical, or blunt, crescent-shaped cells enclosed in a persistent, gelatinous mother cell wall (Figures 3.180–3.188). The cells contain a single parietal chloroplast containing one or more pyrenoids. Compare *Nephrocytium* and *Oonephris* colonies to *Oocystis* colonies (Section 3.24, page 401), which usually do not have a persistent gelatinous mother cell wall surrounding the colony.

Nephrocytium agardhianum colonies contain 4–8 blunt, symmetric, crescent-shaped cells (Figure 3.180). The primary distinction between this species and *Nephrocytium limneticum* (next page) is the degree of curvature; *Nephrocytium limneticum* cells are nearly straight along the inner wall.

Nephrocytium limneticum colonies are contain 4–8 blunt, asymmetric, crescent-shaped cells (Figures 3.181–3.184). Most of the local samples have 8-cell colonies. The individual cells are about twice as long as wide, and slightly asymmetric, with one side straight or convex and the other side strongly curved.

Oonephris obesa cells closely resemble *Nephrocytium* cells, and in some keys will be included as *Nephrocytium obesa*. The colonies are oval and contain 2–8 cells (usually 4) enclosed in a persistent, gelatinous mother cell wall (Figures 3.185–3.188). The individual cells are oval or hemispherical, with thick cell walls. The chloroplast is stellate in young cells but becomes dense and reticulated (net-like), with a prominent central pyrenoid.

Figure 3.180: *Nephrocytium agardhianum* (600x DIC), Coal Lake, IWS water quality sampling site, Snohomish County, August 28, 2014.

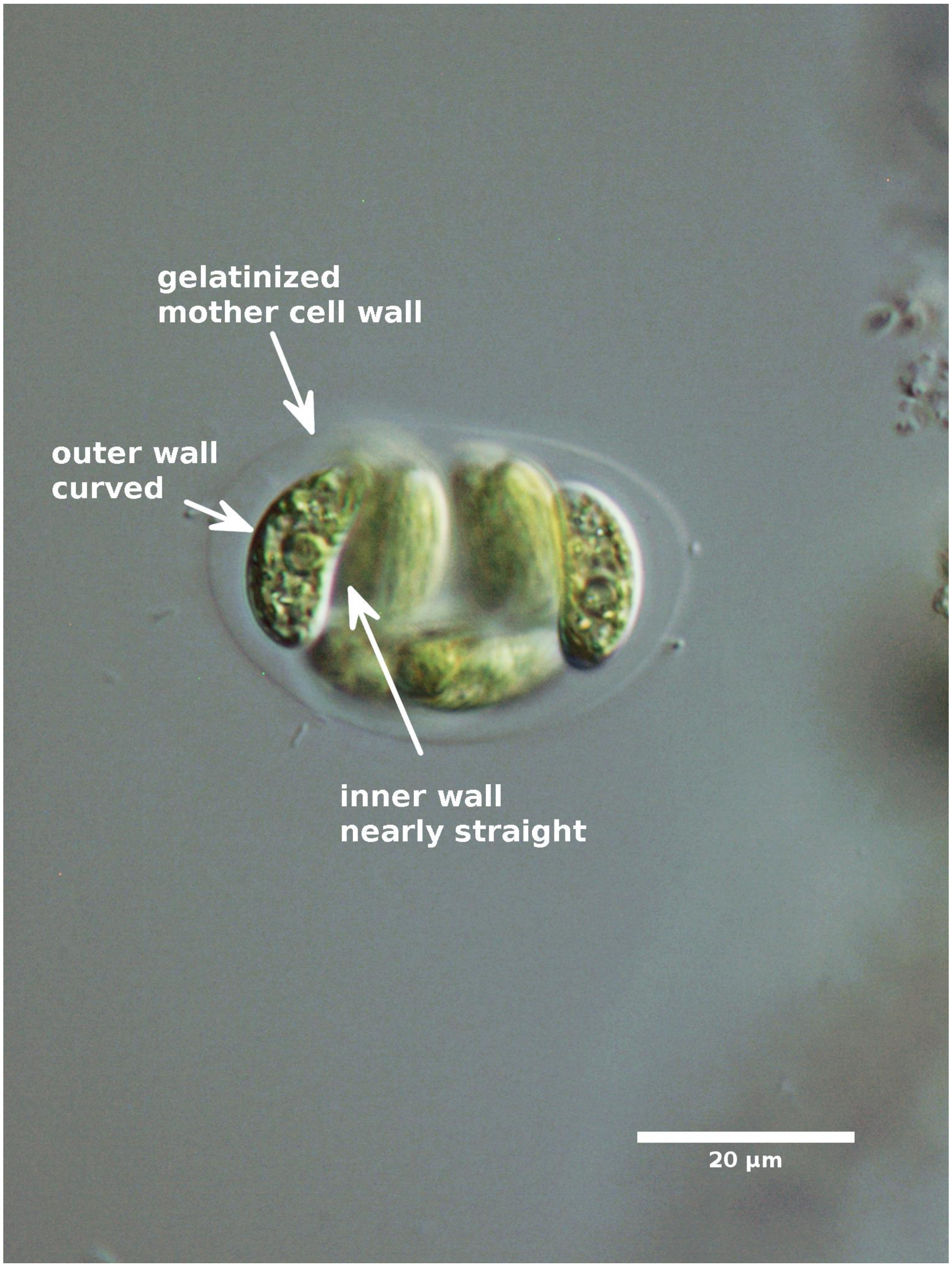

Figure 3.181: *Nephrocytium limneticum* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 29, 2013.

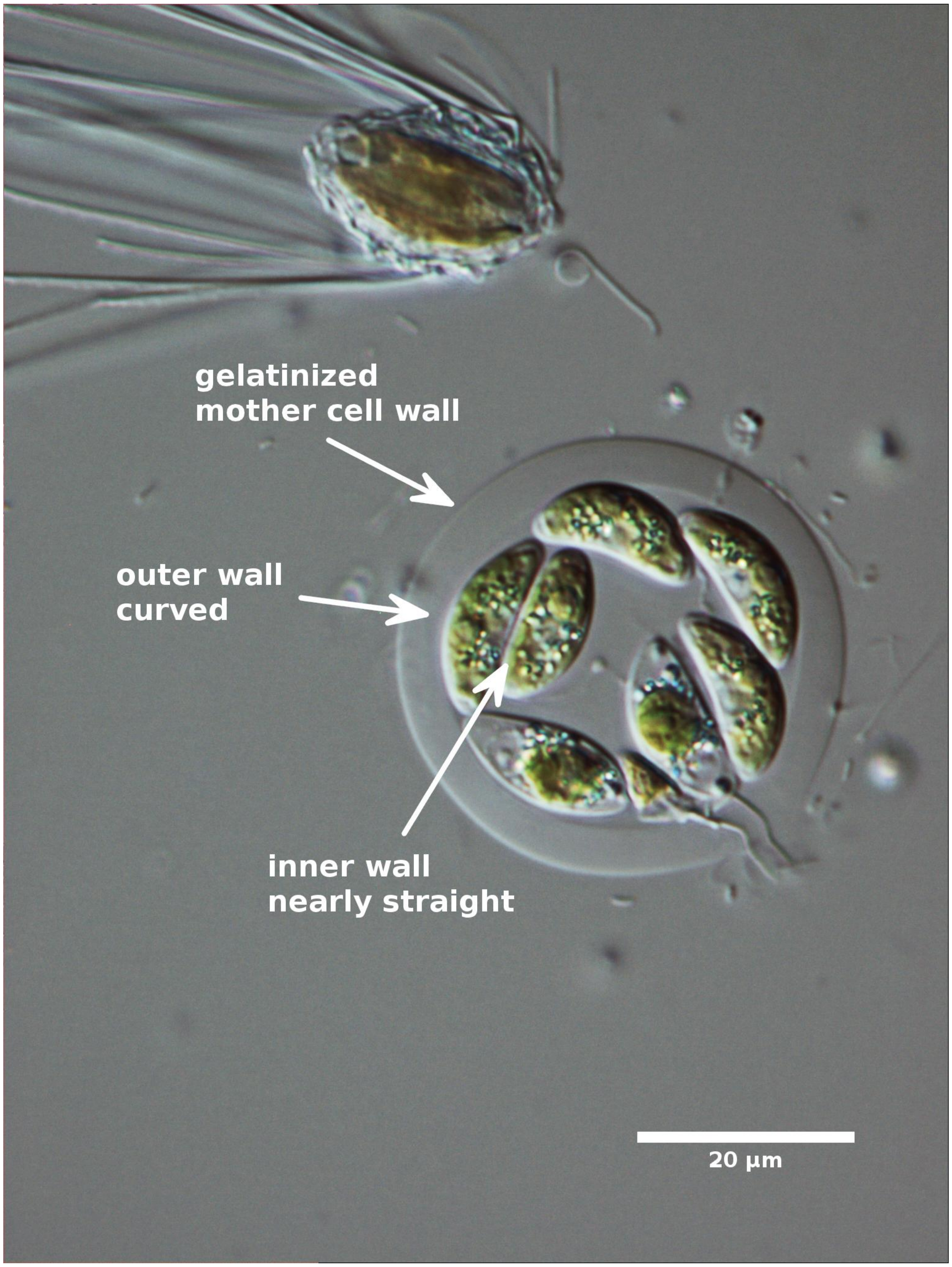

Figure 3.182: *Nephrocytium limneticum* (600x DIC), Cranberry Lake, IWS water quality sampling site, Island County, September 1, 2008.

Figure 3.183: *Nephrocytium limneticum* (600x DIC), Cranberry Lake, IWS water quality sampling site, Island County, September 1, 2008.

Figure 3.184: *Nephrocytium limneticum* (600x DIC), Beaver Lake, IWS water quality sampling site, Skagit County, July 28, 2011.

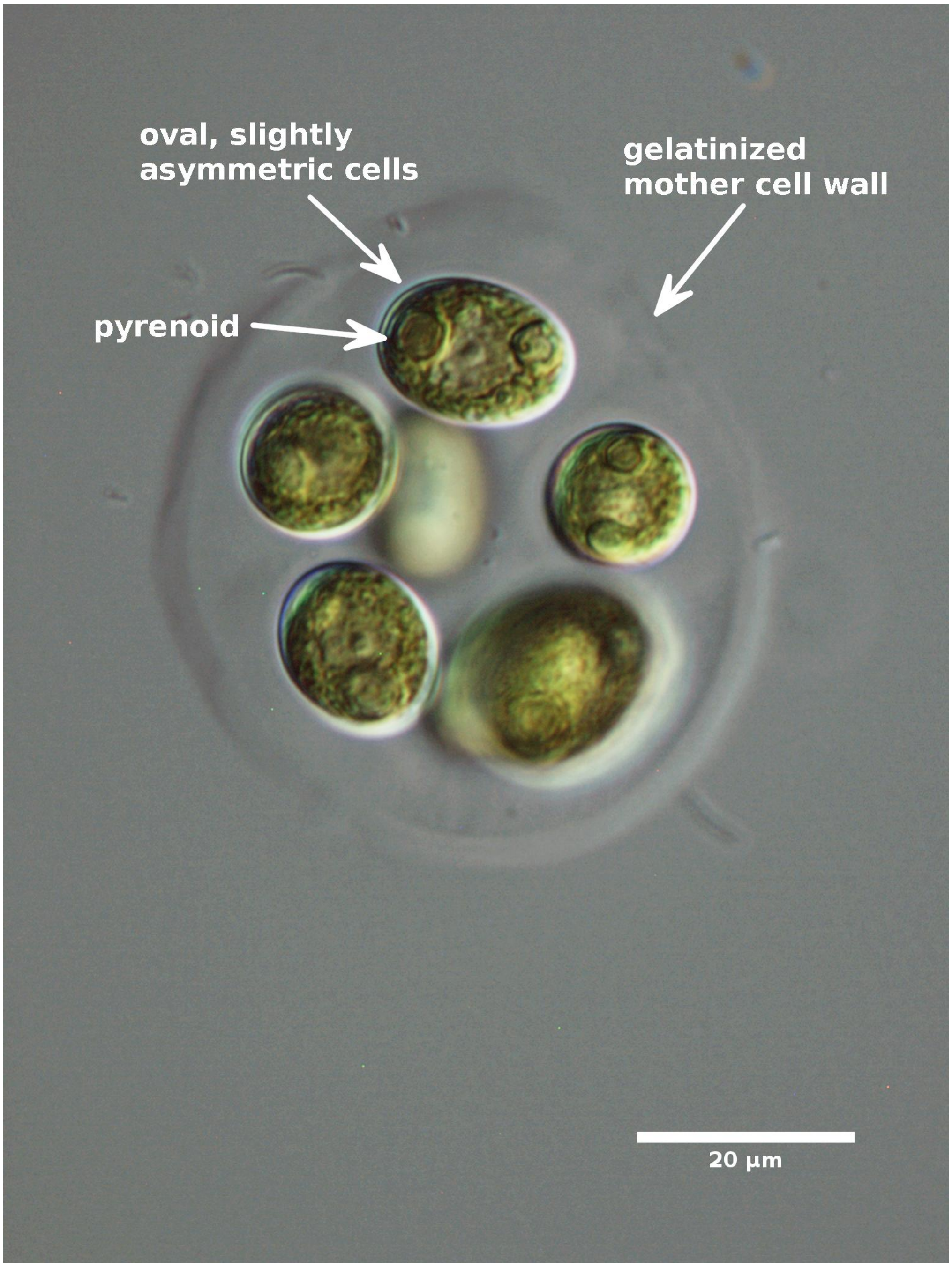

Figure 3.185: *Oonephris obesa* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, August 8, 2013.

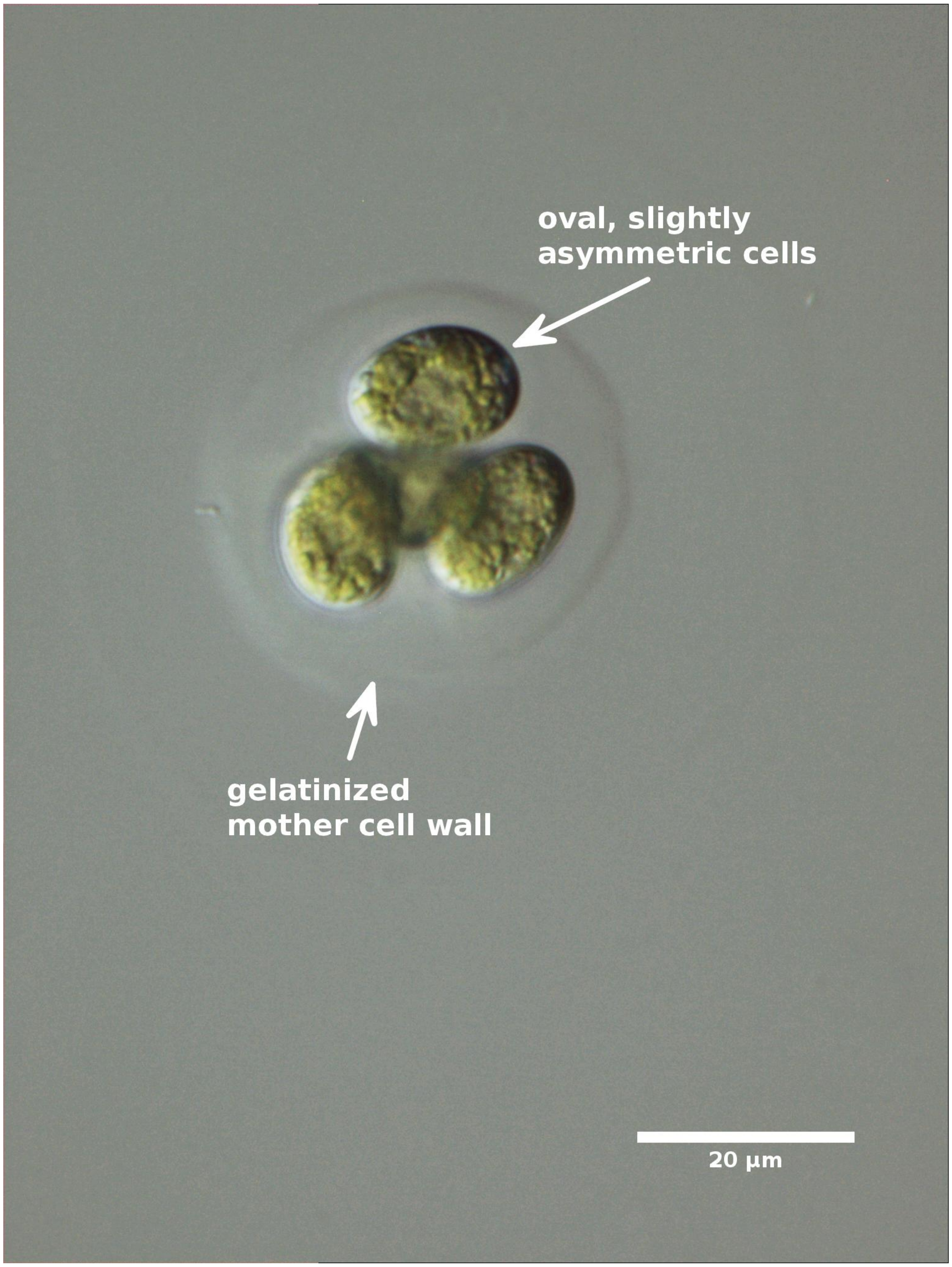

Figure 3.186: *Oonephris obesa* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, July 7, 2011.

Figure 3.187: *Oonephris obesa* (600x DIC), Heart Lake, IWS water quality sampling site, Skagit County, August 21, 2007.

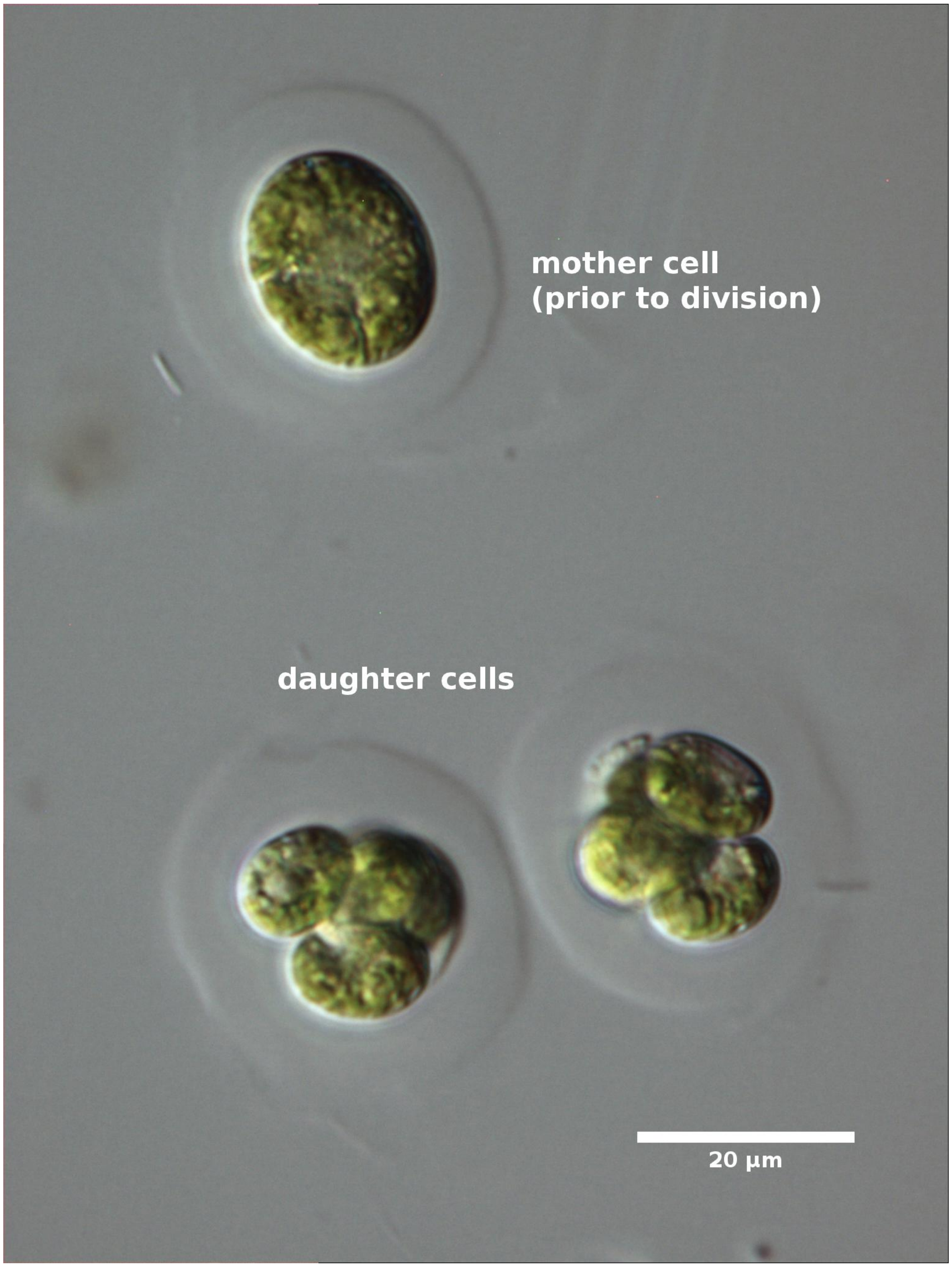

Figure 3.188: *Oonephris obesa* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 5, 2011.

3.24 *Oocystis* Nägeli ex A. Braun

Local taxa

Oocystis borgei Snow;
Oocystis marssonii Lemmermann?;
Oocystis spp.

Abundance

Moderately common; rarely present in large numbers.

Local measurements		Width	Length	Biovolume[†]
Oocystis borgei	min	10.0 μm	12.4 μm	649 μm^3
cells (spheroid)	med	10.7 μm	12.9 μm	772 μm^3
	max	12.4 μm	16.3 μm	1,310 μm^3
Oocystis marssonii?	min	8.9 μm	14.7 μm	647 μm^3
cells (spheroid)	med	11.7 μm	16.8 μm	1,210 μm^3
	max	14.3 μm	19.8 μm	2,050 μm^3
Oocystis sp.1	min	4.0 μm	7.7 μm	67.8 μm^3
cells (spheroid)	med	6.0 μm	11.4 μm	232 μm^3
	max	8.6 μm	13.0 μm	480 μm^3
Oocystis sp.2	min	5.3 μm	8.1 μm	119 μm^3
cells (spheroid)	med	6.1 μm	11.6 μm	226 μm^3
	max	7.2 μm	13.2 μm	358 μm^3

[†]Calculated using original measurements, not summary values.

Description

Oocystis cells are occasionally solitary, but usually form colonies of 4 (or more) cells inside an expanded mother cell (Figures 3.189–3.198). Rapidly growing colonies may aggregate, creating larger groups with cells in multiples of four. Individual cells are oval or broadly fusiform. Many species have apical nodules or thickened walls. Remnants of the mother cell wall may resemble a mucilaginous colonial envelope, making *Oocystis* difficult to distinguish from *Nephrocytium* and *Oonephris* (Section 3.23, page 390), which have gelatinous mother cell walls.

Many of the taxonomic keys have conflicting information about the presence or absence of pyrenoids, the number of chloroplasts, and other morphological characteristics for the different species of *Oocystis*. John, et al. (2011) state that pyrenoids, in particular, may be indistinct and are not a reliable taxonomic feature. As a result, only a few of the local *Oocystis* taxa could be identified to species.

Oocystis borgei cells are oval, $\leq$1.5 longer than broad, with rounded poles (Figures 3.189–3.190). The cells may be solitary or in colonies of 2–8 cells. Each cell contains 1–4 grooved chloroplasts. The cells may be contained within a slightly expanded mother cell wall, but will not usually form multiple generations within a series of expanding mother cell walls.

Most of the local *Oocystis* specimens were tentatively identified as *Oocystis marssonii* (Figures 3.191–3.195). *Oocystis marssonii* cells are football-shaped, with a slight amount of apical thickening, but lack apical knobs. Each cells has one or more grooved chloroplasts, each with pyrenoid. The cells may be solitary or contained inside an expanding mother cell wall. Multiple generations are often enclosed inside sequential mother cell walls.

Oocystis marssonii is separated from *Oocystis lacustris* and *Oocystis parva* almost entirely based on cell size. The cell dimensions for local specimens are similar to the dimensions given by John, et al. (2011) for *Oocystis marssonii* (6.3–12 $\times$ 8.5–18 μm). The other two species are described as having smaller cells (*Oocystis lacustris* = 3.2–9.2 $\times$ 6.4–15 μm; *Oocystis parva* = 3–7 $\times$ 6–12 μm). But size alone is not a good distinguishing feature. All three of these species have cells that are retained inside the expanding mother cell wall and increasing numbers of chloroplasts as the cell ages.

Oocystis sp.1 is characterized by small elliptical cells in groups of 2–4 inside a barely expanded mother cell (Figures 3.196–3.197). The individual cells and the mother cell have distinct apical nodules.

Oocystis sp.2 resembles *Oocystis marssonii*, but the cells are much smaller, matching the range for *Oocystis parva* (John, et al., 2011). The individual cells are oval or broadly elliptical and form small 4-cell colonies enclosed in the expanded mother cell wall (Figure 3.198). The cells lack distinct apical nodules.

Figure 3.189: *Oocystis borgei* (400x DIC), Lake Samish, IWS water quality sampling site, Whatcom County, October 25, 2006.

Figure 3.190: *Oocystis borgei* (400x phase contrast), Lake Samish, IWS water quality sampling site, Whatcom County, October 23, 2006.

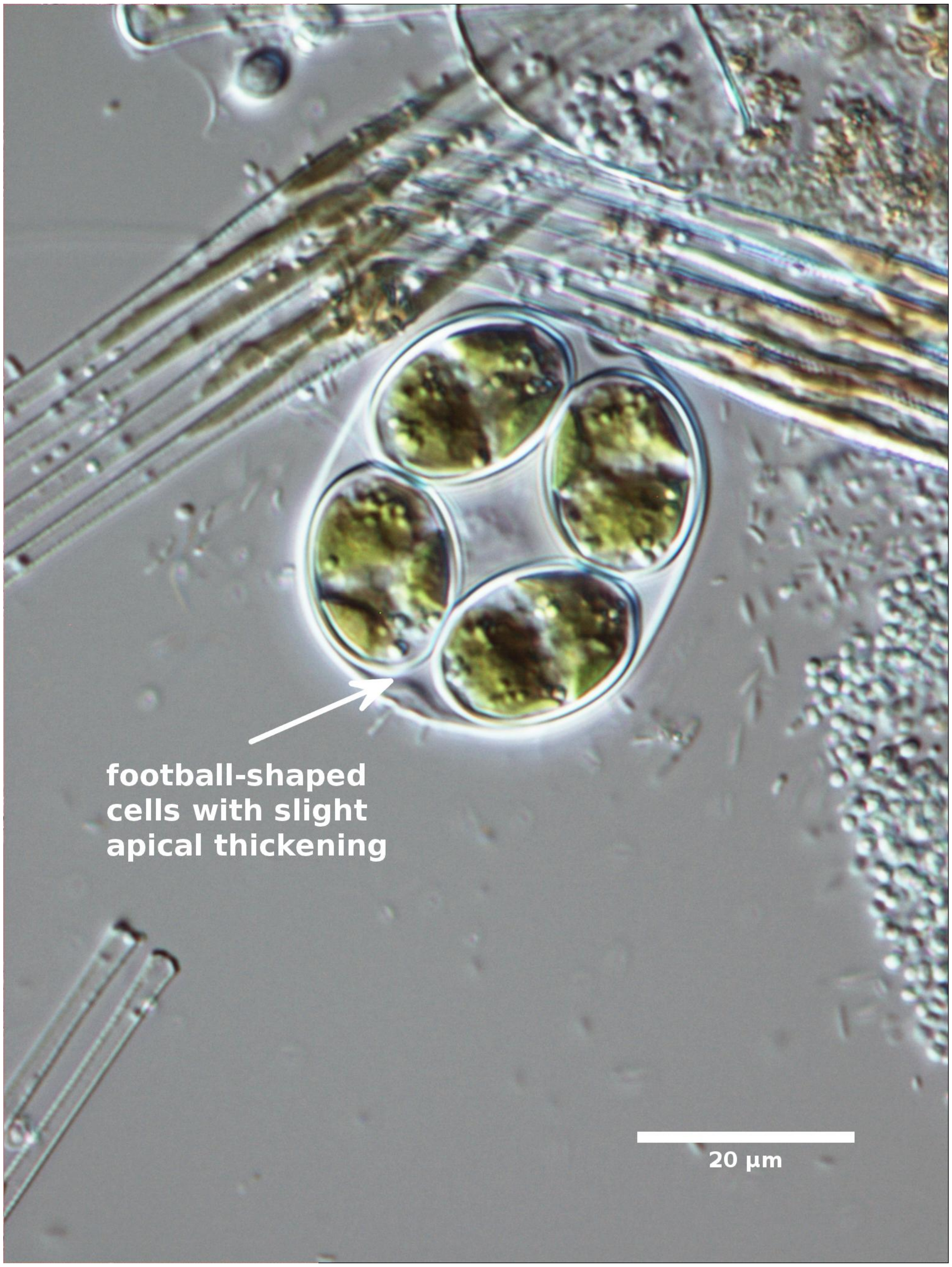

Figure 3.191: *Oocystis marssonii*? (600x DIC), Cranberry Lake, IWS water quality sampling site, Island County, September 1, 2008.

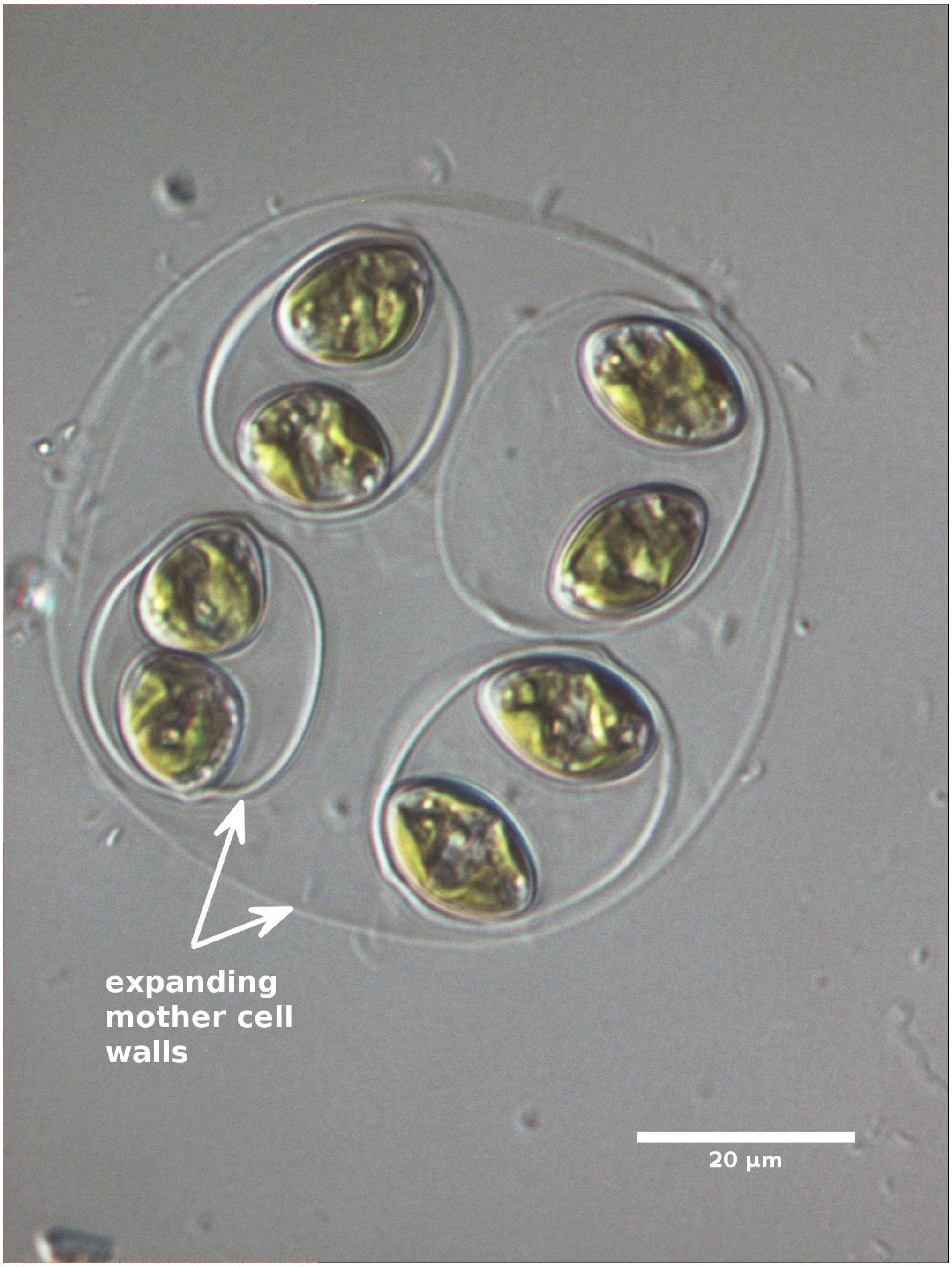

Figure 3.192: *Oocystis marssonii*? (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 12, 2010.

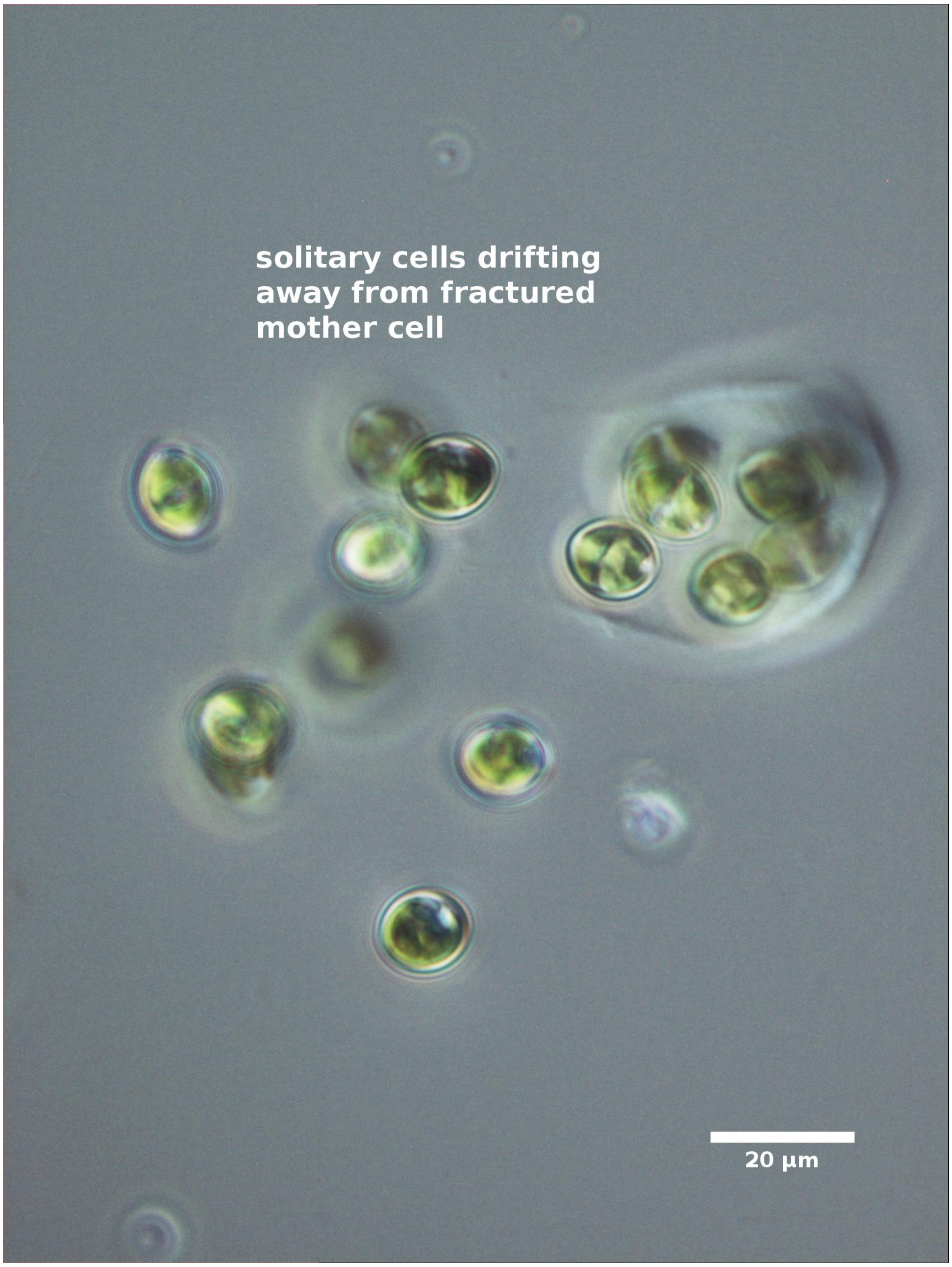

Figure 3.193: *Oocystis marssonii*? (400x DIC), Kwan Lake, IWS water quality sampling site, Whatcom County, September 23, 2011.

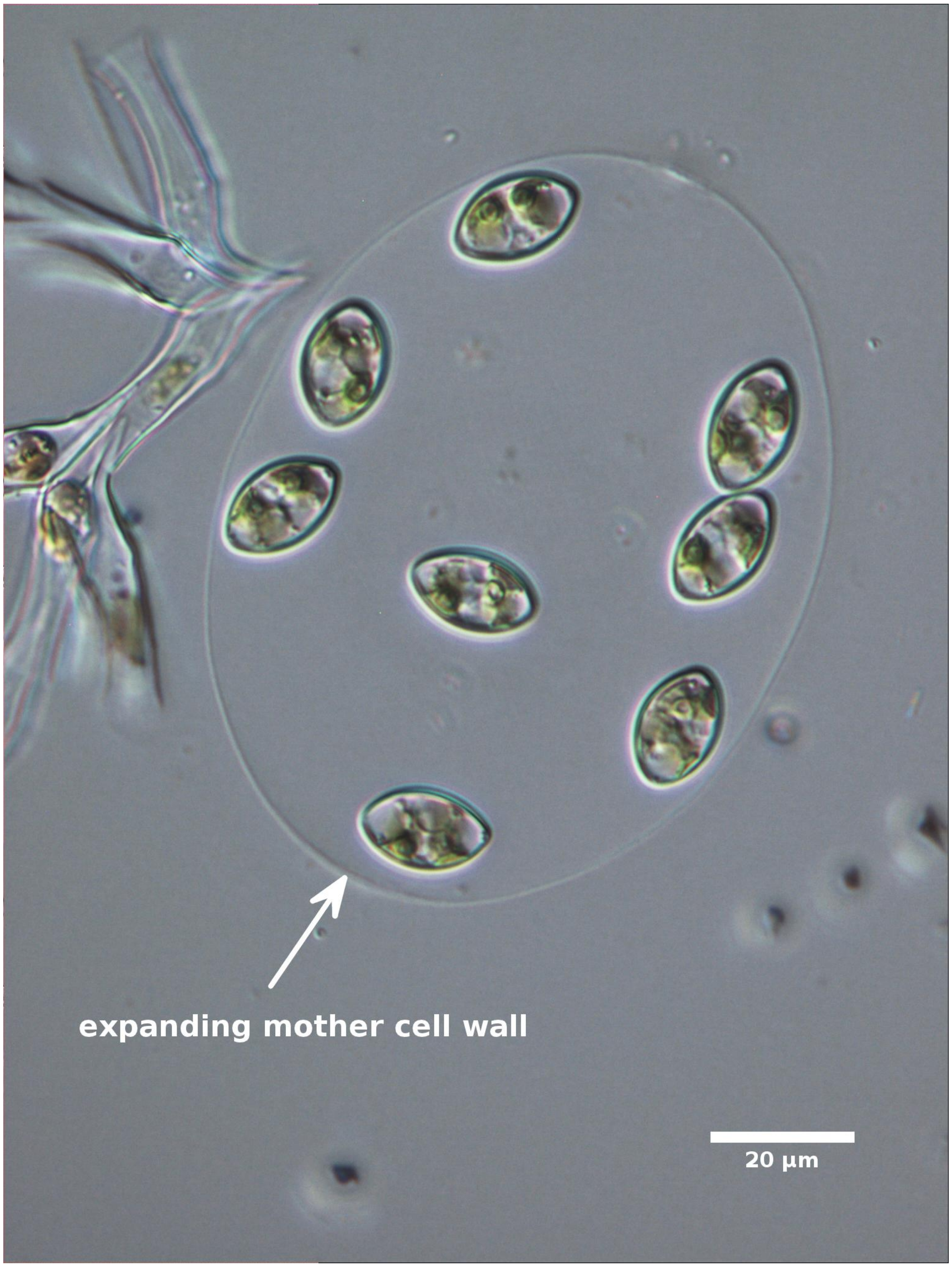

Figure 3.194: *Oocystis marssonii*? (400x DIC), Cranberry Lake, IWS water quality sampling site, Island County, July 8, 2010.

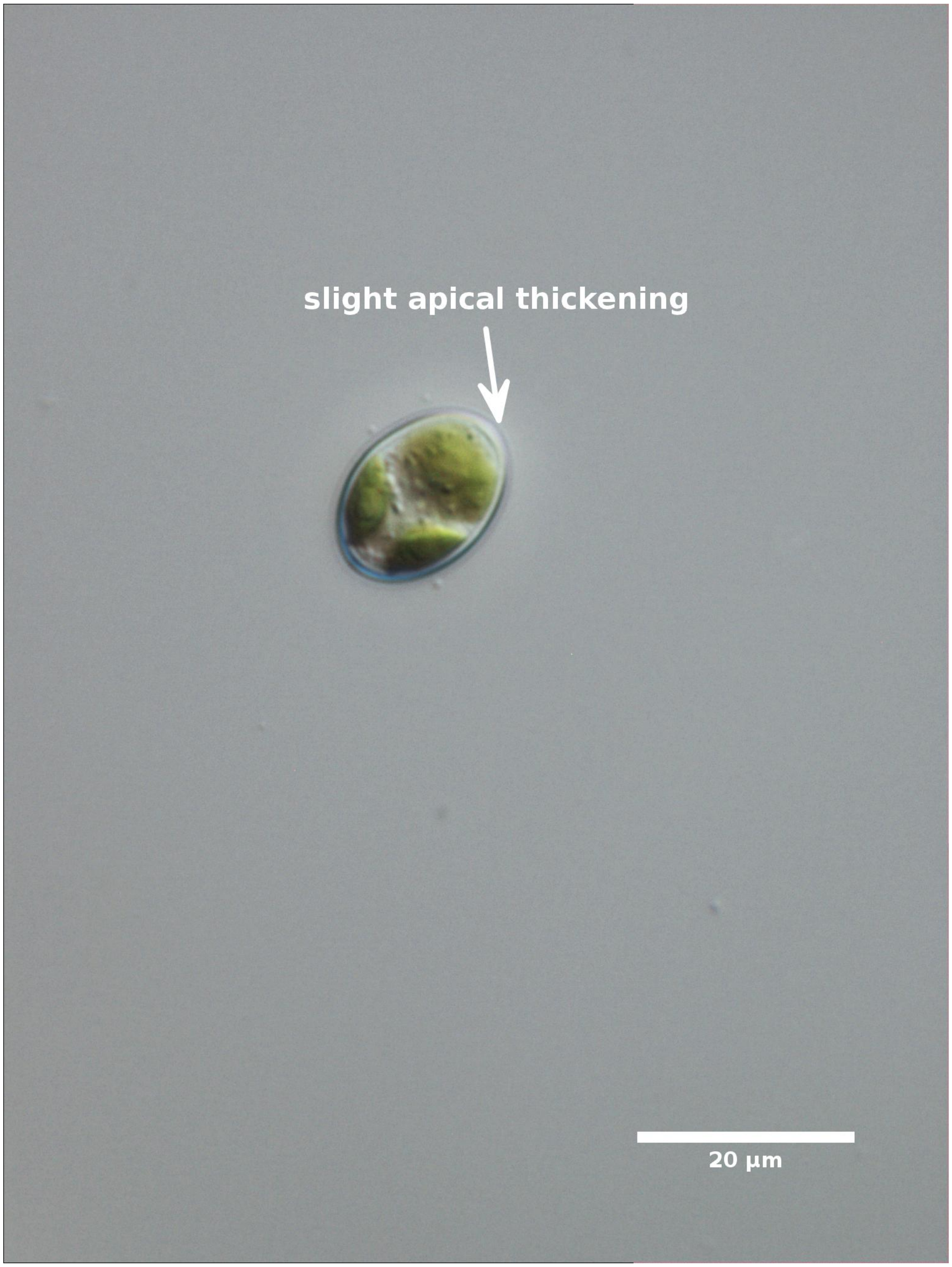

Figure 3.195: *Oocystis marssonii*? (600x DIC), Bug Lake, IWS water quality sampling site, Whatcom County, August 20, 2008.

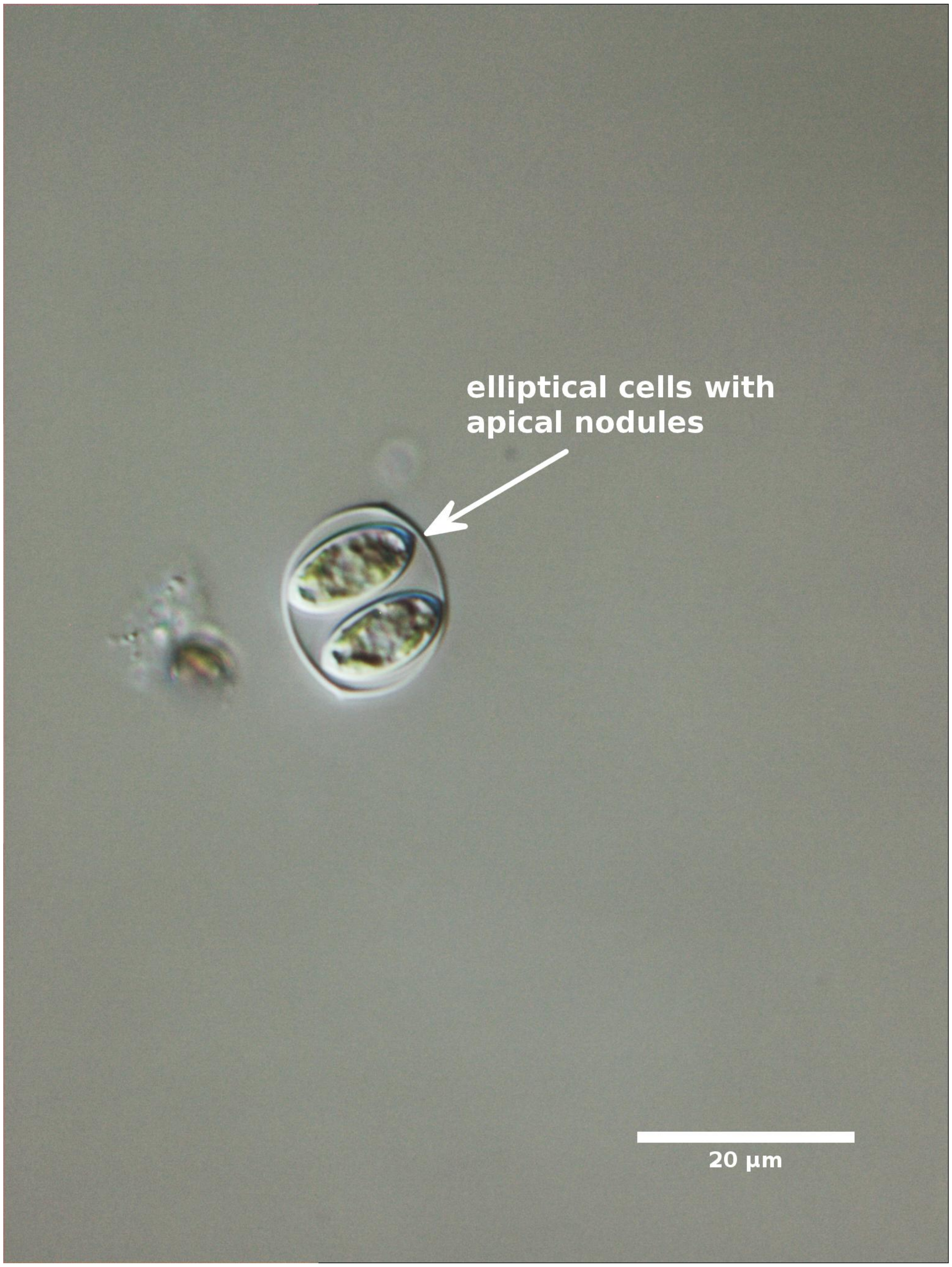

Figure 3.196: *Oocystis* sp.1 (600x DIC), Picture Lake, IWS water quality sampling site, Whatcom County, August 26, 2008.

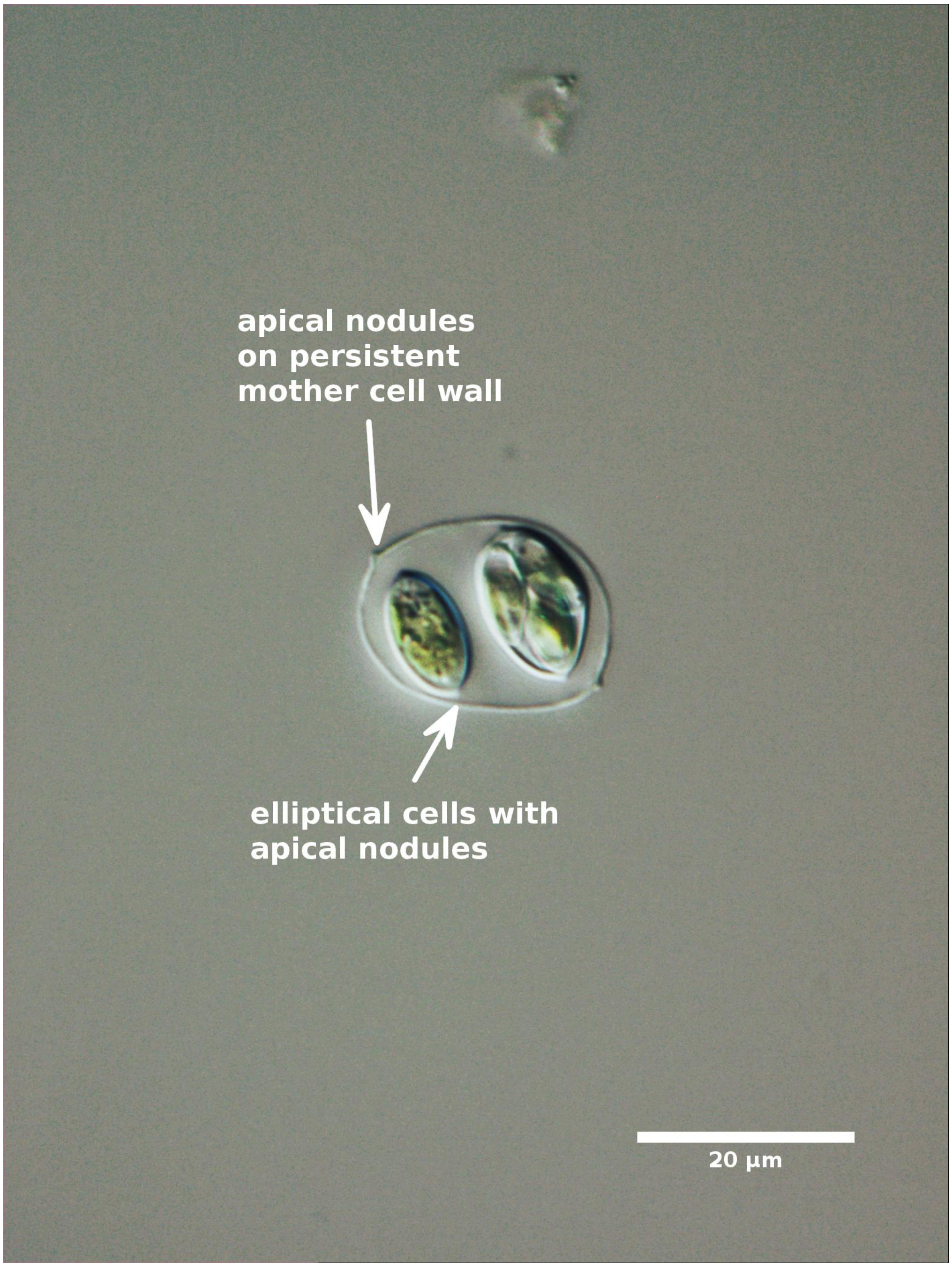

Figure 3.197: *Oocystis* sp.1 (600x DIC), Lake Padden, IWS water quality sampling site, Whatcom County, August 20, 2008.

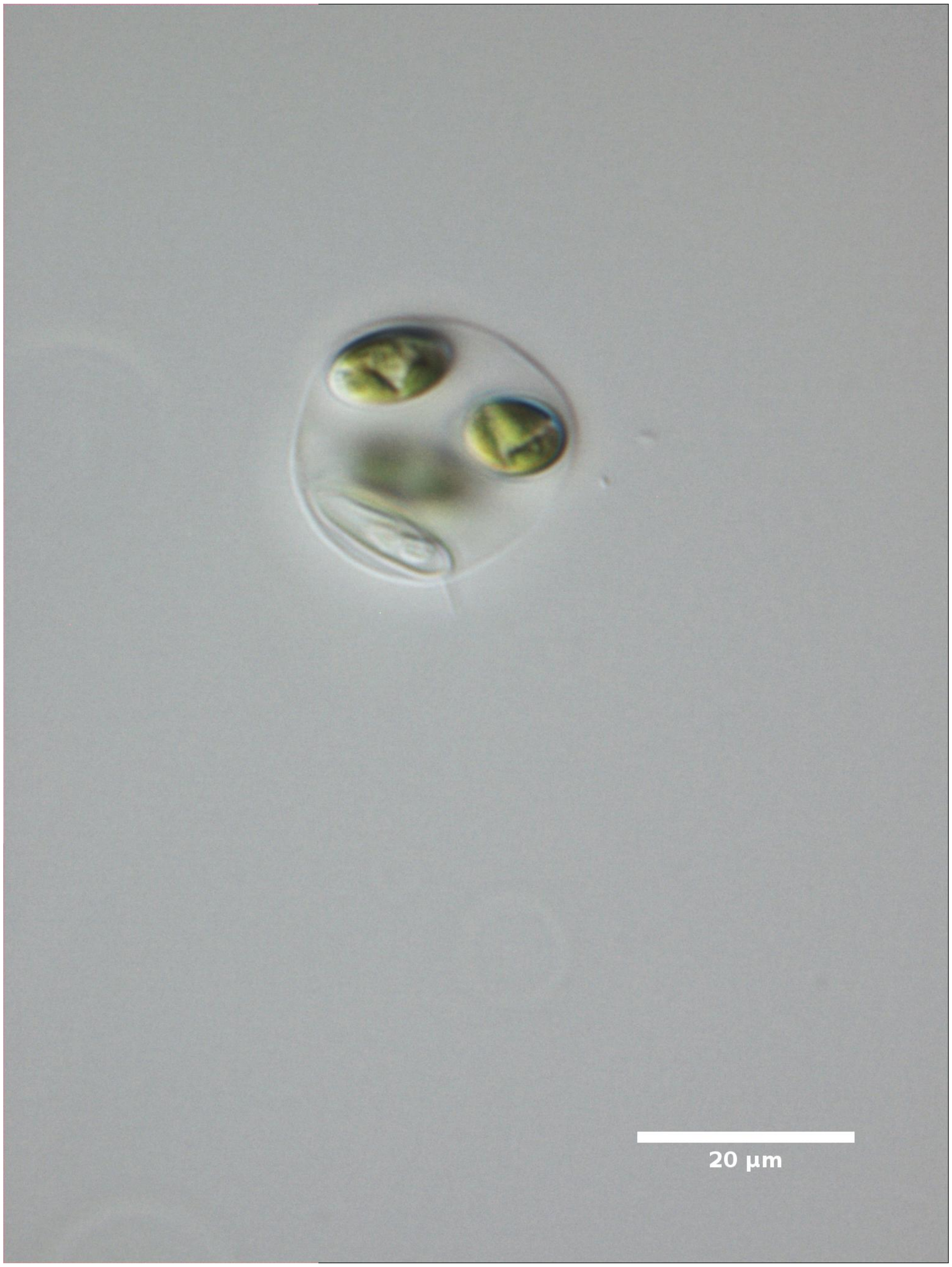

Figure 3.198: *Oocystis* sp.2 (600x DIC), Lake McMurray, IWS water quality sampling site, Skagit County, August 21, 2008.

3.25 *Palmodictyon* Kützing

Local taxon
Palmodictyon varium (Nägeli) Lemmermann

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Palmodictyon varium	min	6.6 μm	–	151 μm^3
cells (sphere)	med	8.0 μm	–	268 μm^3
	max	8.8 μm	–	357 μm^3

†Calculated using original measurements, not summary values.

Description
Palmodictyon cells are spherical or oval, with one or more disc-shaped chloroplasts that may or may not contain visible pyrenoids (Figures 3.199–3.200).[18] The cells form a single or double row inside a thin, tube-shaped mucilage. The colony is often attached to solid substrates, but may also be planktonic. The cells and colony resemble *Apiocystis* (Section 3.5, page 240), which forms club-shaped epiphytic colonies of spherical or oval cells with long, non-motile pseudocilia.

Palmodictyon varium is characterized by cells that contain 4–6 disc-shaped chloroplast that lack visible pyrenoids. The cells usually form a single row inside the mucilage layer. This species is described as common in North America, especially in soft-water (peaty/boggy) ponds and ditches (John, et al., 2011)

[18]The absence of pyrenoids is not a particularly good taxonomic feature. Recent improvements in microscopy have revealed the presence of pyrenoids in species that were initially described as lacking this feature.

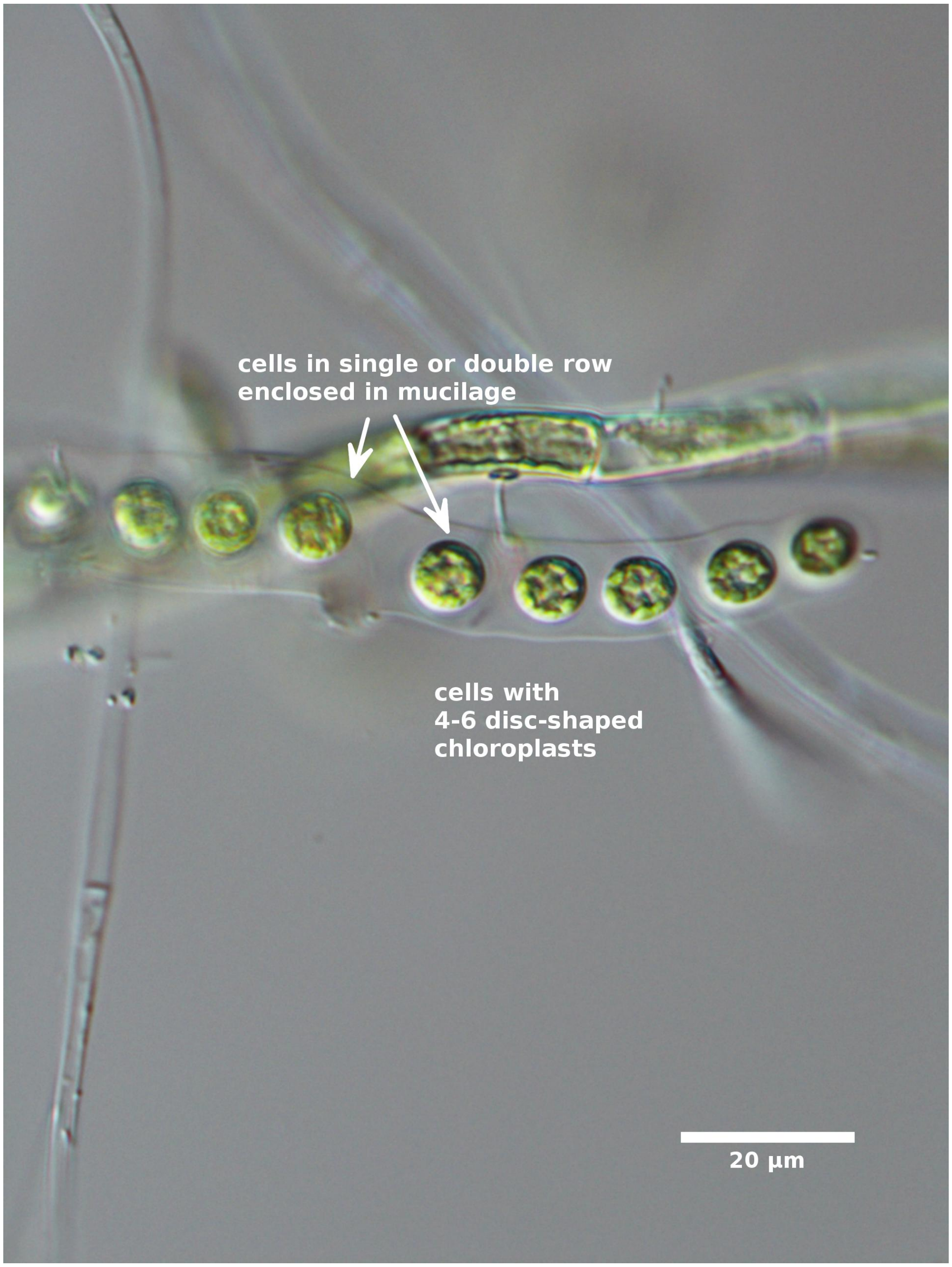

Figure 3.199: *Palmodictyon varium* (600x DIC), small storm water treatment pond, Whatcom County, May 11, 2015.

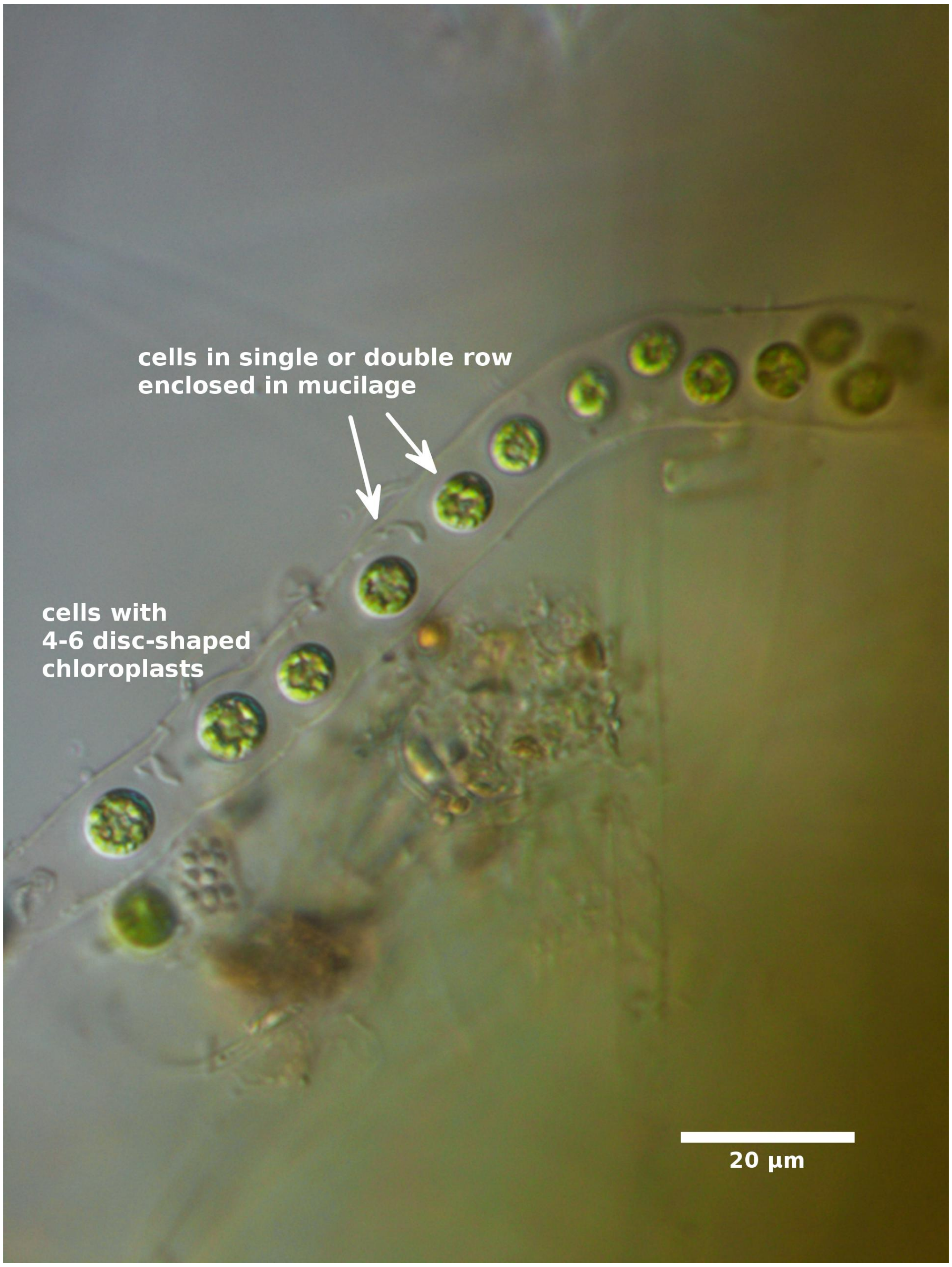

Figure 3.200: *Palmodictyon varium* (600x DIC), small storm water treatment pond, Whatcom County, May 11, 2015.

3.26 *Paradoxia* Svirenko

Local taxon

Paradoxia multiseta Svirenko

Abundance

Infrequently collected.

Local measurements		Width	Length	Biovolume†
Paradoxia multiseta‡	min	2.8 μm	22.3 μm	52.0 μm^3
cells (cone $+\frac{1}{2}$ sphere)	med	5.2 μm	26.1 μm	173 μm^3
	max	7.2 μm	34.0 μm	463 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume based on cone length (< cell length).

Description

Paradoxia cells are club-shaped or fusiform, and occur in pairs (Figures 3.201–3.204). The apical end of each cell contains many long, thin, hair-like spines or setae; the posterior end tapers, then splits into twisted extensions that link the cells. The cell pairs are described as facing in opposite directions, but other orientations are often observed in local samples (Figure 3.203). The apical portion of the cell is usually blunt, but some lakes have a mixture of blunt, club-shaped cells and pointed, fusiform cells.

This unusual species resembles *Ankyra ancora* (Section 3.4, page 228) and is rare in most regions (you won't find it in most taxonomic keys). While not exactly common, *Paradoxia* is present in several local lakes and is regularly collected in late summer samples from Lake Fazon and Cranberry Lake.

Figure 3.201: *Paradoxia multiseta* (600x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, August 16, 2007.

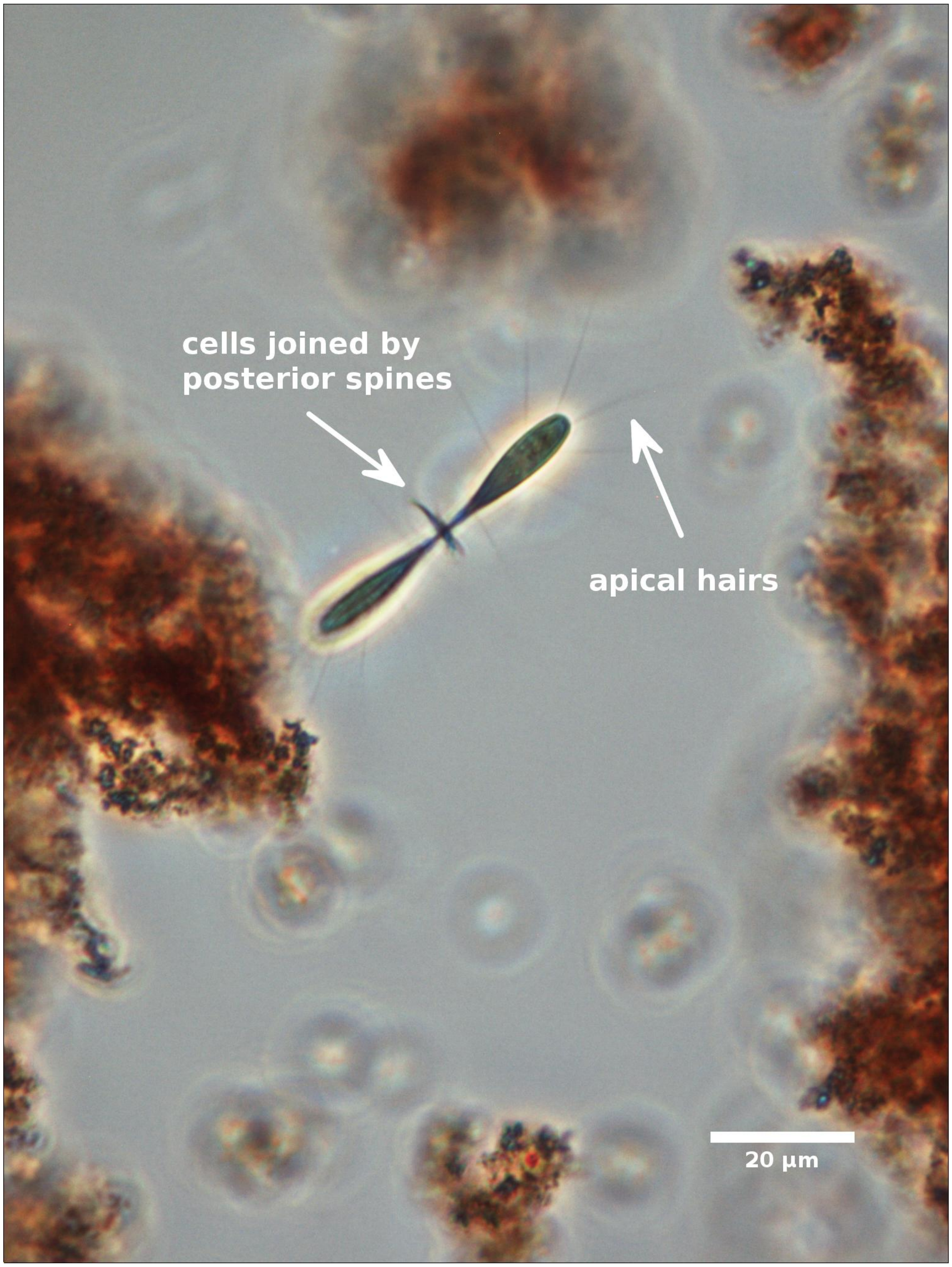

Figure 3.202: *Paradoxia multiseta* (400x phase contrast), Lake Fazon, IWS water quality sampling site, Whatcom County, August 16, 2007.

Figure 3.203: *Paradoxia multiseta* (600x DIC), Cranberry Lake, IWS water quality sampling site, Island County, September 1, 2008.

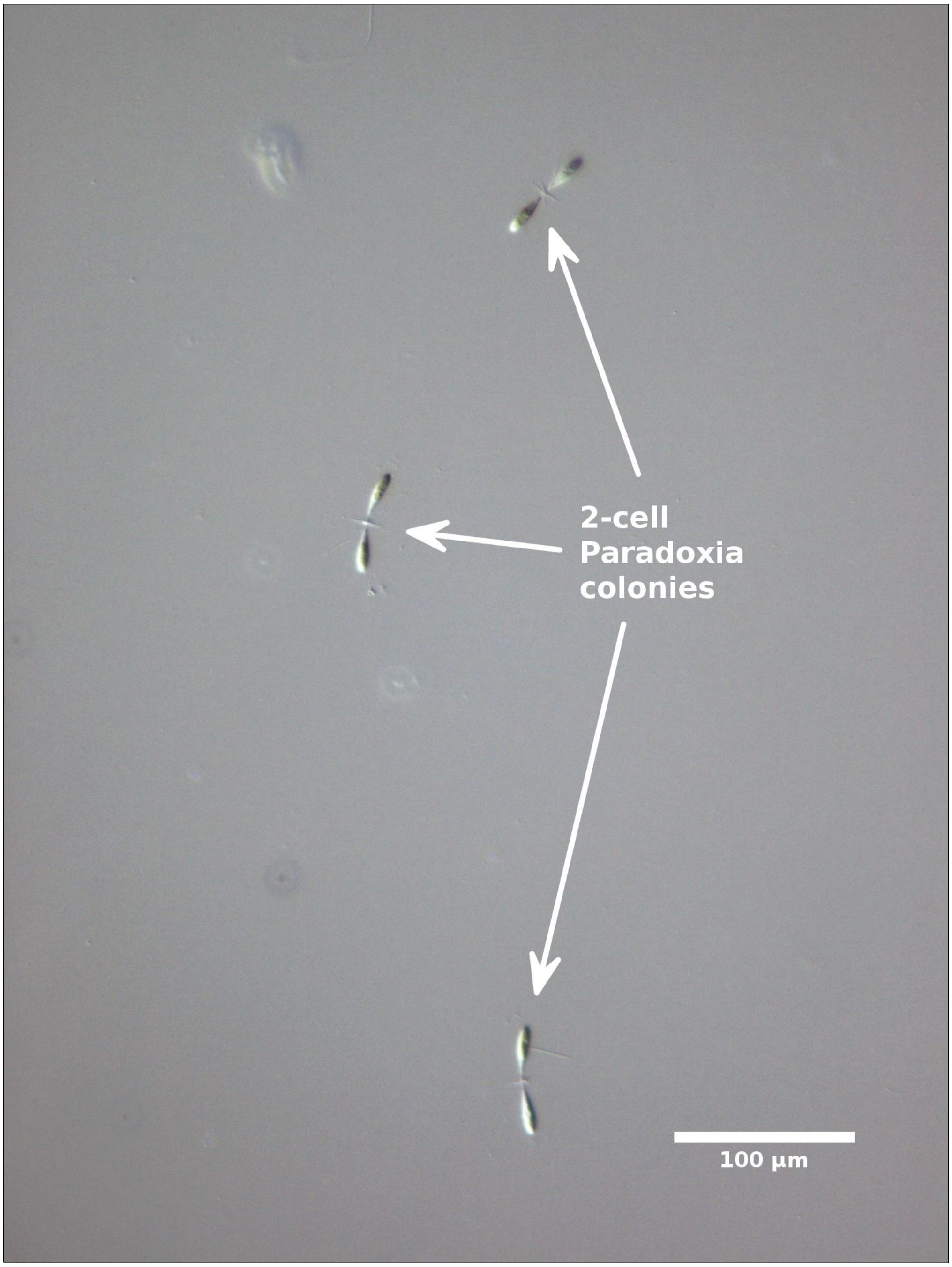

Figure 3.204: *Paradoxia multiseta* (100x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, August 24, 2007.

3.27 *Paulschulzia* Skuja

Local taxon
Paulschulzia pseudovolvox (Schultz) Skuja

Abundance
Infrequently collected; occasionally forms blooms.

Local measurements		Width	Length	Biovolume†
Paulschulzia pseudovolvox	min	7.4 μm	–	212 μm^3
cells (sphere)	med	9.1 μm	–	388 μm^3
	max	12.1 μm	–	928 μm^3

†Calculated using original measurements, not summary values.

Description
Paulschulzia pseudovolvox cells are spherical, with a cup-shaped chloroplast that contains a distinct pyrenoid (Figures 3.205–3.206). The cells form 4-cell subgroups that aggregate to form larger colonies. The individual cells, 2-cell and 4-cell subgroups, and the colony are surrounded by distinct mucilage layers. Each cell has 2 long thread-like pseudocilia that extend beyond the margin of the colonial mucilage The striated mucilage separates *Paulschulzia pseudovolvox* from *Tetraspora* (Section 3.37, page 508).

Paulschulzia belongs to the order **Tetrasporales**, which contains nonmotile cells that are closely related to the motile **Volvocales** (e.g., *Volvox*, Section 2.13, page 134). Although *Paulschulzia* cells are nonmotile in the vegetative state, the cells have long pseudocilia that are structurally similar to flagella. Other **Tetrasporales** that are found in local lakes and streams include *Apiocystis* (Section 3.5, page 240), *Asterococcus* (Section 3.6, page 245), *Schizochlamys* (Section 3.31, page 465), and *Tetraspora* (Section 3.37, page 508).

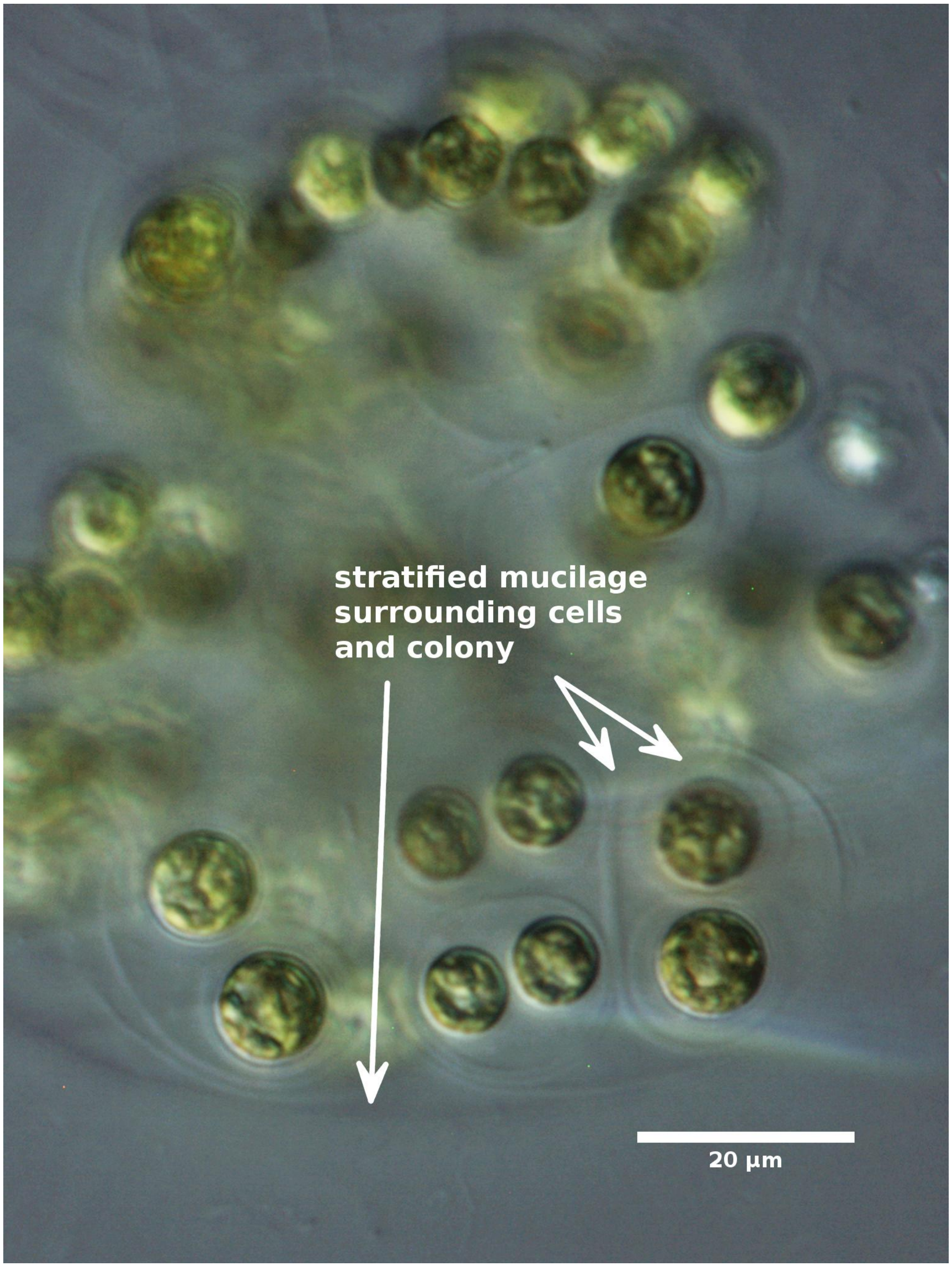

Figure 3.205: *Paulschulzia pseudovolvox* (600x DIC), small pond near Lake Anderson, North Cascades along Hwy 20, August 31, 2012.

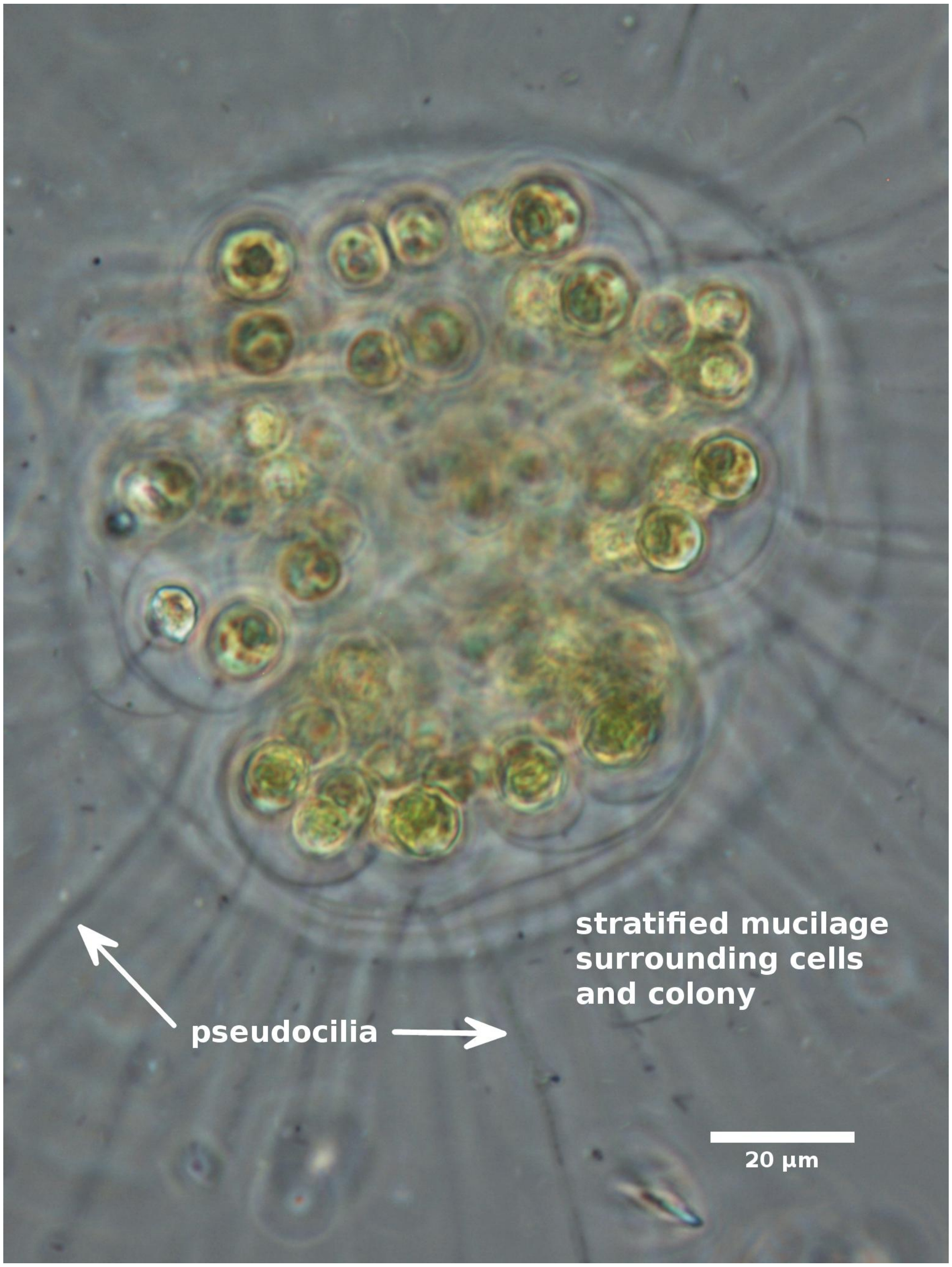

Figure 3.206: *Paulschulzia pseudovolvox* (400x phase contrast), small pond near Lake Anderson, North Cascades along Hwy 20, August 31, 2012.

3.28 *Pediastrum* Meyen

Local taxa
Pediastrum angulosum Ehrenberg ex Meneghini;
Pediastrum boryanum (Turpin) Meneghini
(=*Pseudopediastrum boryanum* [Turpin] E. Hegewald);
Pediastrum boryanum var. *longicorne* Reinsch
(=*Pediastrum glanduliferum* A. W. Bennett);
Pediastrum duplex Meyen;
Pediastrum integrum Nägeli;
Pediastrum kawraiskyi Schmidle
(=*Pseudopediastrum kawraiskyi* [Schmidle] E. Hegewald);
Pediastrum obtusum Lucks;
Pediastrum tetras (Ehrenberg) Ralfs
(=*Stauridium tetras* [Ehrenberg] E. Hegewald)

Abundance
Moderately common; may be present in large numbers; occasionally forms blooms.

Local measurements		Width	Length	Biovolume$^{\dagger *}$
Pediastrum angulosum	min	9.1 μm	6.7 μm	260 μm^3
inner cells (elliptical prism)	med	10.6 μm	7.9 μm	326 μm^3
	max	11.8 μm	8.8 μm	380 μm^3
Pediastrum angulosum	min	10.8 μm	10.6 μm	462 μm^3
outer cells (elliptical prism)	med	11.1 μm	11.1 μm	479 μm^3
	max	11.3 μm	11.4 μm	501 μm^3
Pediastrum angulosum	min	–	–	–
colonies‡	med	58.5 μm	61.5 μm	–
	max	–	–	–
Pediastrum boryanum	min	8.1 μm	5.7 μm	181 μm^3
inner cells (elliptical prism)	med	12.7 μm	9.0 μm	458 μm^3
	max	23.5 μm	16.0 μm	1,480 μm^3

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Local measurements		Width	Length	Biovolume†
Pediastrum boryanum	min	7.6 μm	11.4 μm	340 μm^3
outer cells (elliptical prism)	med	11.1 μm	14.1 μm	661 μm^3
	max	24.1 μm	25.4 μm	2,400 μm^3
Pediastrum boryanum	min	54.0 μm	55.7 μm	–
colonies‡	med	56.0 μm	60.9 μm	–
	max	131.1 μm	131.2 μm	–
Pediastrum boryanum var.	min	5.1 μm	4.0 μm	80.1 μm^3
longicorne inner cells	med	11.2 μm	8.8 μm	390 μm^3
(elliptical prism)	max	23.1 μm	18.6 μm	1,400 μm^3
Pediastrum boryanum var.	min	5.7 μm	8.6 μm	193 μm^3
longicorne outer cells	med	11.7 μm	17.0 μm	779 μm^3
(elliptical prism)	max	23.9 μm	28.8 μm	2,510 μm^3
Pediastrum boryanum var.	min	49.1 μm	51.8 μm	–
longicorne colonies‡	med	82.5 μm	88.8 μm	–
	max	141.1 μm	151.0 μm	–
Pediastrum duplex	min	6.2 μm	4.8 μm	119 μm^3
inner cells (elliptical prism)	med	12.6 μm	10.8 μm	546 μm^3
	max	20.1 μm	15.4 μm	1,140 μm^3
Pediastrum duplex	min	5.8 μm	7.3 μm	166 μm^3
outer cells (elliptical prism)	med	11.1 μm	13.9 μm	601 μm^3
	max	19.1 μm	20.9 μm	1,540 μm^3
Pediastrum duplex	min	40.6 μm	43.1 μm	–
colonies‡	med	91.4 μm	95.5 μm	–
	max	159.9 μm	160.3 μm	–
Pediastrum integrum	min	9.7 μm	9.9 μm	797 μm^3
inner cells (elliptical prism)	med	19.1 μm	12.6 μm	995 μm^3
	max	20.5 μm	16.4 μm	1,280 μm^3

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Local measurements		Width	Length	Biovolume†
Pediastrum integrum	min	12.7 μm	11.7 μm	1,040 μm^3
outer cells (elliptical prism)	med	17.5 μm	16.8 μm	1,270 μm^3
	max	20.3 μm	20.6 μm	1,520 μm^3
Pediastrum integrum	min	38.8 μm	42.5 μm	–
colonies‡	med	72.8 μm	76.3 μm	–
	max	89.1 μm	92.5 μm	–
Pediastrum kawraiskyi	min	7.0 μm	5.8 μm	159 μm^3
inner cells (elliptical prism)	med	9.4 μm	9.3 μm	356 μm^3
	max	10.3 μm	12.7 μm	417 μm^3
Pediastrum kawraiskyi	min	7.4 μm	7.0 μm	215 μm^3
outer cells (elliptical prism)	med	9.6 μm	10.3 μm	369 μm^3
	max	13.5 μm	13.4 μm	631 μm^3
Pediastrum kawraiskyi	min	17.9 μm	20.5 μm	–
colonies‡	med	23.4 μm	24.2 μm	–
	max	47.0 μm	48.8 μm	–
Pediastrum obtusum	min	10.6 μm	10.0 μm	470 μm^3
inner cells (elliptical prism)	med	13.8 μm	12.0 μm	653 μm^3
	max	16.2 μm	15.6 μm	950 μm^3
Pediastrum obtusum	min	11.4 μm	12.0 μm	582 μm^3
outer cells (elliptical prism)	med	14.4 μm	14.4 μm	803 μm^3
	max	17.0 μm	16.1 μm	1,070 μm^3
Pediastrum obtusum	min	51.5 μm	53.5 μm	–
colonies‡	med	61.5 μm	75.4 μm	–
	max	80.2 μm	98.6 μm	–
Pediastrum tetras	min	6.8 μm	6.1 μm	177 μm^3
inner and outer cells	med	8.3 μm	7.6 μm	248 μm^3
(elliptical prism)	max	11.2 μm	11.5 μm	422 μm^3

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Local measurements		Width	Length	Biovolume†
Pediastrum tetras	min	12.5 μm	12.7 μm	–
colonies‡	med	17.5 μm	18.3 μm	–
	max	24.6 μm	24.7 μm	–

†Calculated using original measurements, not summary values; estimated cell depth = 5 μm.
‡Colony biovolume can estimated using an elliptical prism shape.

Description

The genus *Pediastrum* has been revised extensively, and several very common species have been moved to new genera. The synonyms are noted in the taxa list above, but all former members of the genus *Pediastrum* are included in this section.

Pediastrum cells are arranged in distinctively flattened, circular or oval, coin-shaped colonies (Figures 3.207–3.227). The inner cells are usually angular, with a single large chloroplast and distinct pyrenoid. The outer cells may resemble the inner cells, but are frequently ornate, with horn-like wall extensions.

Pediastrum angulosum colonies contain up to 128 cells (Figure 3.207). The marginal cells are cubical, with a deep, central, U-shaped notch and extend into blunt lobes, but do not have long, horn-like extensions. The inner cells are wider than long, with a shallow groove on one side, and are either adjacent to other cells or have small, Both marginal and interior cells have distinctively ridged (reticulated) cell walls, which is visible in empty cells.

Pediastrum boryanum colonies and cells are quite variable, which has given rise to many subspecies (Figures 3.208–3.211). The cells are typically wider than long (not including projections from marginal cells), with a smooth or granular cell wall. The marginal cells are notched, with two very long, horn-like projections that are frequently longer than the rest of the cell. The inner cells are irregularly shaped and lack intercellular spaces or have very small, inconspicuous spaces. Figure 3.211 shows an unusual, red-stained *Pediastrum boryanum* colony. The color may result from accumulation of metals such as manganese (C. F. Carter, UK, pers. comm., 2013). The specimen was collected in Coal Lake, in the Stillaguamish River (WA) drainage on the Mt. Loop Hwy, which is a region with current and historic mining activity.

The only *Pediastrum boryanum* subspecies (variety) included in this guide is *Pediastrum boryanum* var. *longicorne* (Figures 3.212–3.213), which was called *Pediastrum glanduliferum* A. W. Bennell in older keys. *Pediastrum boryanum* var. *longicorne* has long, thin, gelatinous projections on the marginal cells that usually end in rounded (capitate) knobs. The inner cells usually have no intercellular spaces.

Pediastrum duplex colonies are often large, and may contain up to 128 cells (Figures 3.214–3.216). The cells are usually wider than long (not including projections), with a smooth or granular cell wall. The marginal cells are notched, with two blunt horn-like projections that may be tapered. The interior cells are angular and have small or large intercellular spaces. As with *Pediastrum boryanum*, *Pediastrum duplex* is polymorphic and has many varieties and subspecies.

Pediastrum integrum colonies are relatively small (up to 32 cells) and circular or oval (Figure 3.217). The interior and marginal cells are similar in shape, either angular or heart-shaped, with a smooth or granular cell wall and no intercellular spaces. The marginal cells have no projections or very short, peg-like projections. The partial colony in Figure 3.218 was tentatively identified as *Pediastrum integrum*, but the marginal cells have longer knobs than the *Pediastrum integrum* cells in Figure 3.217.

Pediastrum kawraiskyi colonies are also relatively small (up to 32 cells) and circular (Figures 3.219–3.221). The marginal cells have bent or twisted, cone-shaped projections that extend in different directions. The colony may consist entirely of marginal cells; interior cells, when present, have no intercellular spaces. This species was moderately common in high elevation snow-melt ponds.

Pediastrum obtusum colonies contain up to 32 cells, with cubical, deeply incised marginal cells that form broad, notched lobes (Figures 3.222–3.223). The interior cells are approximately cubical and deeply notched on one side. The cell shape resembles *Pediastrum tetras*, but is distinguished by the larger colonies, lobed marginal cells, and cubical interior cells. *Pediastrum tetras* is morphologically diverse, so it is possible that these specimens are a variety of *P. tetras*.

Pediastrum tetras forms small colonies with only 4–16 cells (Figures 3.224–3.226). The marginal cells are deeply incised and triangular, trapezoidal or wedge-shaped. Many colonies contain only 4 deeply incised marginal cells. Interior cells, when present, are angular ($\geq$4 sides), with a deep notch one one side. Because of its small size, this common, morphologically diverse species of *Pediastrum* is often overlooked. Compare *Pediastrum tetras* to young colonies of *Pediastrum boryanum*, which will have horn-like projections on the marginal cells.

The specimen in Figure 3.227 forms small, 4-cell colonies, like *Pediastrum tetras*, but can be distinguished by the very shallow, U-shaped median notches and tiny, knob-like projections. This colony was collected from a small, high elevation pond and may represent a variety of *P. tetras* or a different species of *Pediastrum*.

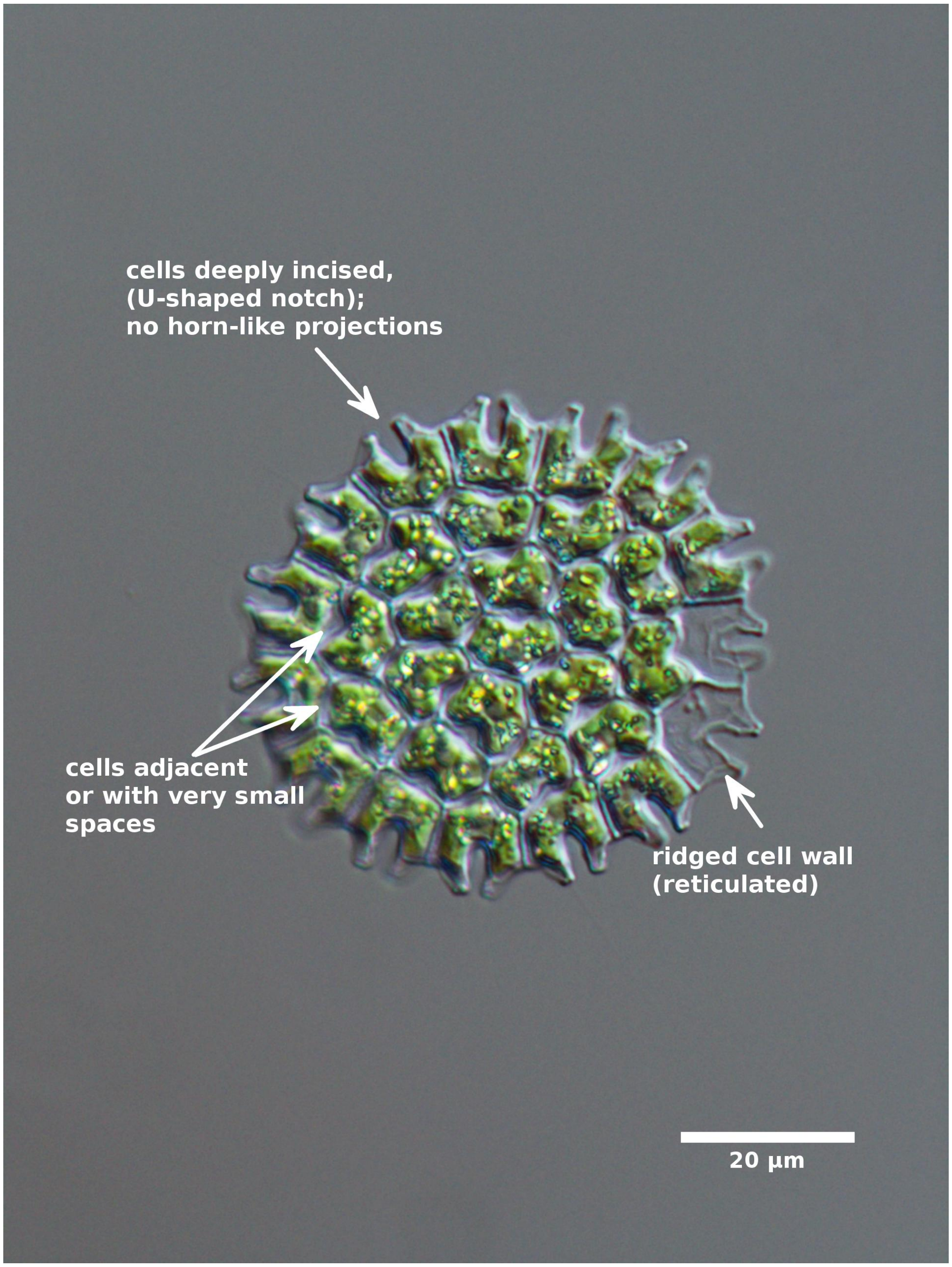

Figure 3.207: *Pediastrum angulosum* (600x DIC), small pond near Fairhaven College, Whatcom County, June 2, 2015.

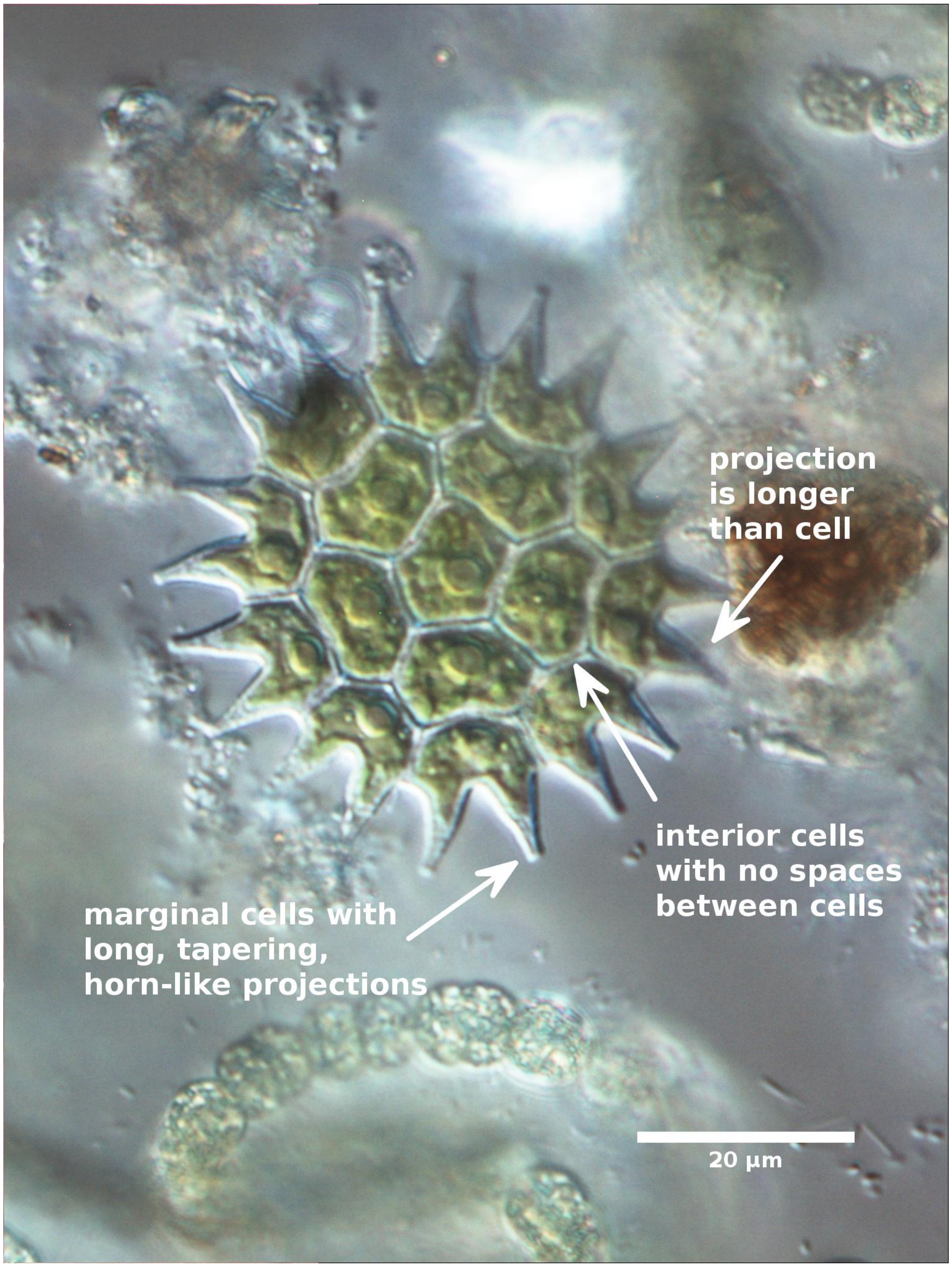

Figure 3.208: *Pediastrum boryanum* (600x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, August 19, 2009.

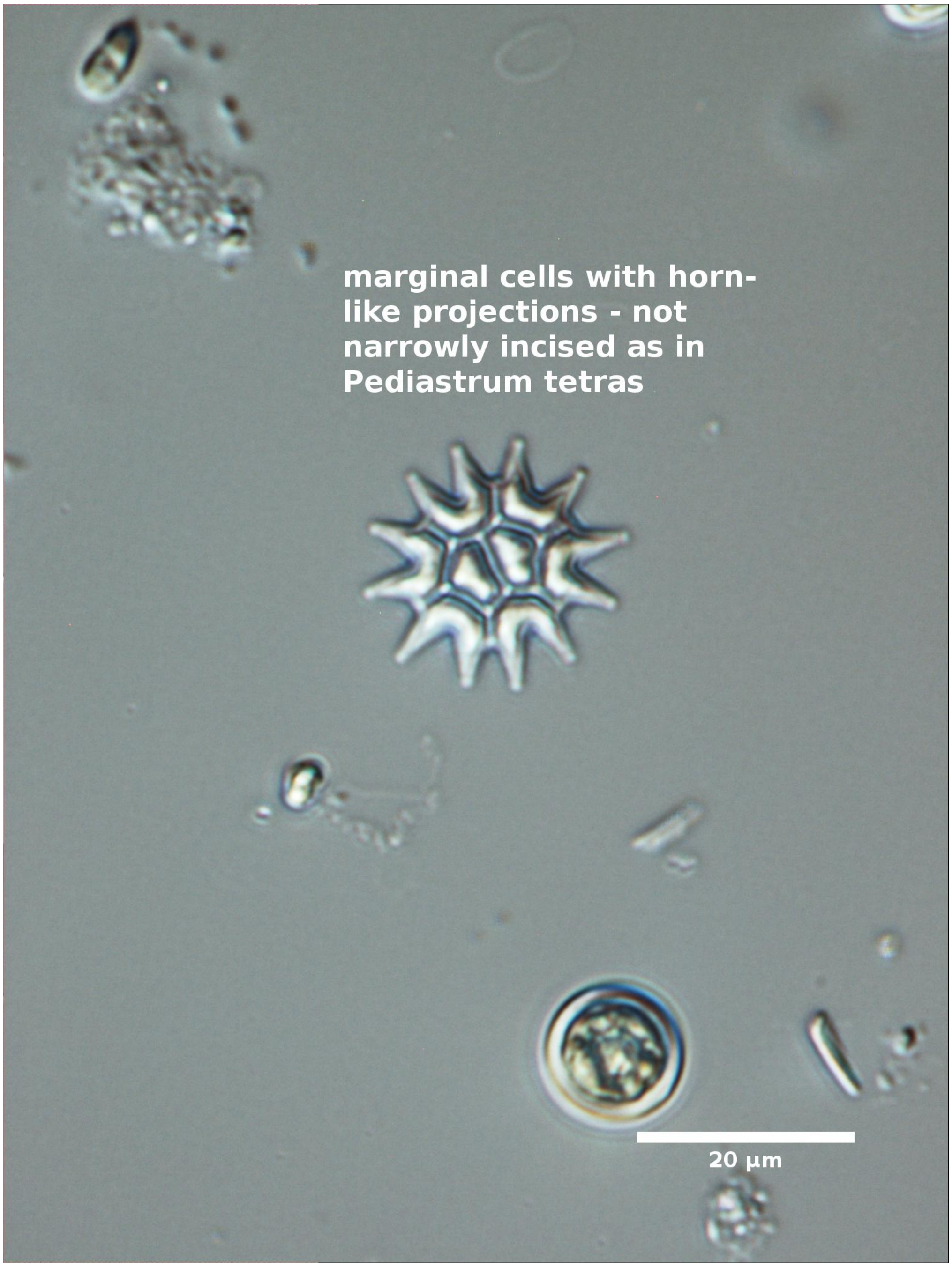

Figure 3.209: *Pediastrum boryanum* in Lugol's iodine solution (600x DIC), Lake Campbell, IWS water quality sampling site, Skagit County, September 3, 2009.

Figure 3.210: *Pediastrum boryanum* reproducing, Lake Erie, IWS water quality sampling site, Skagit County, July 31, 2013.

Figure 3.211: *Pediastrum boryanum* showing red coloration (200x DIC), Coal Lake, IWS water quality sampling site, Snohomish County, August 28, 2013.

Figure 3.212: *Pediastrum boryanum* var. *longicorne* (200x DIC), Lake Ketchum, IWS water quality sampling site, Snohomish County, July 31, 2012.

Figure 3.213: *Pediastrum boryanum* var. *longicorne* (400x DIC), Lake Ketchum, IWS water quality sampling site, Snohomish County, June 23, 2010.

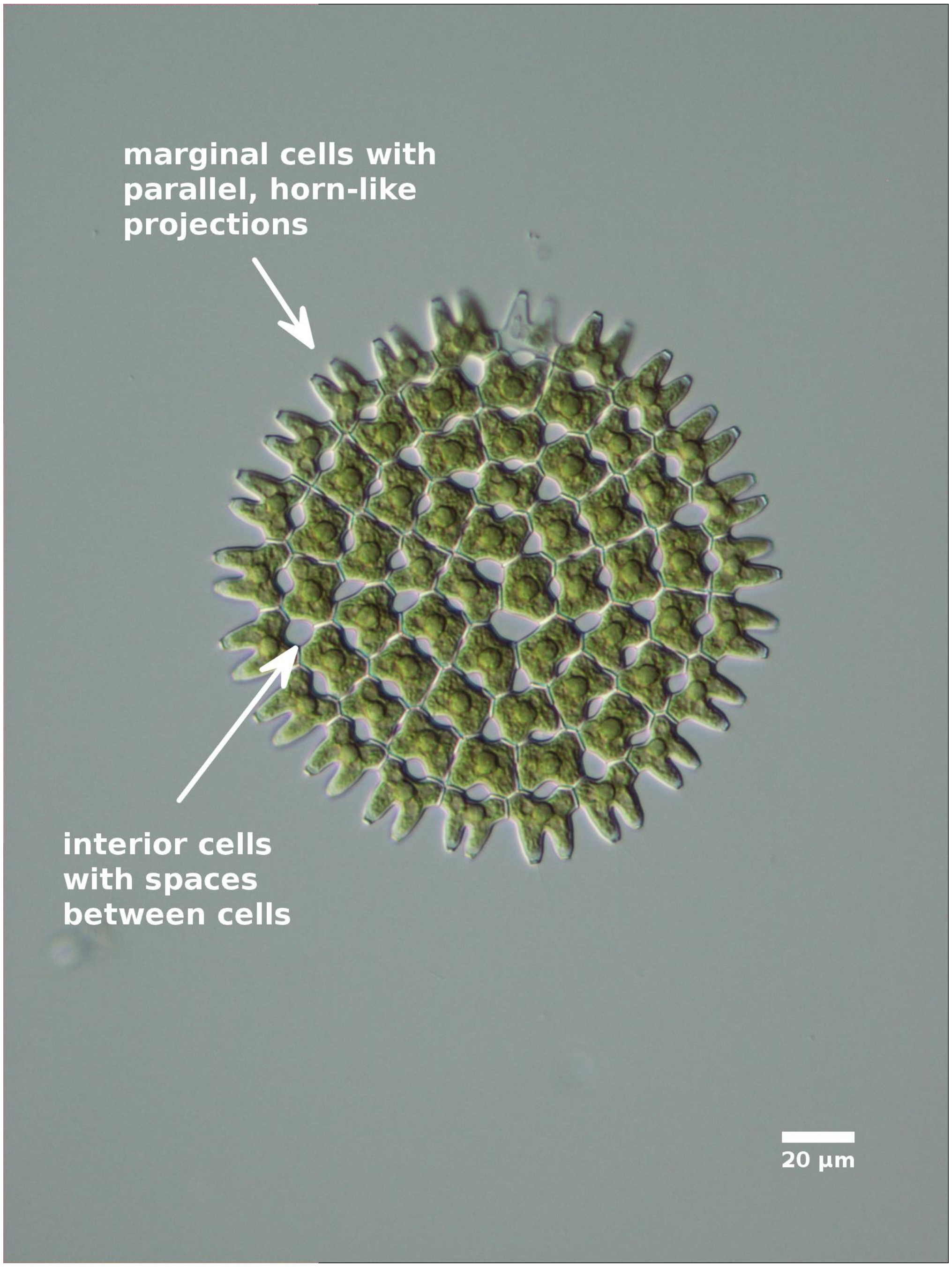

Figure 3.214: *Pediastrum duplex* (200x DIC), Kwan Lake, IWS water quality sampling site, Whatcom County, September 23, 2011.

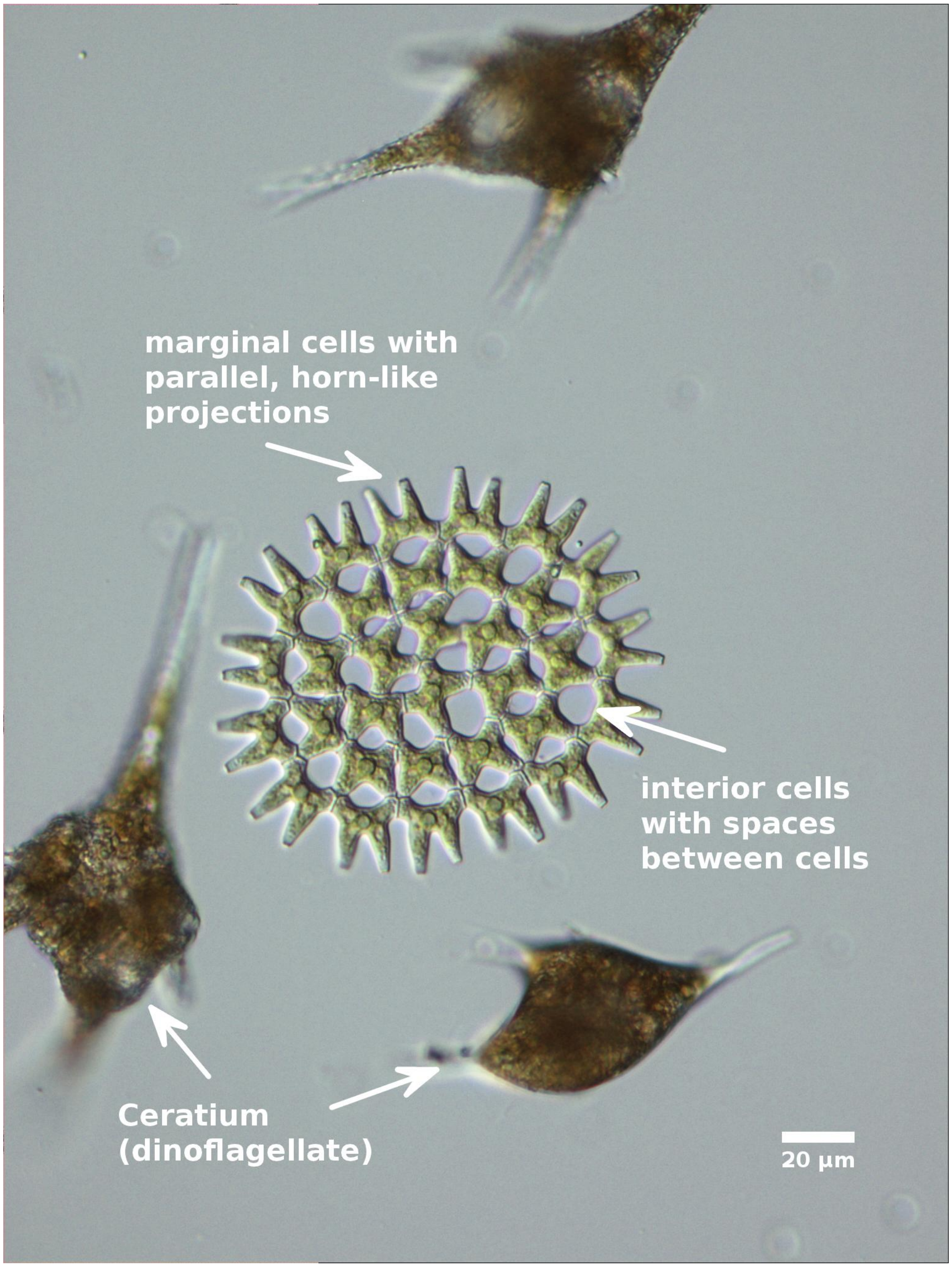

Figure 3.215: *Pediastrum duplex* (200x DIC), Kwan Lake, IWS water quality sampling site, Whatcom County, September 16, 2010.

Figure 3.216: *Pediastrum duplex* bloom (100x DIC), Kwan Lake, IWS water quality sampling site, Whatcom County, September 23, 2011.

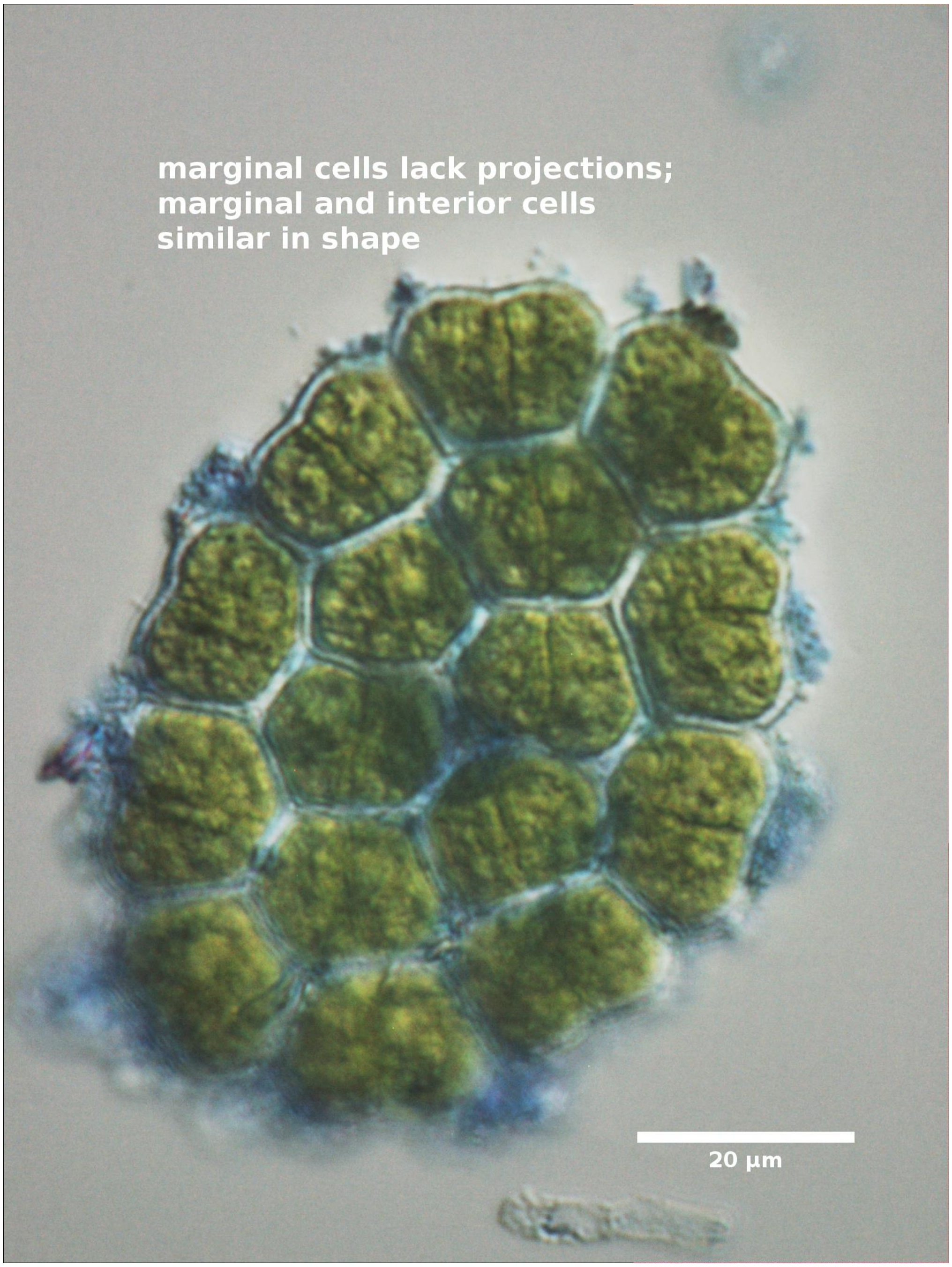

Figure 3.217: *Pediastrum integrum* stained with methylene blue (600x DIC), Heart Lake, IWS water quality sampling site, Skagit County, July 9, 2010.

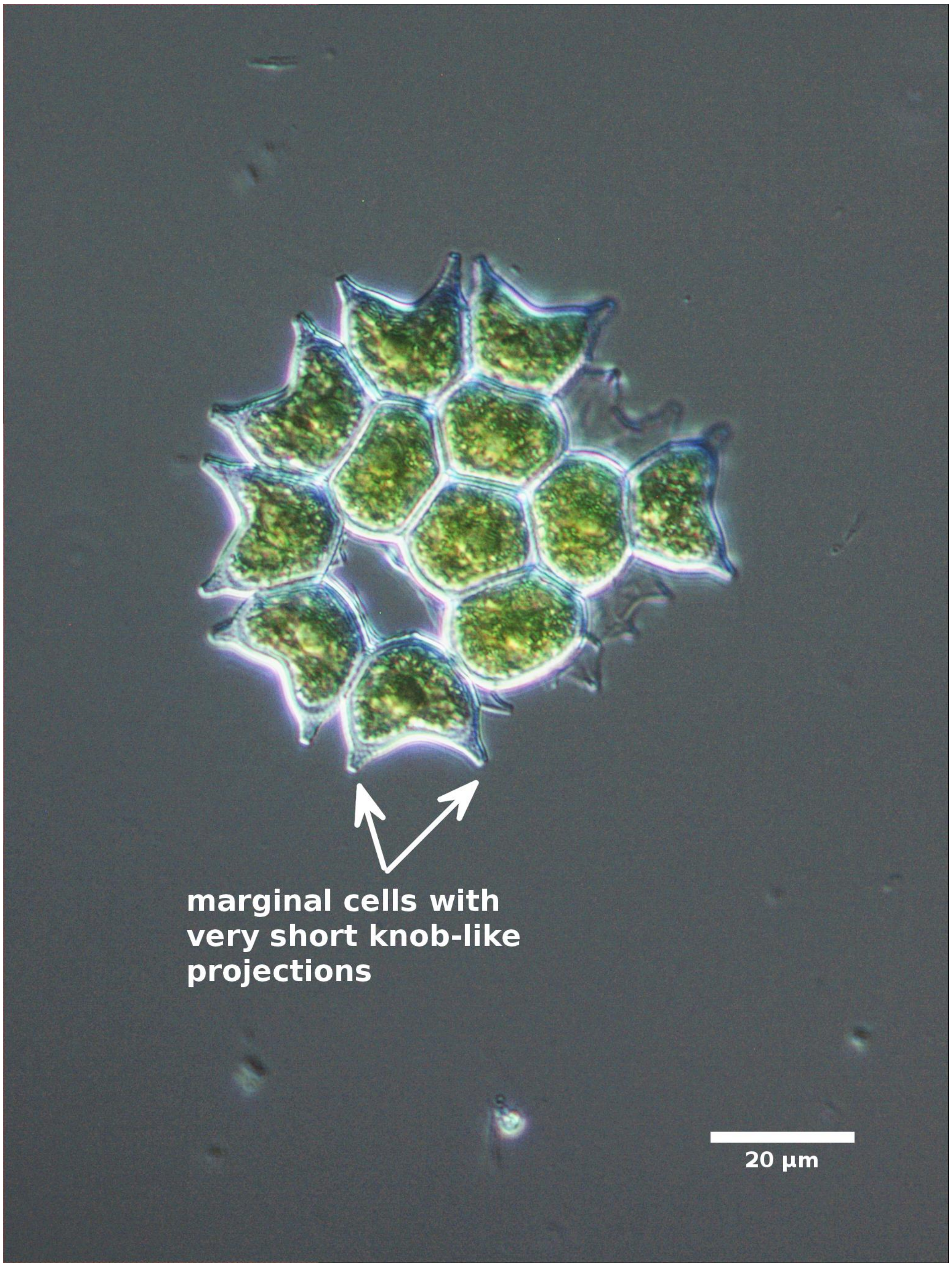

Figure 3.218: *Pediastrum integrum*? (400x DIC), Cranberry Lake, IWS water quality sampling site, Island County, March 26, 2010.

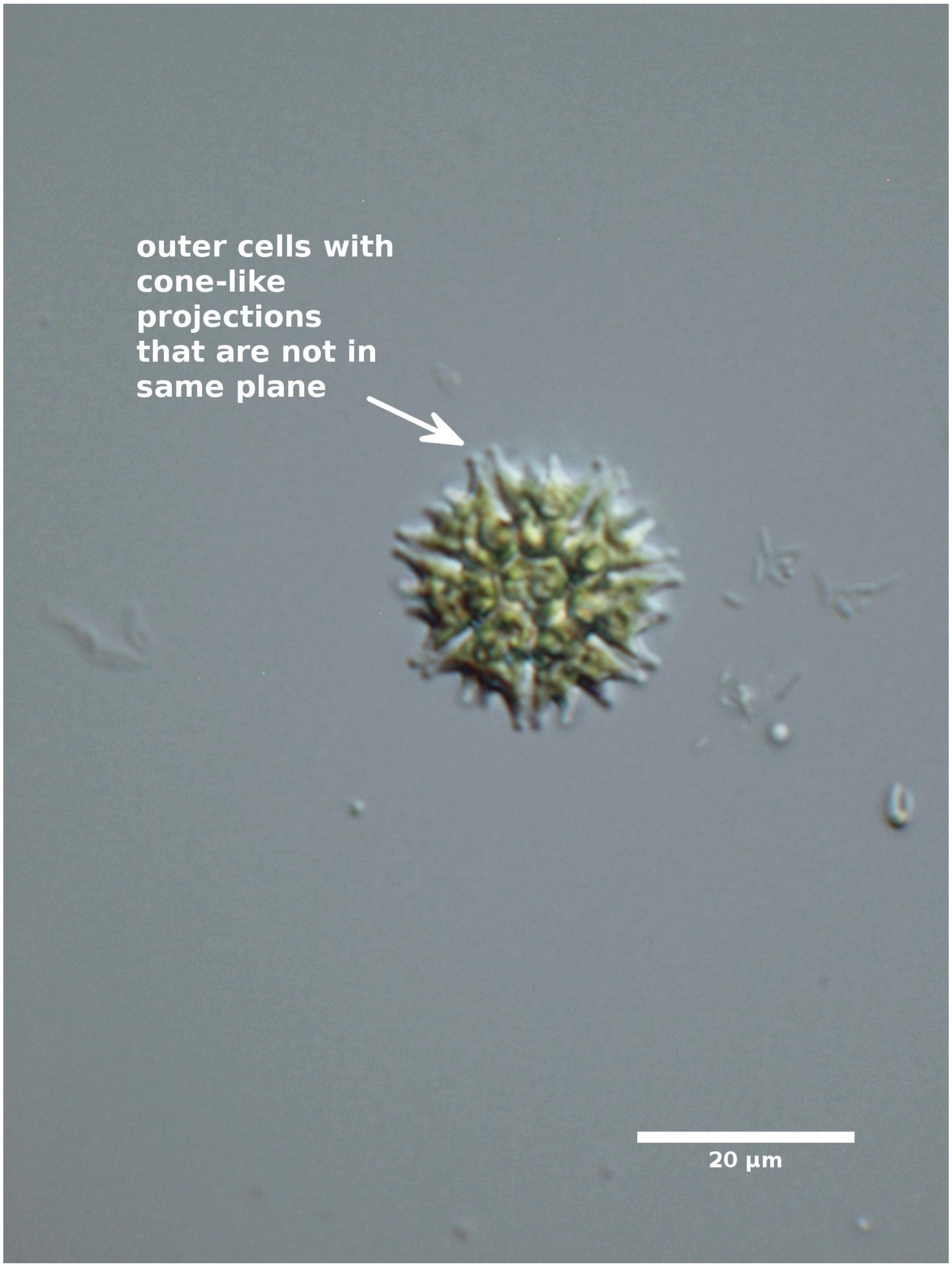

Figure 3.219: *Pediastrum kawraiskyi* (600x DIC), small pond near Lake Anderson, North Cascades along Hwy 20, September 3, 2012.

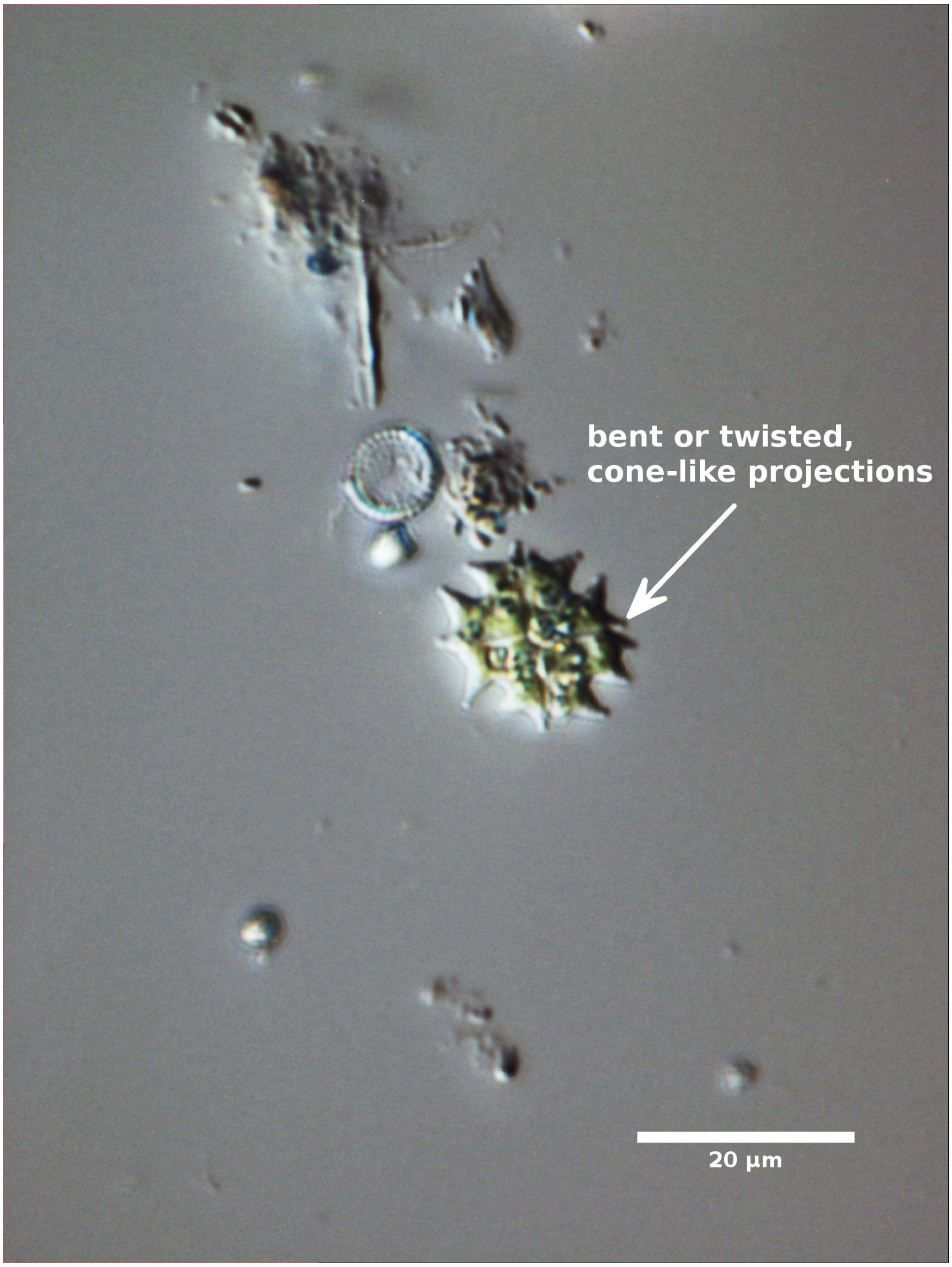

Figure 3.220: *Pediastrum kawraiskyi* (600x DIC), snow melt pond on Railroad Grade trail (Park Butte), North Cascades near Mt. Baker, September 6, 2011.

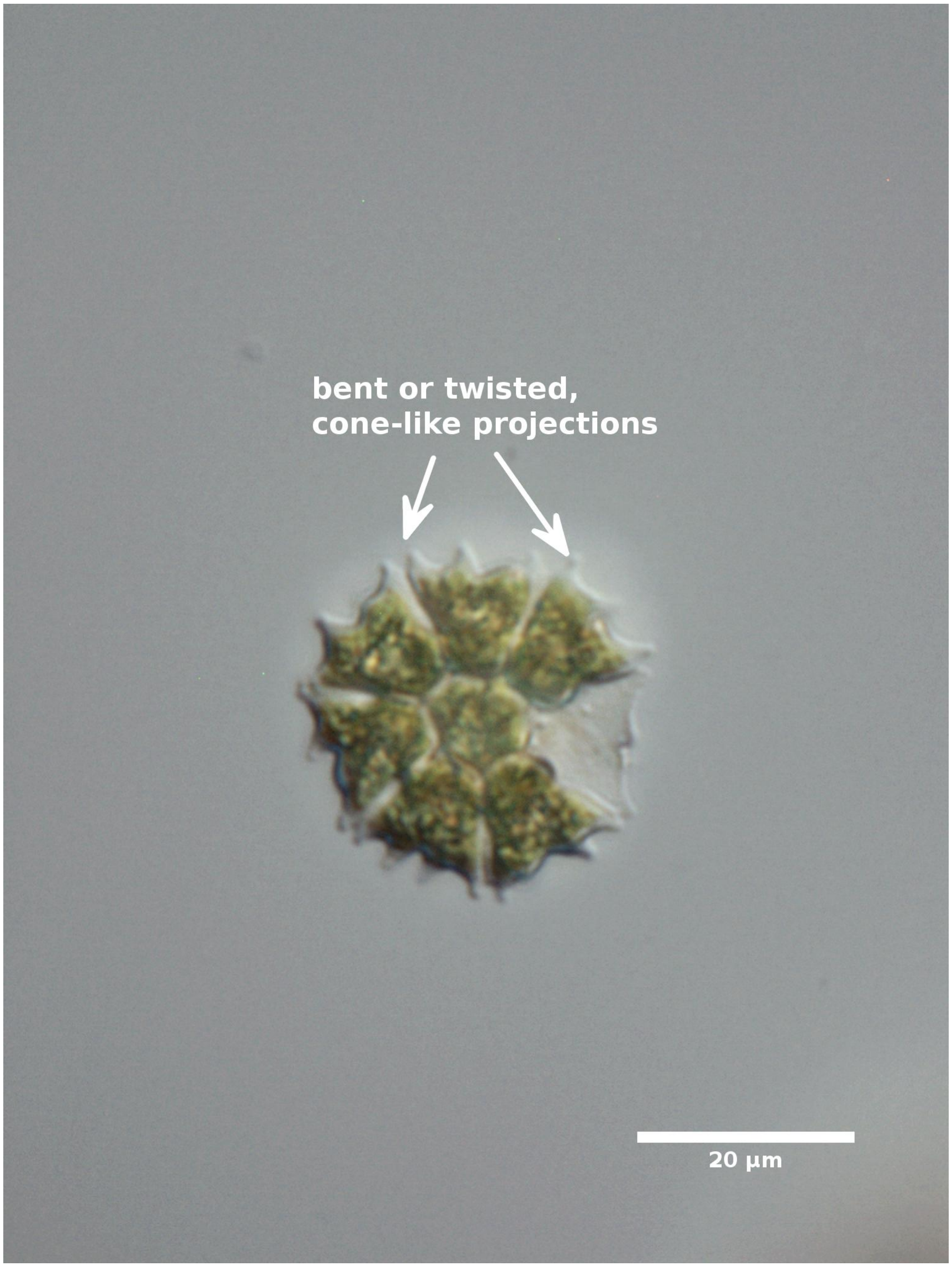

Figure 3.221: *Pediastrum kawraiskyi* (600x DIC), small pond near Lake Anderson, North Cascades along Hwy 20, September 3, 2012.

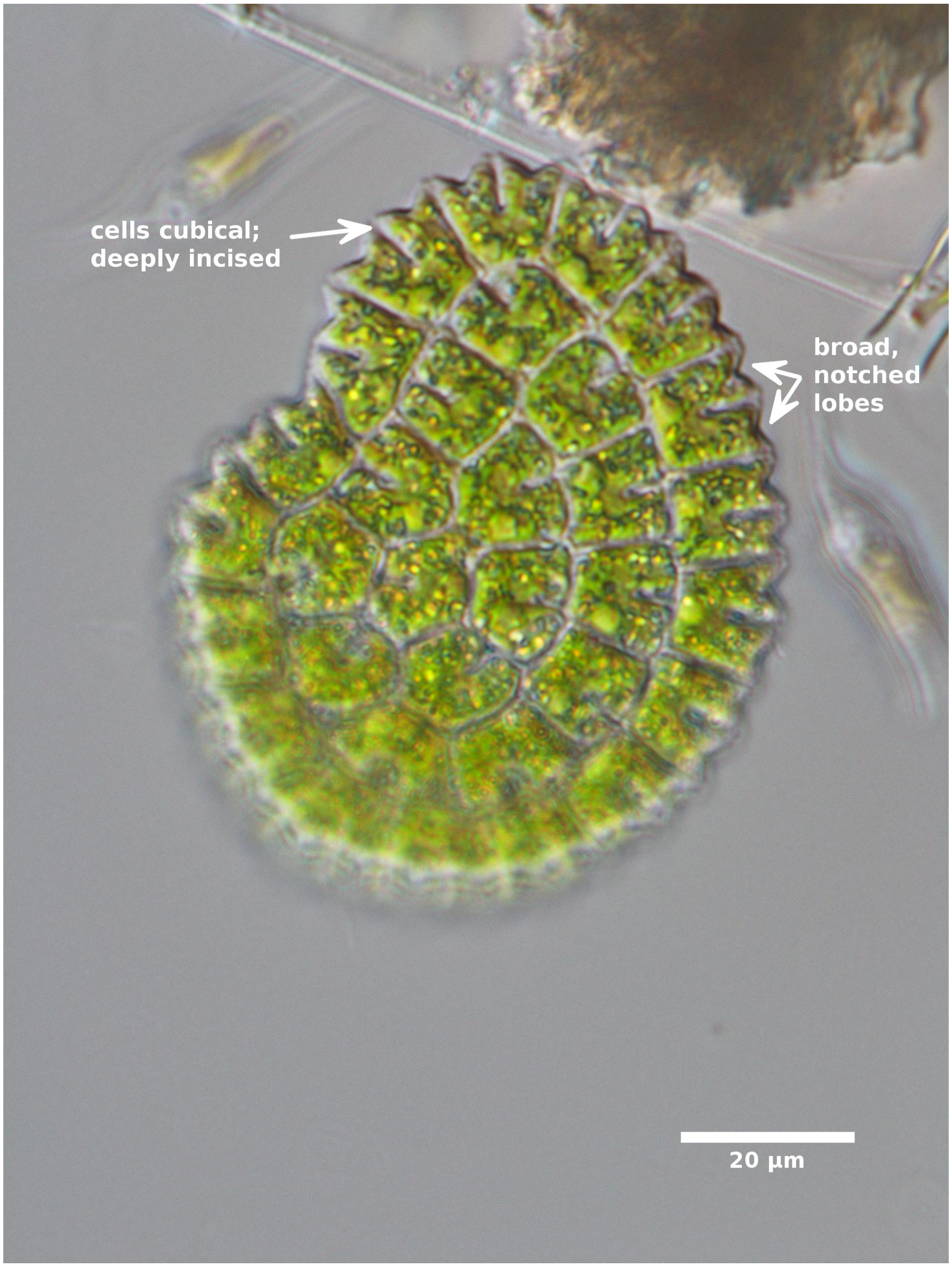

Figure 3.222: *Pediastrum obtusum* (600x DIC), Lake Everett, IWS water quality sampling site, Skagit County, August 5, 2015.

Figure 3.223: *Pediastrum obtusum* (600x DIC), Lake Everett, IWS water quality sampling site, Skagit County, August 5, 2015.

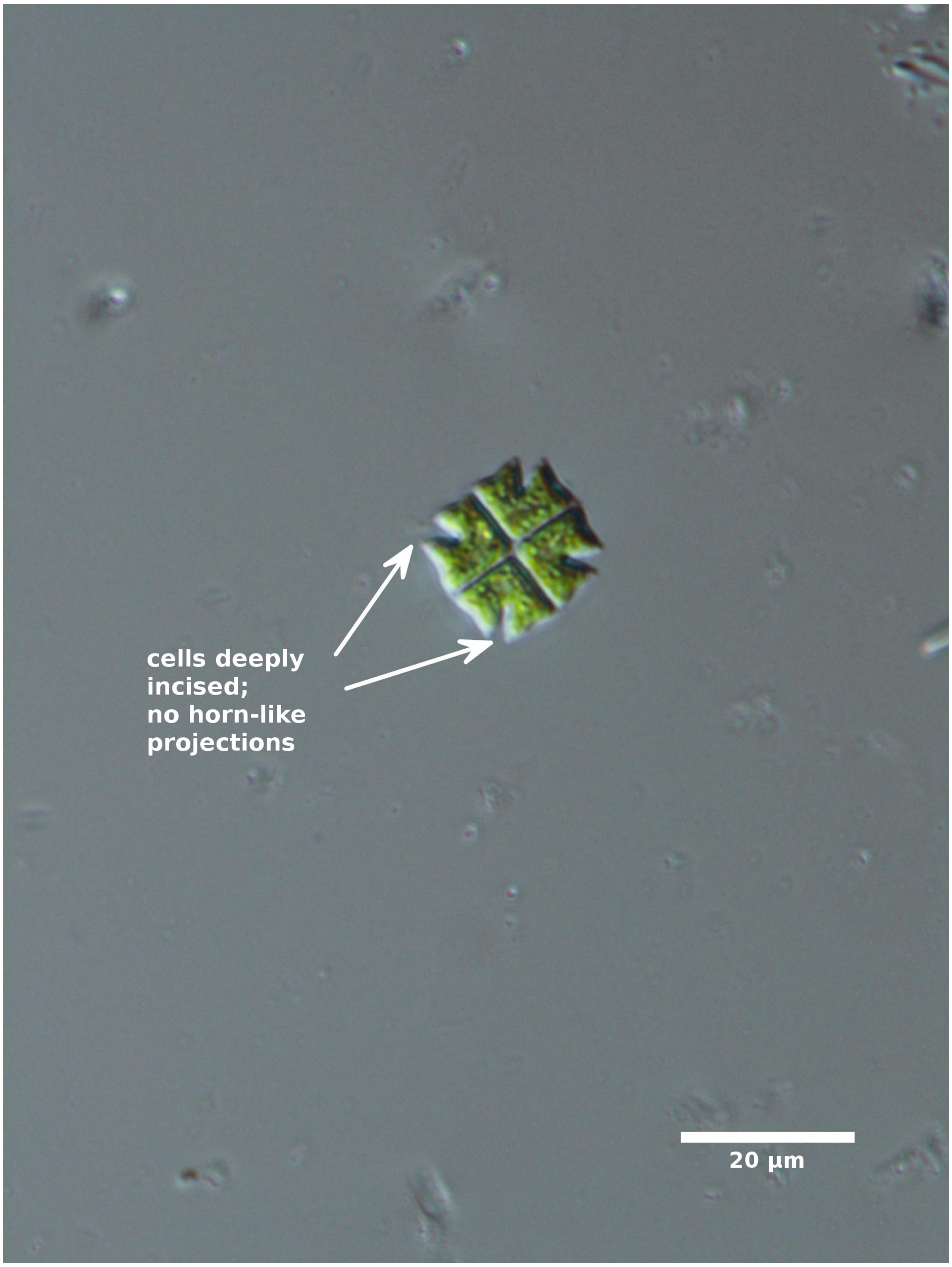

Figure 3.224: *Pediastrum tetras* (600x DIC), Chamber's Lake, Olympia, Thurston County, May 27, 2015.

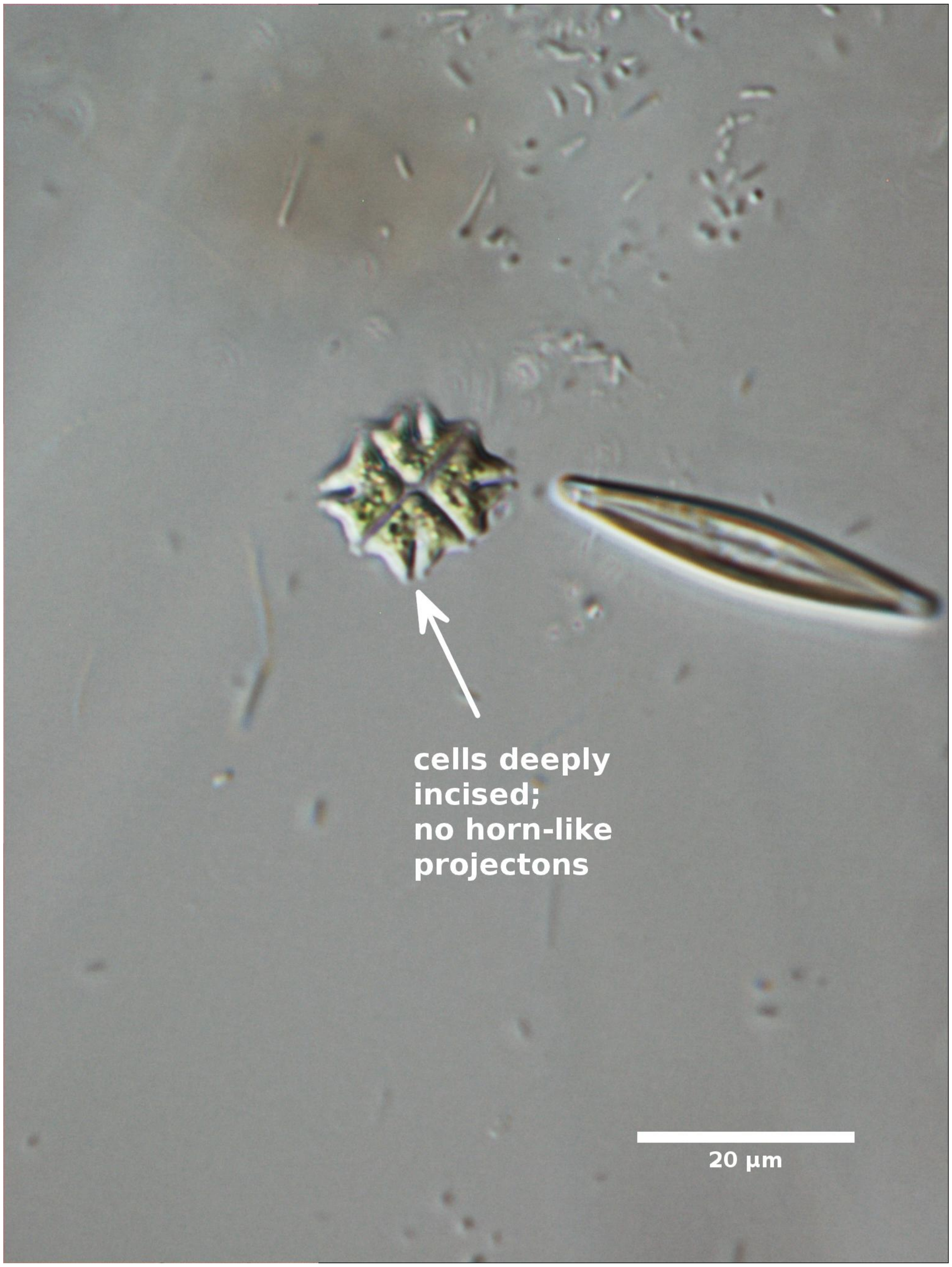

Figure 3.225: *Pediastrum tetras* (600x DIC), Picture Lake, IWS water quality sampling site, Whatcom County, September 30, 2011.

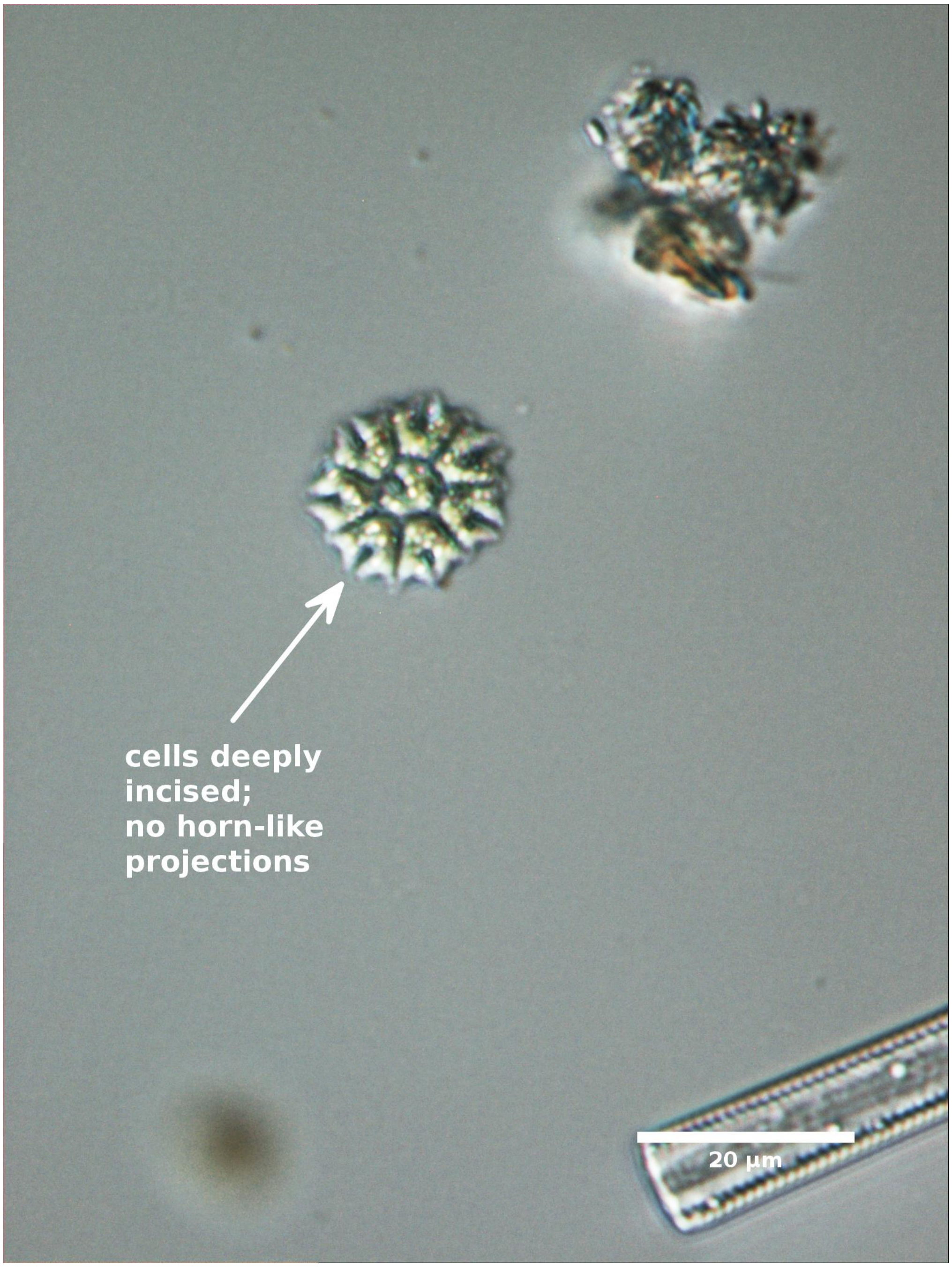

Figure 3.226: *Pediastrum tetras* (600x DIC), Ross Lake, Ross Lake National Recreation Area, November 7, 2009.

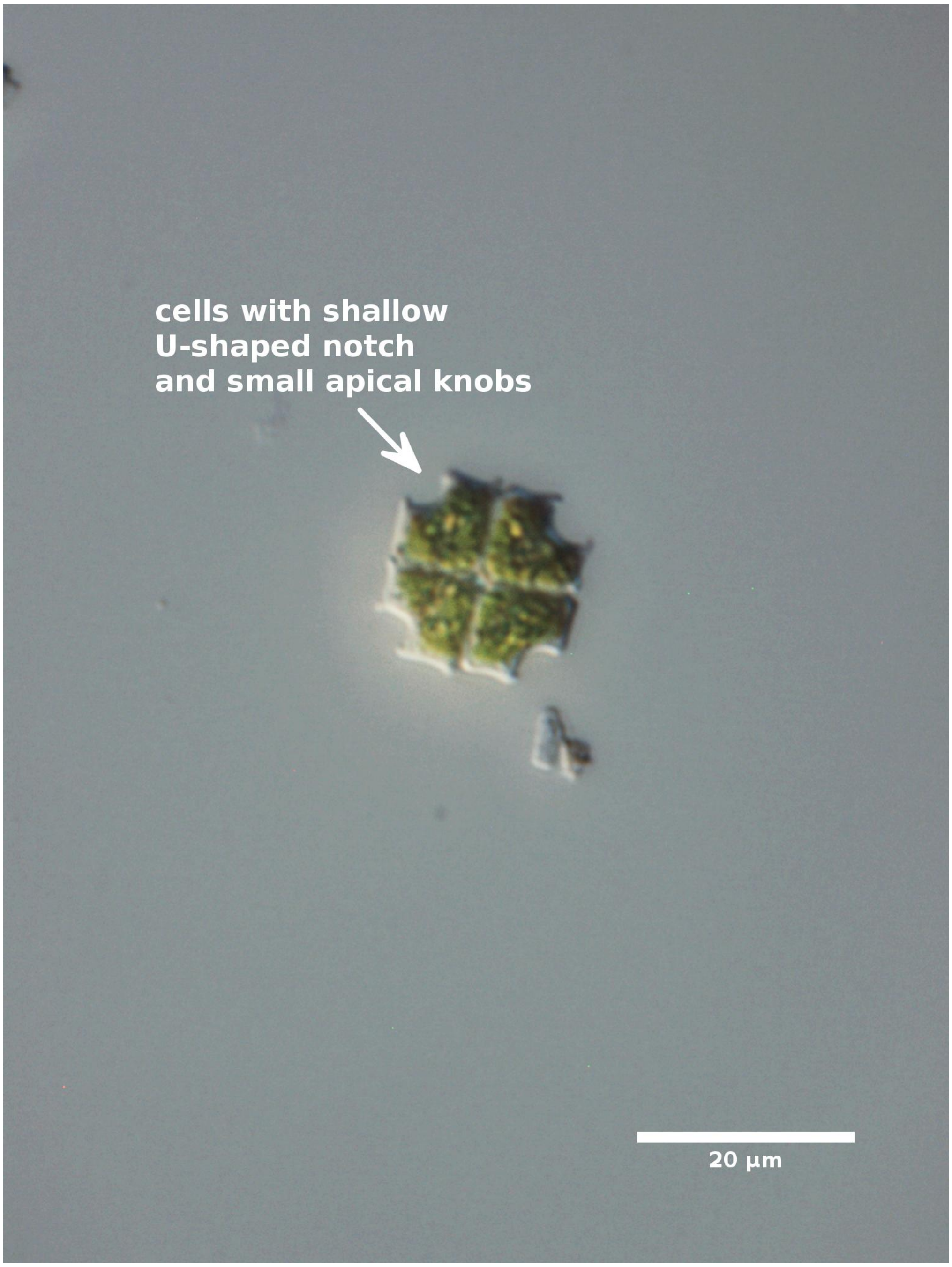

Figure 3.227: *Pediastrum* sp.1 (600x DIC), Lake Evan, IWS water quality sampling site, Snohomish County, August 2, 2012.

3.29 *Planktosphaeria* G. M. Smith

Local taxon

Planktosphaeria gelatinosa G. M. Smith

Abundance

Moderately common; rarely present in large numbers.

Local measurements		Width	Length	Biovolume†
Planktosphaeria gelatinosa	min	13.9 μm	–	1,410 μm^3
cells (sphere)	med	20.4 μm	–	4,460 μm^3
	max	34.6 μm	–	21,700 μm^3

†Calculated using original measurements, not summary values.

Description

Planktosphaeria gelatinosa cells are spherical and usually solitary, but may form loose aggregations during cell division (Figures 3.228–3.233). Mature cells are spherical, with a cup-shaped chloroplast and basal pyrenoid. The chloroplast is visible in young cells, but as the cell ages the chloroplast becomes dense, filling most of the cell volume. The cells are surrounded by a firm mucilage layer that is usually homogeneous, but occasionally shows faint concentric striations (Figure 3.231). The mucilage layer is usually very obvious, but may be narrow or even absent in recently divided cells (Figures 3.232–3.233).

Vegetative reproduction is commonly observed in samples from local lakes. The newly formed daughter cells typically have an interesting ring-like aggregation, retaining some of the original spherical shape of the mother cell (Figure 3.229). The remnant of the mother cell wall can be found in the vicinity of the daughter cells (Figure 3.230). The “ghost” mother cell wall is a particularly useful feature for distinguishing *Planktosphaeria* from other solitary, nonmotile, spherical green algae, which, as a group, are difficult to identify.

According to John, et al. (2011), *Planktosphaeria* is rarely solitary, and usually forms small colonies enclosed in mucilage. The local specimens seem to disperse rapidly after division and are more likely to be solitary or in the loose, ring-like aggregation described above.

Compare *Planktosphaeria* to *Chlorella* (Section 3.9, page 282), which does not form distinct colonies and has little if any mucilage surrounding the cells. Also compare specimens to *Asterococcus* (Section 3.6, page 245), which has stellate chloroplasts and stratified mucilage surrounding the cells and colony; *Gloeocystis* (Section 3.16, page 343), which has cup-shaped chloroplasts and stratified mucilage surrounding the cells and colony; and *Sphaerocystis* (Section 3.35, page 493), which forms irregular colonies containing large and small cells surrounded by a diffuse, unstriated colonial mucilage.

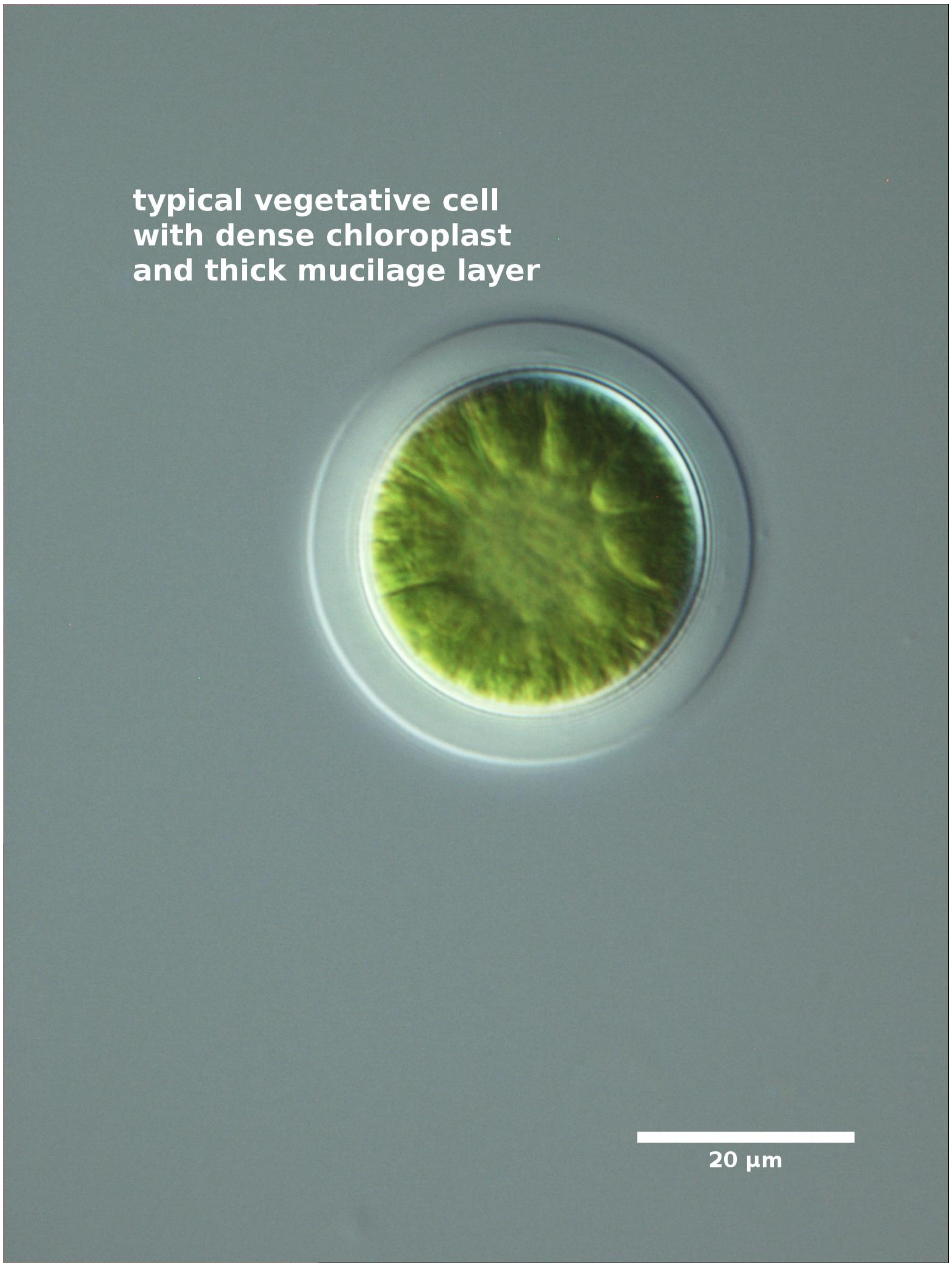

Figure 3.228: *Planktosphaeria gelatinosa* (600x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, March 29, 2012.

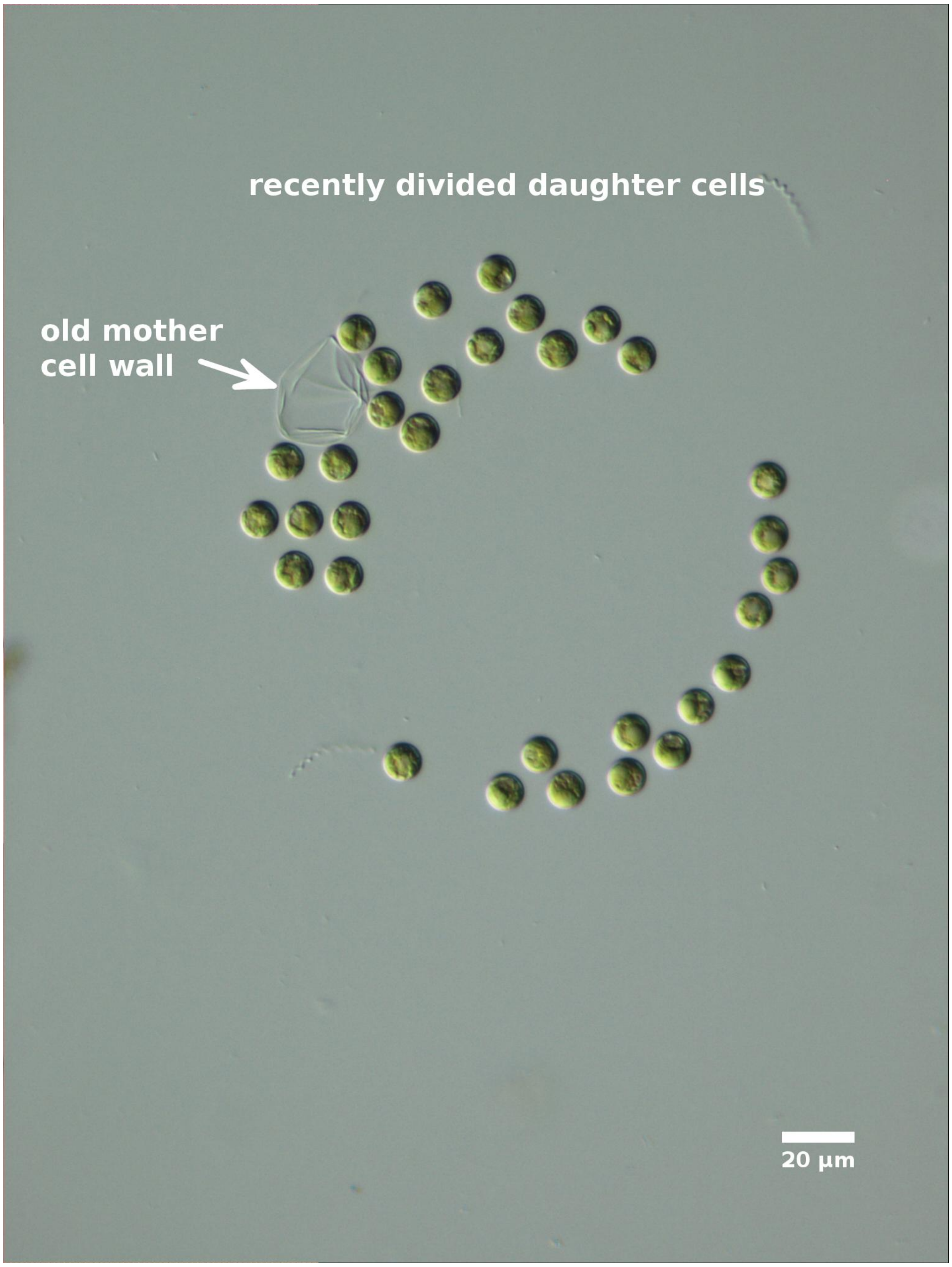

Figure 3.229: *Planktosphaeria gelatinosa* (200x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, March 30, 2012.

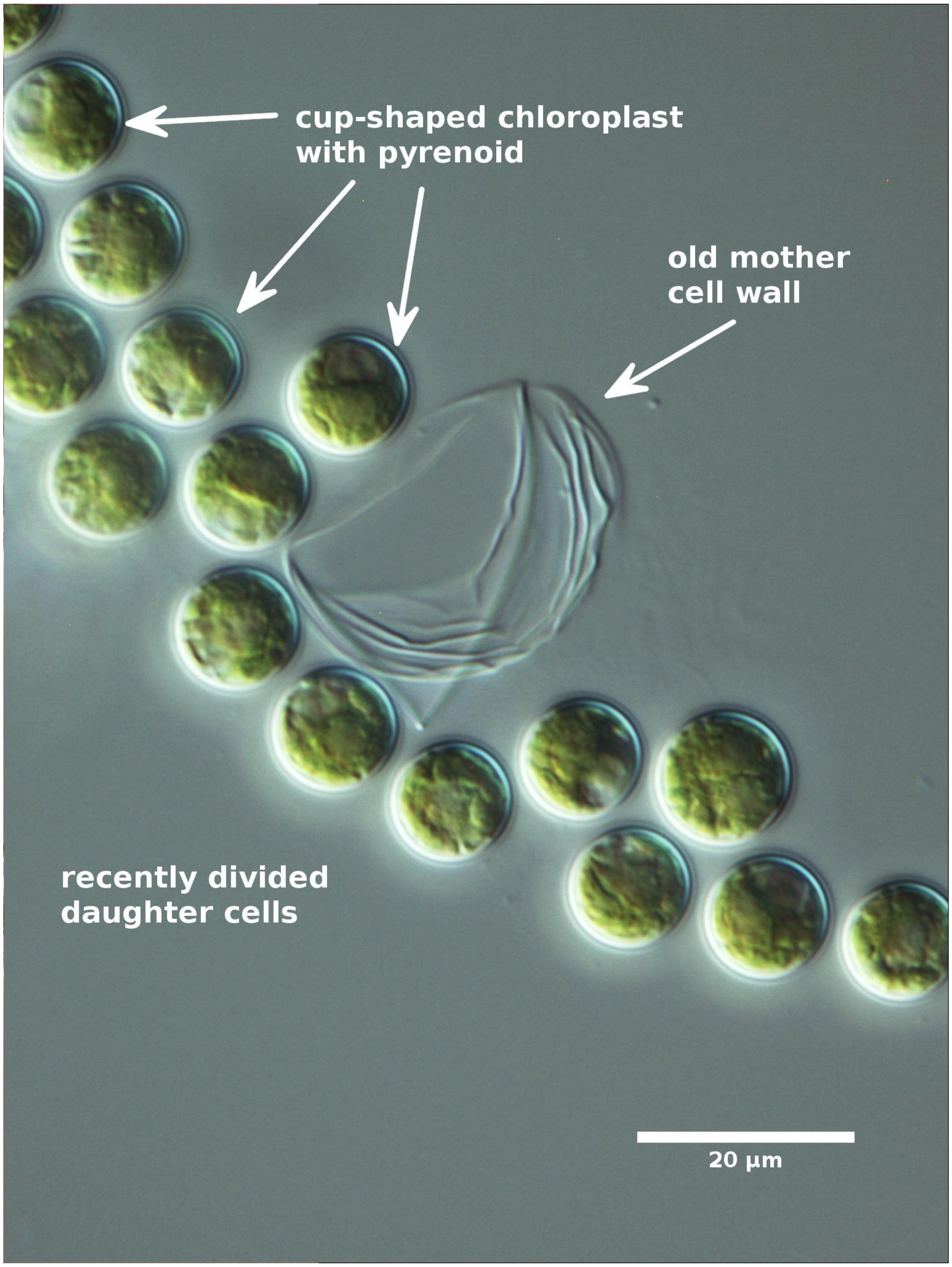

Figure 3.230: *Planktosphaeria gelatinosa* (600x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, March 29, 2012.

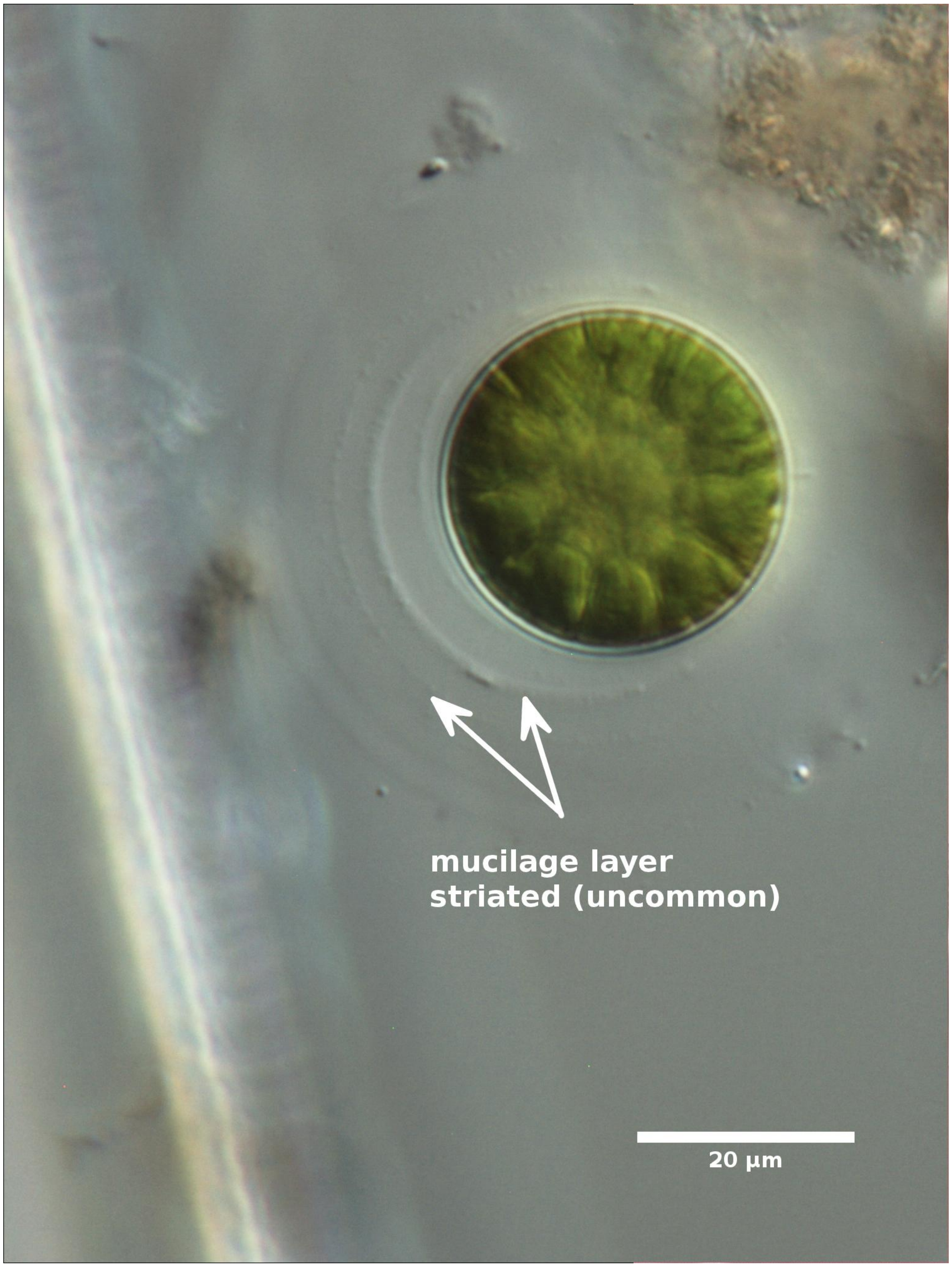

Figure 3.231: *Planktosphaeria gelatinosa* (600x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, March 30, 2012.

Figure 3.232: *Planktosphaeria gelatinosa* (200x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, March 30, 2012.

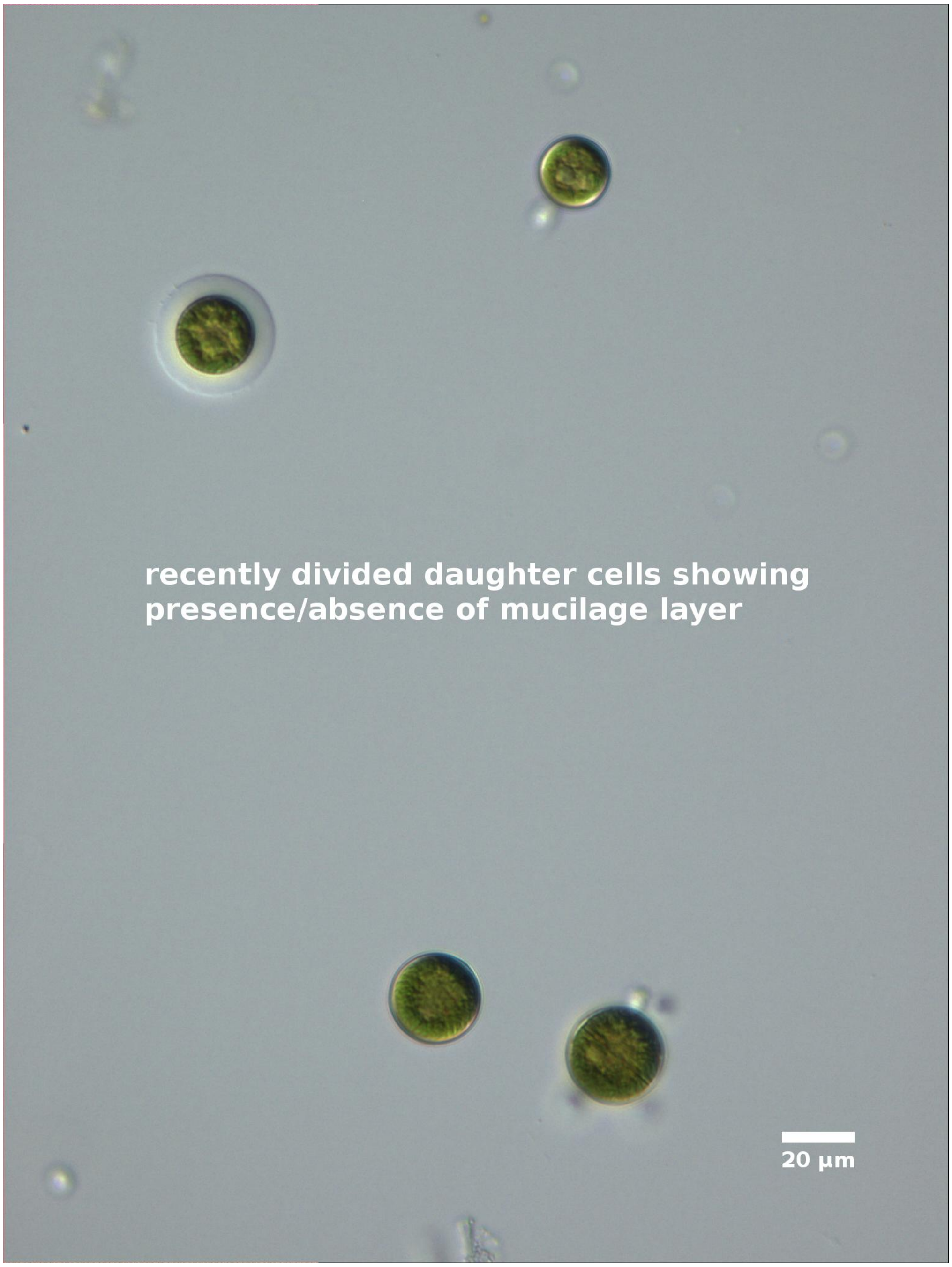

Figure 3.233: *Planktosphaeria gelatinosa* (200x DIC), Heart Lake, IWS water quality sampling site, Skagit County, September 21, 2010.

3.30 *Quadrigula* Printz

Local taxon
Quadrigula closterioides (Bohlin) Printz

Abundance
Moderately common; rarely present in large numbers.

Local measurements		Width	Length	Biovolume†
Quadrigula closterioides‡	min	2.5 μm	22.0 μm	111 μm^3
cells (cyl + two $\frac{1}{2}$ spheres)	med	3.6 μm	24.4 μm	191 μm^3
	max	5.6 μm	36.1 μm	672 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume calculated using cylinder length ($<$ cell length).

Description
Quadrigula closterioides colonies contain groups of cells in multiples of four surrounded by a diffuse colonial mucilage (Figure 3.234–3.238). The individual cells are narrowly fusiform, with blunt, rounded ends. Each cell has a single parietal chloroplast. The cells are usually in colonies, but may occasionally be solitary, especially just prior to division.

Quadrigula colonies superficially resemble *Elakatothrix gelatinosa* (Section 3.14, page 327), but *Elakatothrix* cells divide transversely while *Quadrigula* cells divide laterally, giving rise to parallel bundles of daughter cells. In addition, *Elakatothrix gelatinosa* colonies are surrounded by a distinctive, lens-shaped mucilage; the colonial mucilage surrounding *Quadrigula* colonies is diffuse.

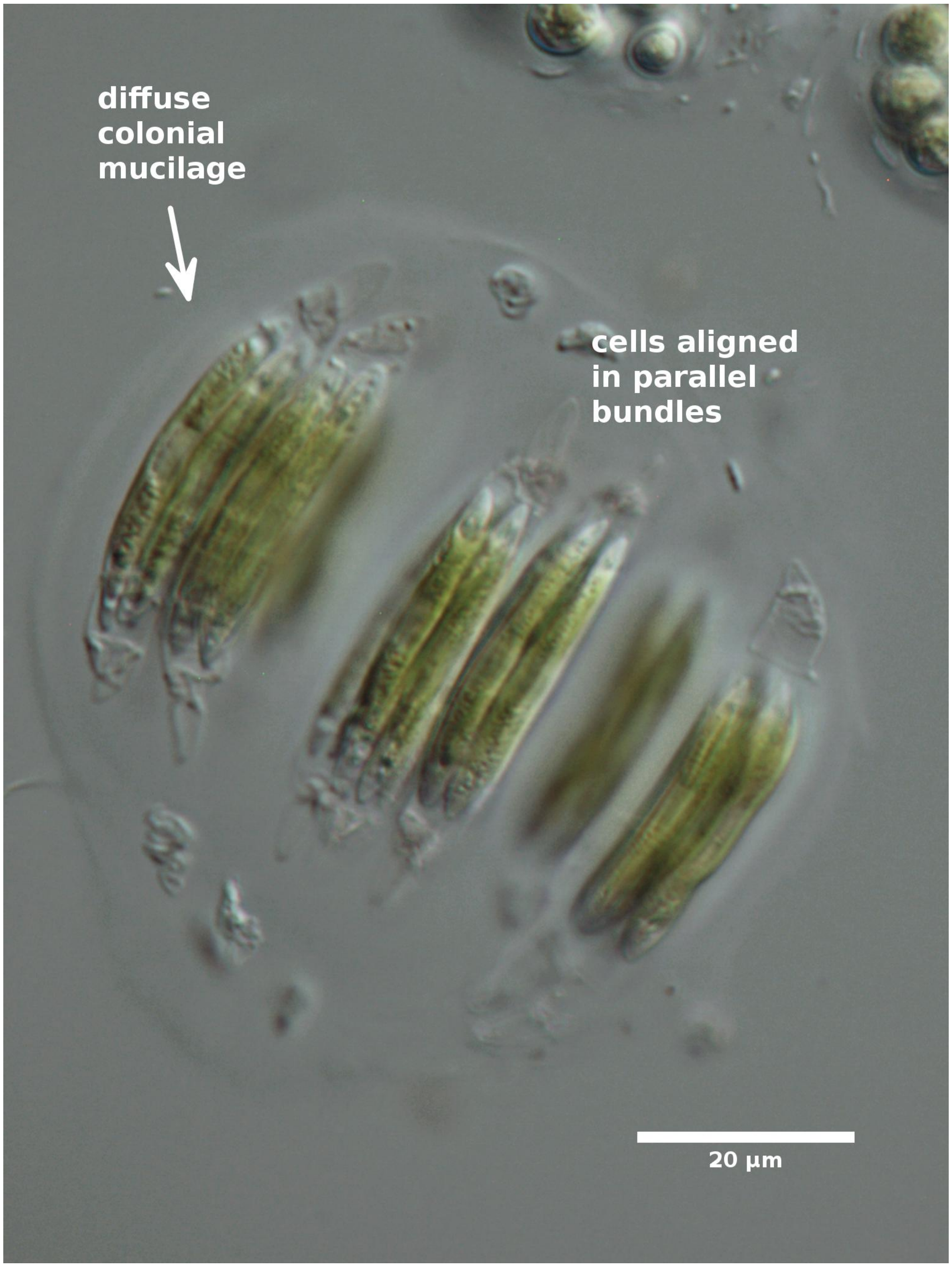

Figure 3.234: *Quadrigula closterioides* (600x DIC), Silver Lake, IWS water quality sampling site, Whatcom County, August 28, 2012.

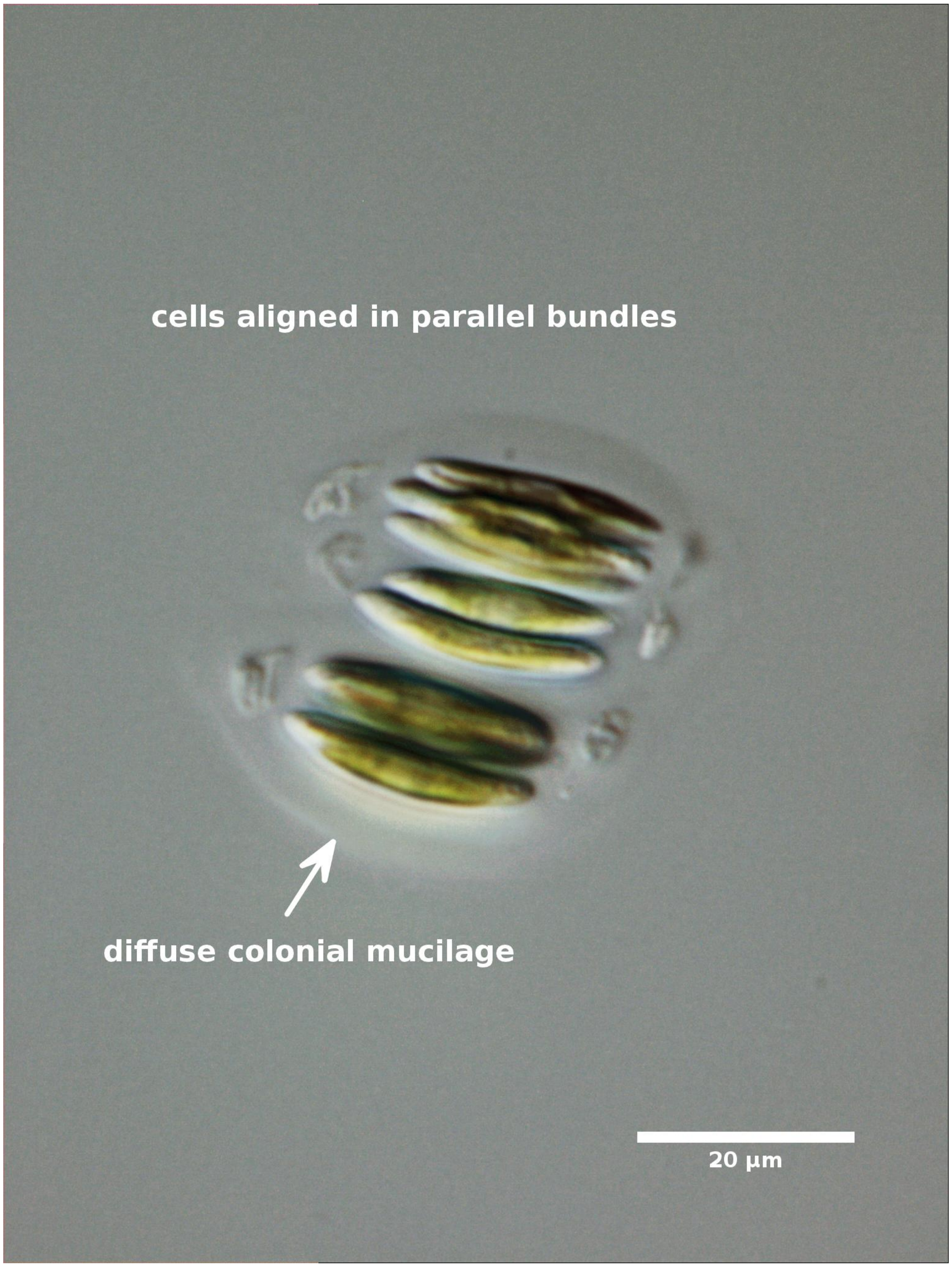

Figure 3.235: *Quadrigula closterioides* (600x DIC), Lake Padden, IWS water quality sampling site, Whatcom County, October 21, 2009.

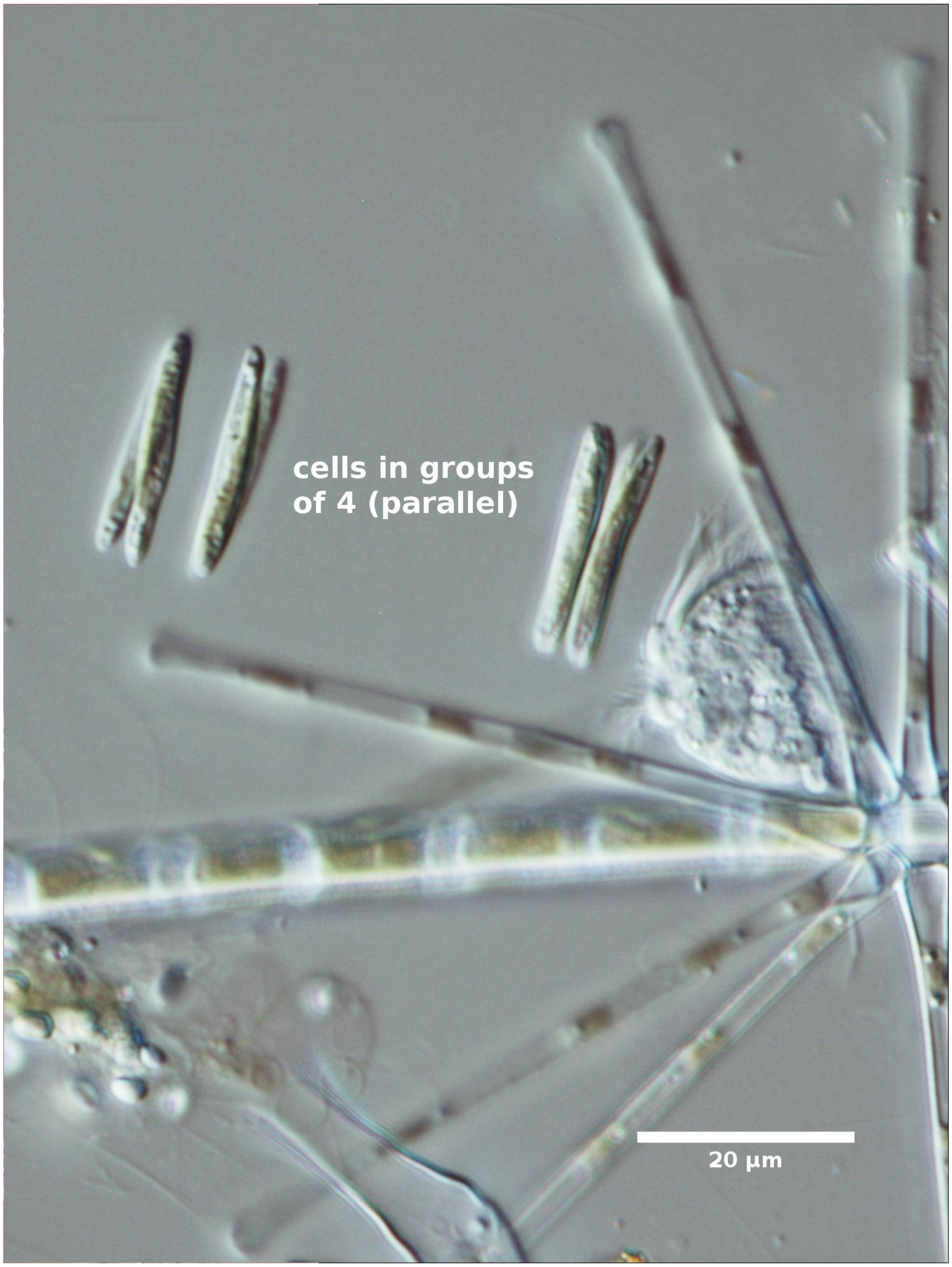

Figure 3.236: *Quadrigula closterioides* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, July 8, 2011.

Figure 3.237: *Quadrigula closterioides* (600x DIC), Lake Ki, IWS water quality sampling site, Snohomish County, April 1, 2010.

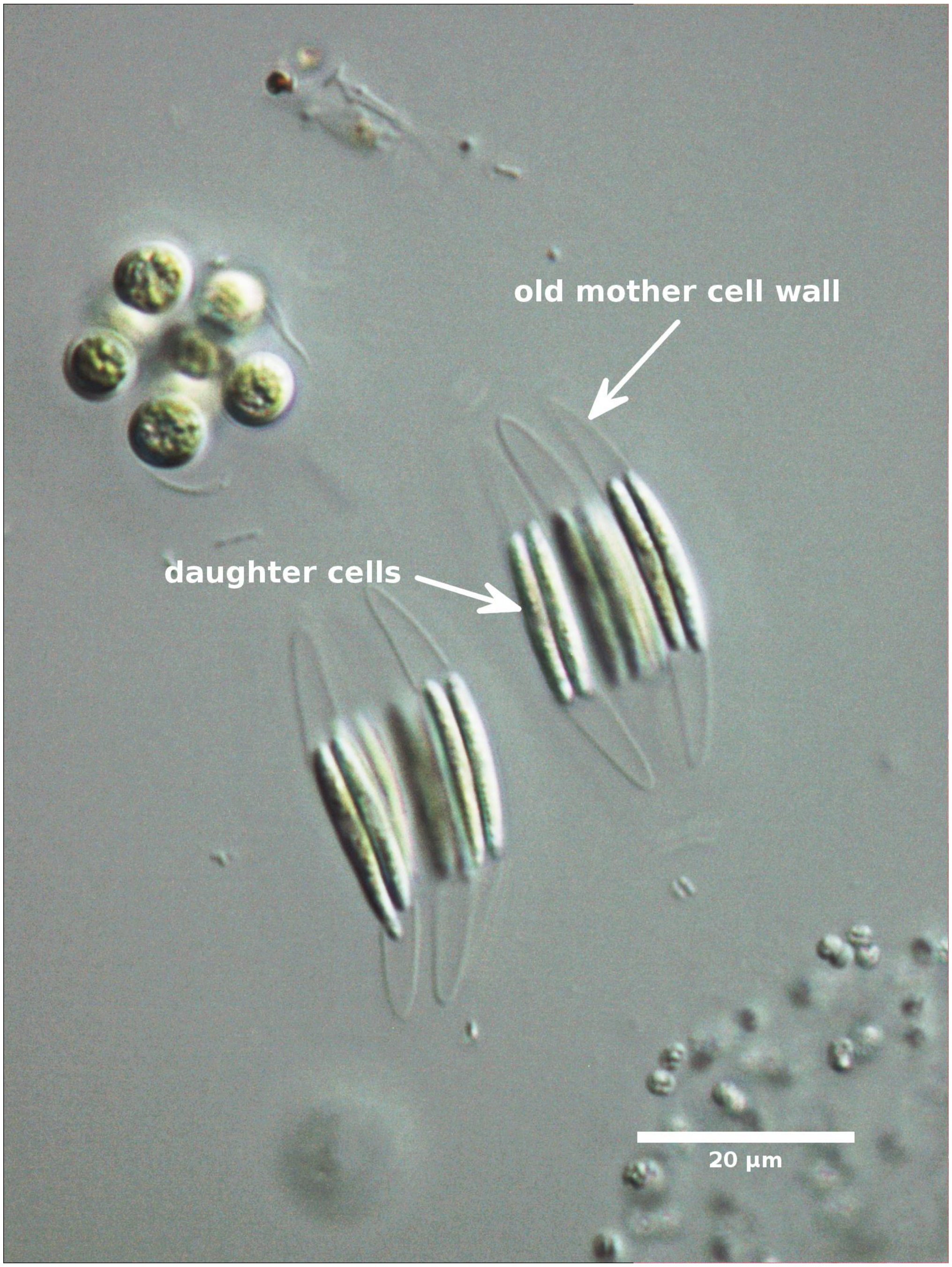

Figure 3.238: *Quadrigula closterioides* (600x DIC), Clear Lake, IWS water quality sampling site, Skagit County, July 13, 2010.

3.31 *Schizochlamys* Braun ex Kützing

Local taxon

Schizochlamys gelatinosa A. Braun

Abundance

Infrequently collected; occasionally forms blooms.

Local measurements		Width	Length	Biovolume†
Schizochlamys gelatinosa	min	7.7 μm	8.8 μm	273 μm^3
cells (spheroid)	med	8.8 μm	10.3 μm	399 μm^3
	max	10.5 μm	11.9 μm	661 μm^3

†Calculated using original measurements, not summary values.

Description

Schizochlamys gelatinosa cells are nearly spherical, slightly flattened on one end, with a cup-shaped chloroplast (Figures 3.239–3.242). The cells often form 2-cell or 4-cell subgroups and are embedded in a clear, diffuse mucilage. The cells have tufts of long pseudocilia attached at the flattened end that extend beyond the mucilage layer. Individual cells and cell groups are surrounded by fragments of old mother cell walls.

Schizochlamys belongs to the order **Tetrasporales**, which contains nonmotile cells that are closely related to the motile **Volvocales** (e.g., *Volvox*, Section 2.13, page 134). Although *Schizochlamys* cells are nonmotile in the vegetative state, the cells have long pseudocilia that are structurally similar to flagella. Other members of this order that are found in local lakes and streams include *Apiocystis* (Section 3.5, page 240), *Asterococcus* (Section 3.6, page 245), *Paulschulzia* (Section 3.27, page 465), and *Tetraspora* (Section 3.37, page 508).

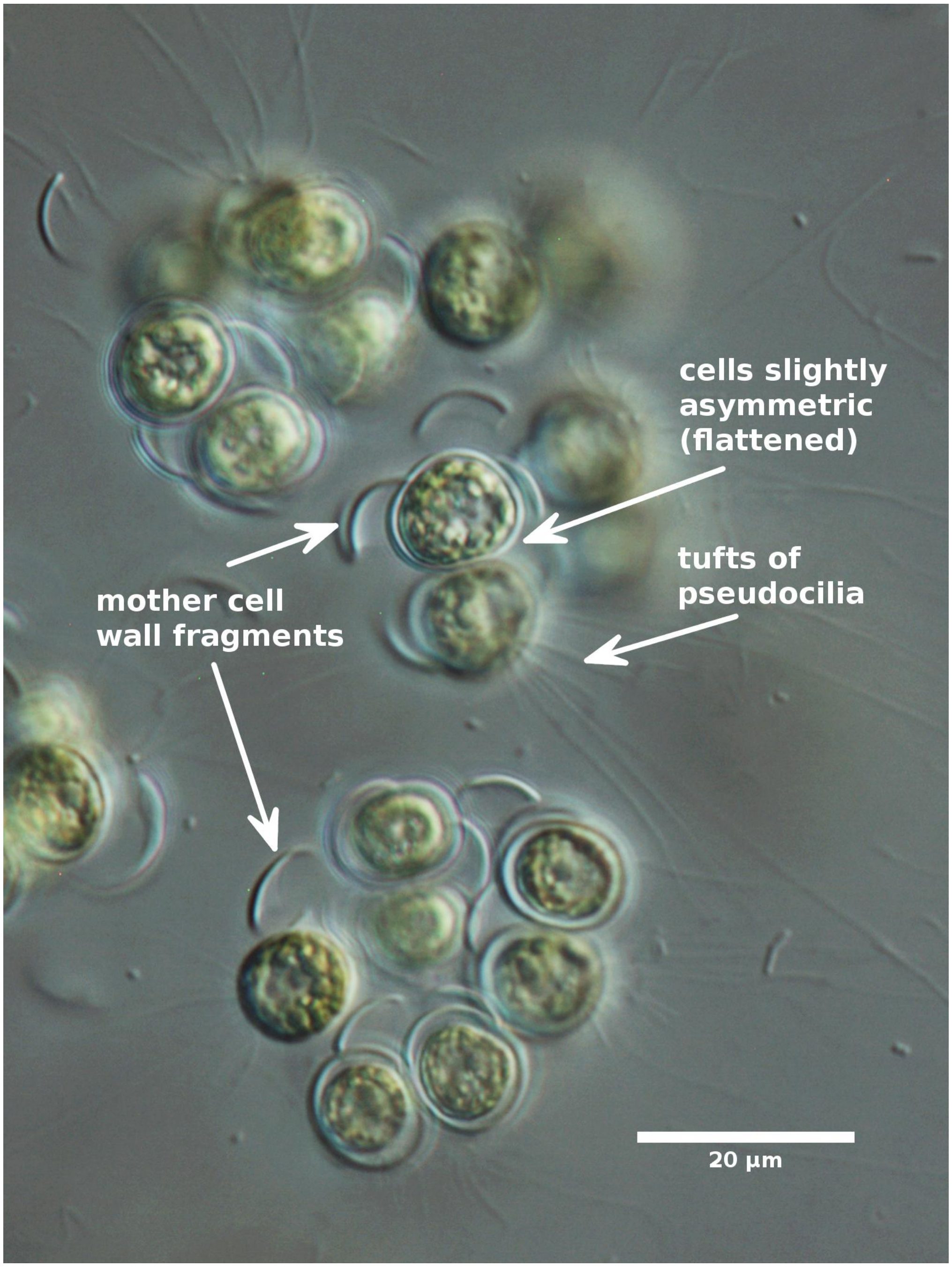

Figure 3.239: *Schizochlamys gelatinosa* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 9, 2013.

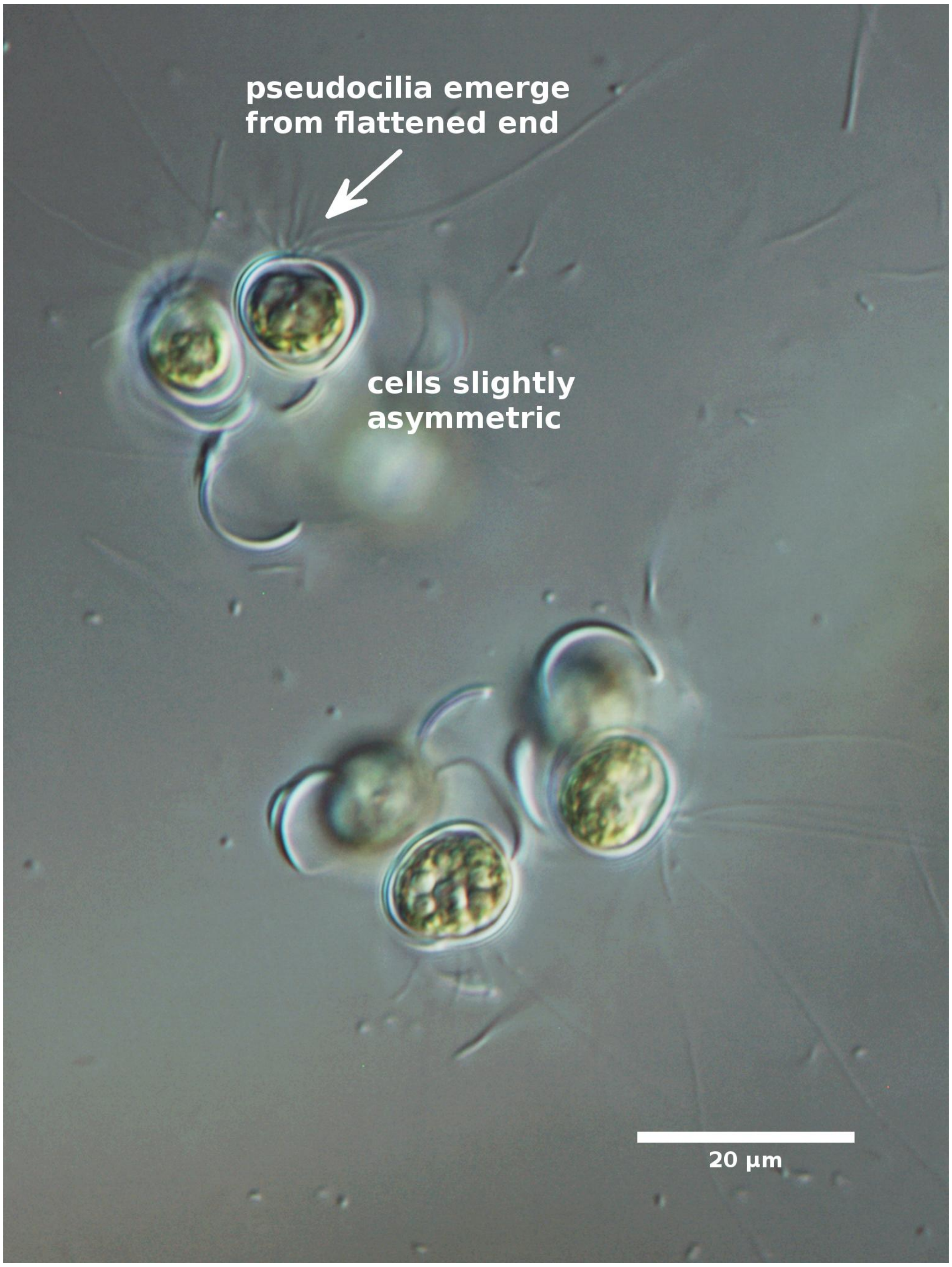

Figure 3.240: *Schizochlamys gelatinosa* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 9, 2013.

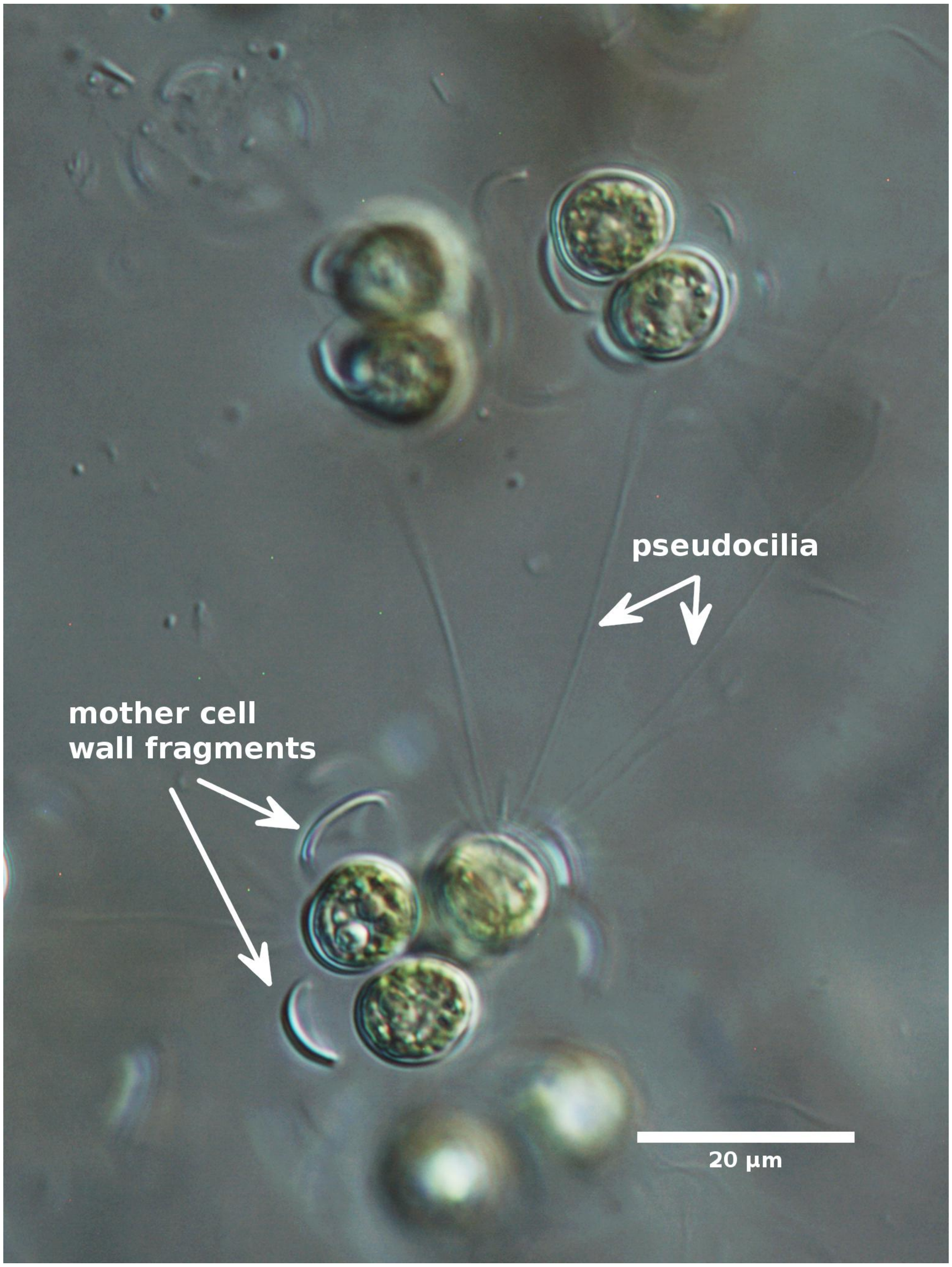

Figure 3.241: *Schizochlamys gelatinosa* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 9, 2013.

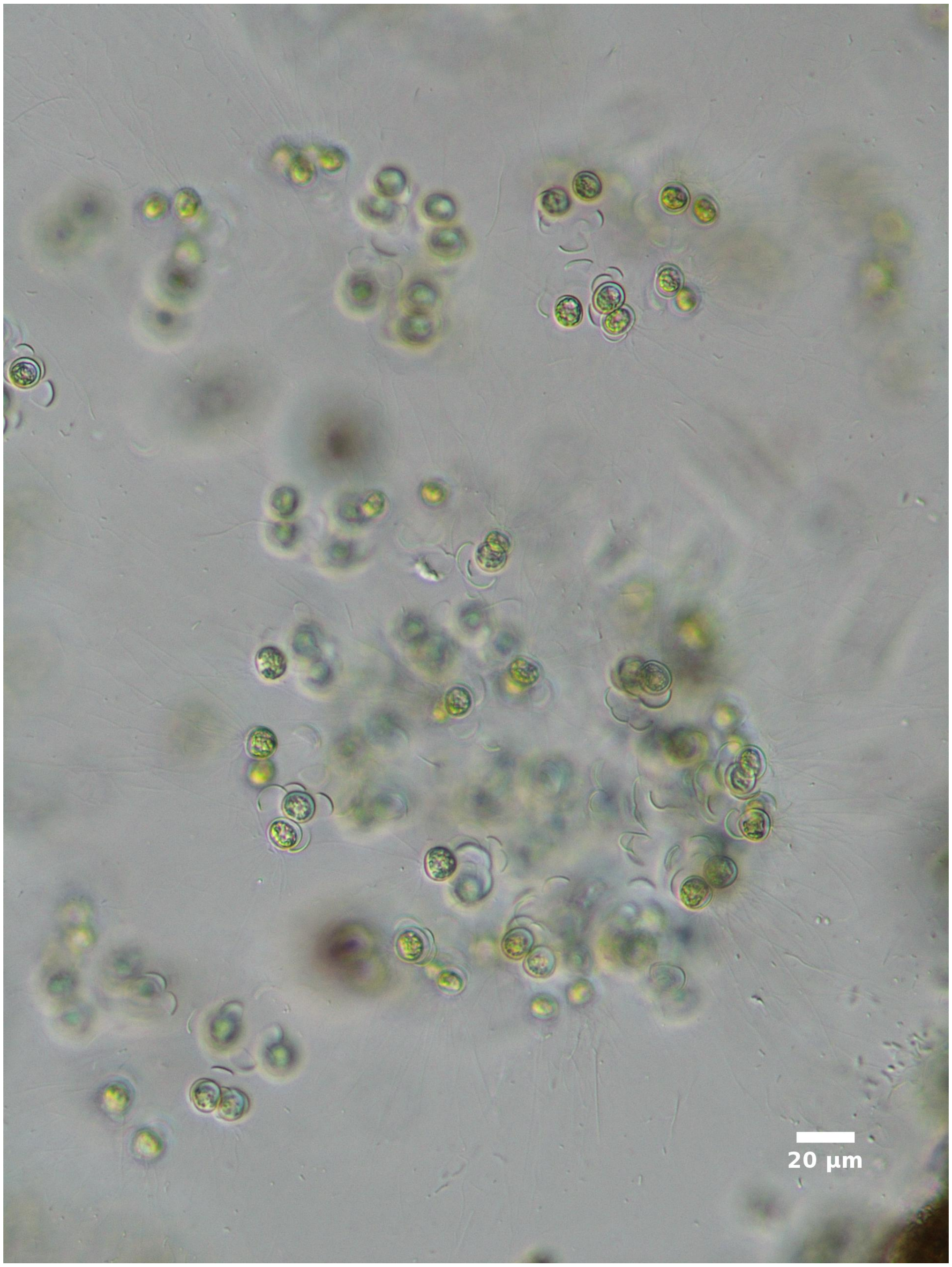

Figure 3.242: *Schizochlamys gelatinosa* bloom (200x DIC), Sunrise Lake, IWS water quality sampling site, Whatcom County, August 11, 2015.

3.32 *Schroederia* Lemmermann

Local taxa

Schroederia robusta Korshikov
(=*Pseudoschroederia robusta* [Korshikov] E. Hegewald & E. Schnepf);
Schroederia setigera (Schröder) Lemmermann

Abundance

Infrequently collected; occasionally forms blooms.

Local measurements		Width	Length	Biovolume†
Schroederia robusta	min	3.5 μm	38.6 μm	143 μm^3
cells (fusiform)	med	4.1 μm	45.4 μm	190 μm^3
	max	5.2 μm	51.2 μm	338 μm^3
Schroederia setigera‡	min	2.2 μm	41.2 μm	52.2 μm^3
cells (fusiform)	med	3.7 μm	84.0 μm	361 μm^3
	max	4.6 μm	117.9 μm	597 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume estimate based on <5 cells.

Description

Schroederia cells are solitary and narrowly fusiform, with long spine-like extensions at both ends of the cell (Figures 3.243–3.247). The chloroplasts are parietal bands with one or more pyrenoids that should be visible using phase contrast or DIC illumination.

Schroederia cells resemble some of the narrow species of *Ankyra* (Section 3.4, page 228), but unlike *Ankyra*, the posterior projection in *Schroederia* cells is not split. *Schroederia* cells also resemble *Monoraphidium* cells (Section 3.22, page 383), but *Monoraphidium* cells lack the long, spine-like projections and rarely have visible pyrenoids.[19]

[19]The absence of pyrenoids is not a particularly good taxonomic feature. Recent improvements in microscopy have revealed the presence of pyrenoids in species that were initially described as lacking this feature.

Schroederia robusta cells are broadly fusiform and curved (crescent-shaped) or twisted into a helix (Figures 3.243–3.244). The apical and posterior spines are stout and straight. *Schroederia setigera* cells are very narrow and nearly straight, tapering into long, straight or very slightly curved apical and posterior spines (Figures 3.245–3.247).

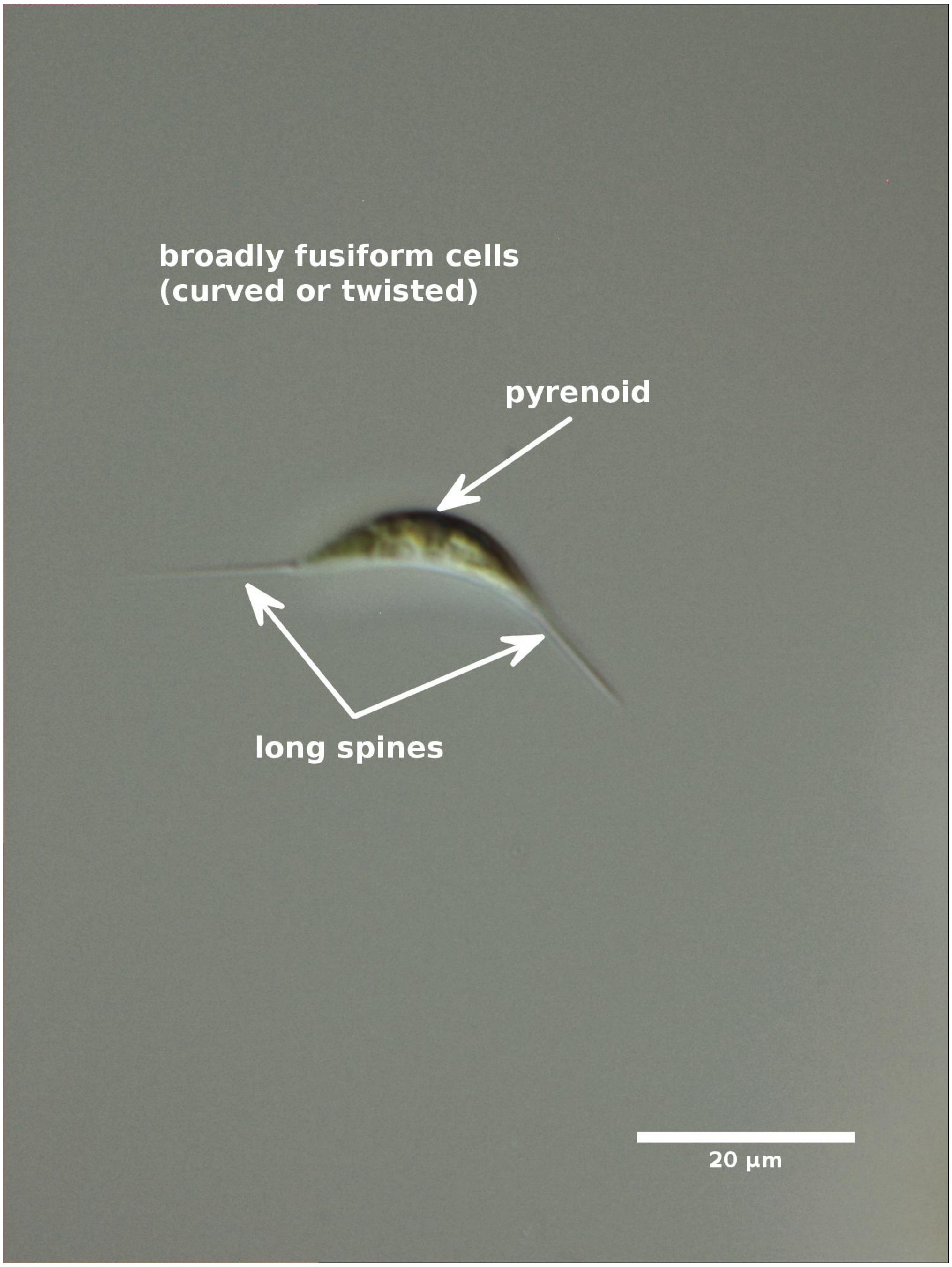

Figure 3.243: *Schroederia robusta* (600x DIC), Thunderbird Lake, IWS water quality sampling site, Whatcom County, September 23, 2011.

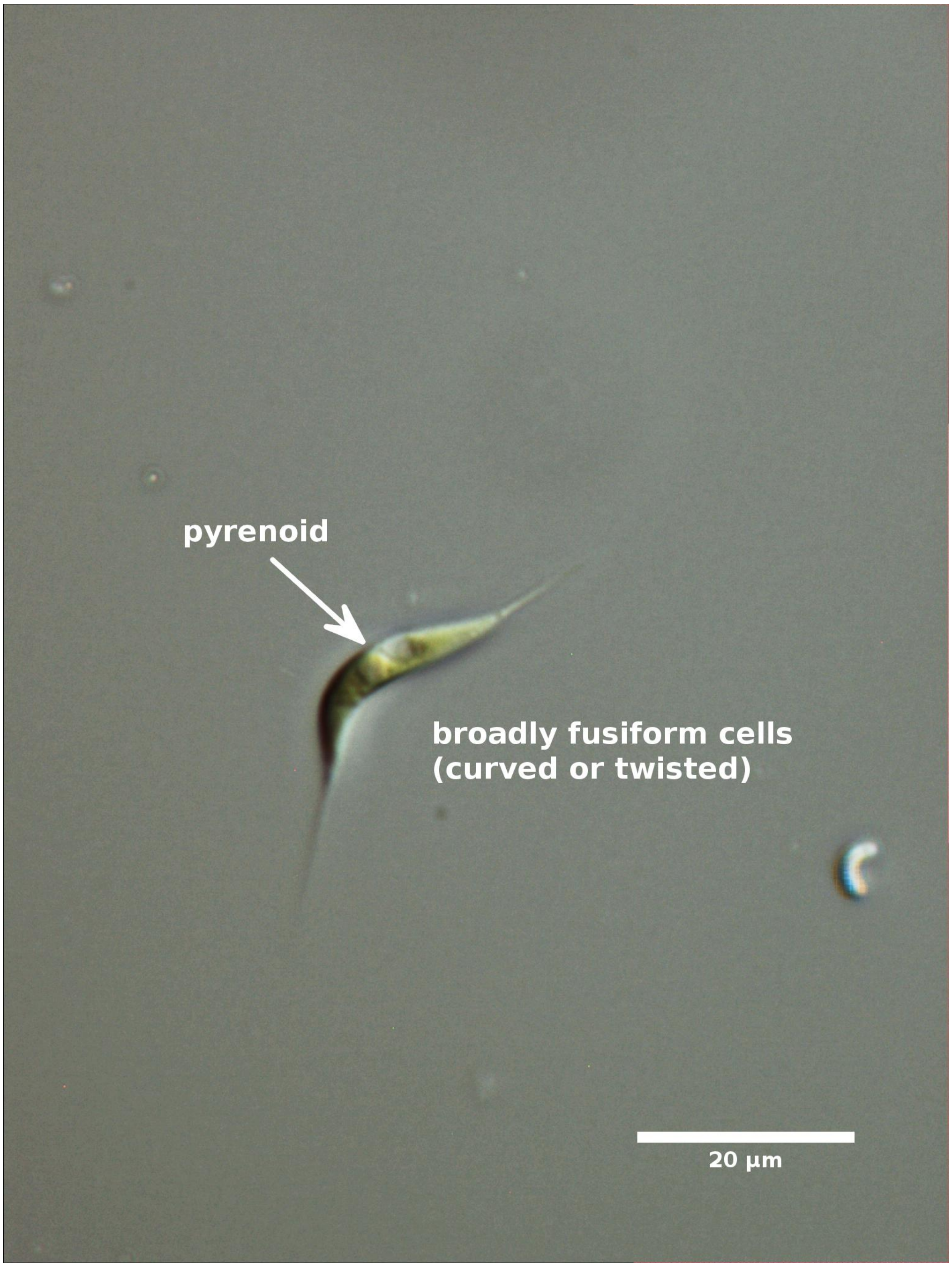

Figure 3.244: *Schroederia robusta* (600x DIC), Thunderbird Lake, IWS water quality sampling site, Whatcom County, September 23, 2011.

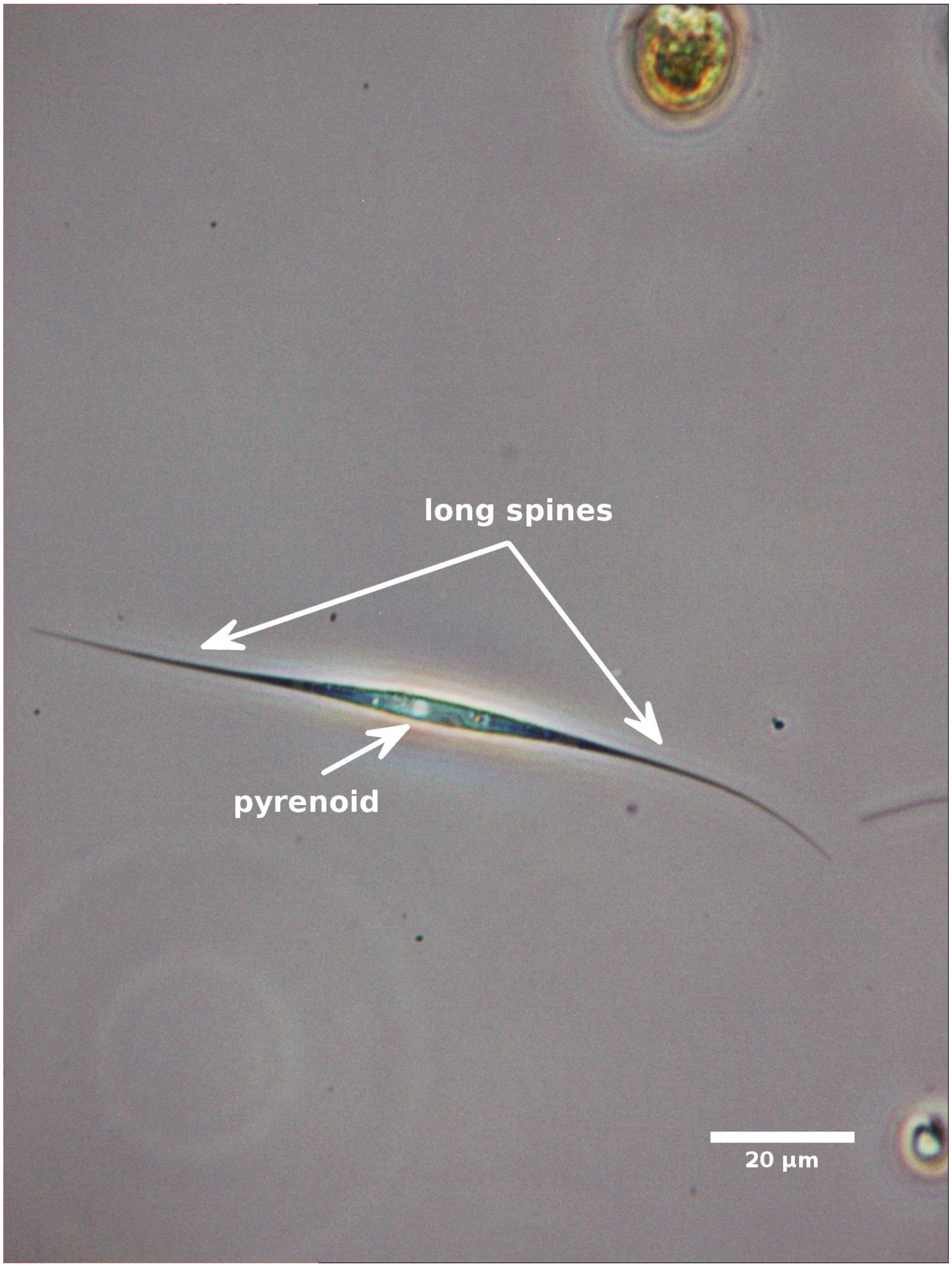

Figure 3.245: *Schroederia setigera* (400x phase contrast), Kwan Lake, IWS water quality sampling site, Whatcom County, August 24, 2009.

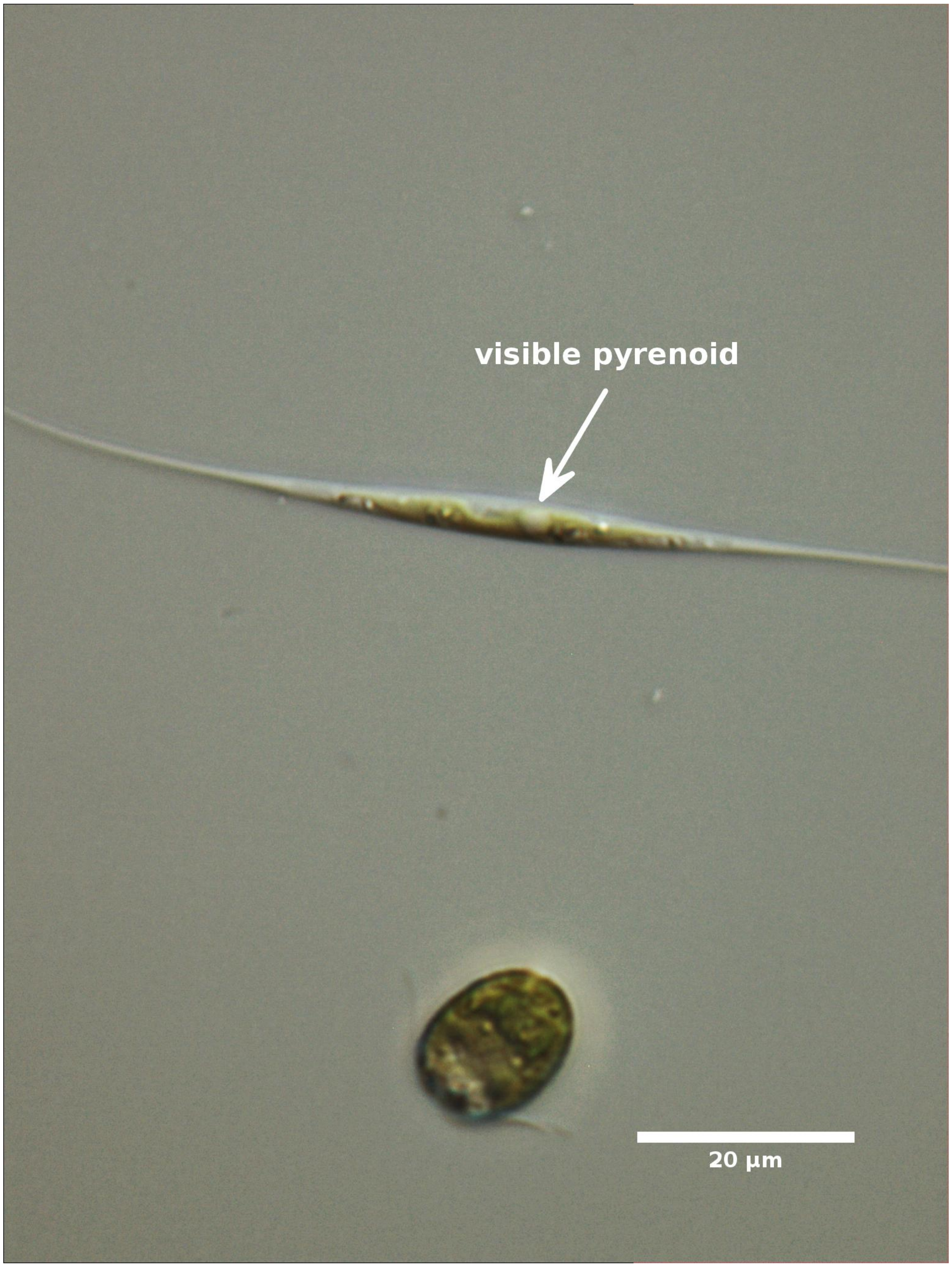

Figure 3.246: *Schroederia setigera* (600x DIC), Kwan Lake, IWS water quality sampling site, Whatcom County, August 24, 2009.

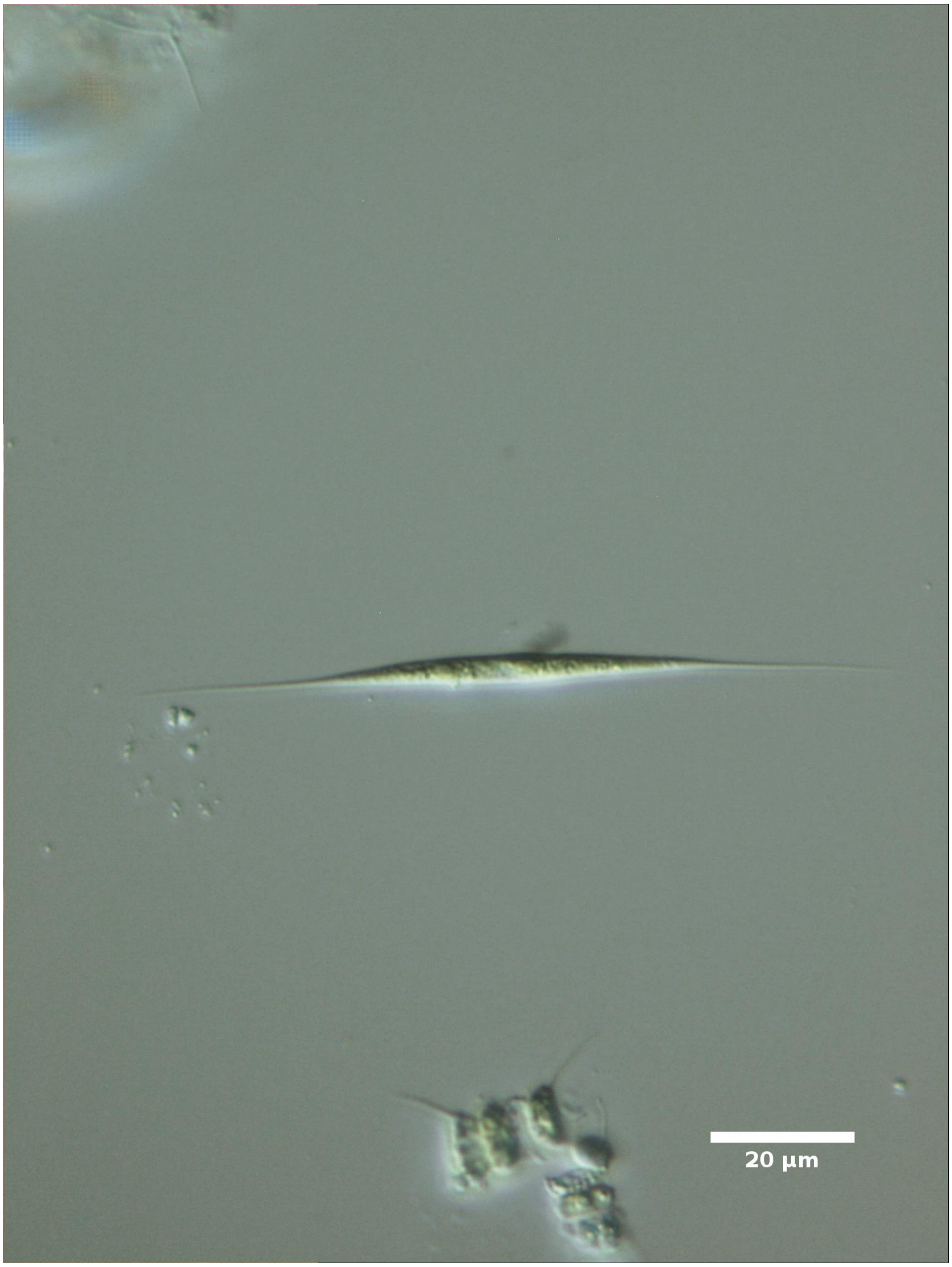

Figure 3.247: *Schroederia setigera* (400x DIC), Manito Park duck pond (Spokane area), eastern Washington, May 27, 2009.

3.33 *Selenastrum* Reinsch

Local taxa
Selenastrum bibraianum Reinsch;
Selenastrum gracile Reinsch

Abundance
Selenastrum bibraianum is moderately common, but rarely resent in large numbers; *Selenastrum gracile* is infrequently collected.

Local measurements		Width	Length	Biovolume†
Selenastrum bibraianum	min	3.8 μm	26.8 μm	112 μm^3
cells (fusiform)	med	5.4 μm	32.6 μm	248 μm^3
	max	6.5 μm	38.4 μm	374 μm^3
Selenastrum gracile	min	1.7 μm	17.6 μm	13.3 μm^3
cells (fusiform)	med	2.3 μm	24.6 μm	37.8 μm^3
	max	3.9 μm	30.0 μm	94.8 μm^3

†Calculated using original measurements, not summary values.

Description
Selenastrum cells are occasionally solitary, but are more likely to be found loosely connected by their dorsal (convex) edge in small colonies surrounded by a diffuse colonial mucilage (Figures 3.248–3.254). The cells often form tetrahedral subgroups in the colony. The individual cells are crescent-shaped and strongly curved. The chloroplast is a parietal band; pyrenoids may or may not be visible.

Selenastrum cells and colonies closely resemble some species of *Kirchneriella* (Section 3.18, page 356). *Selenastrum* cells are narrower and joined to other cells in the colony by their dorsal (convex) edge; *Kirchneriella* cells are thicker, may have bluntly rounded ends, and are loosely arranged in the colonial mucilage.

Selenastrum bibraianum cells are crescent-shaped, strongly curved (nearly circular), with narrow, bluntly rounded apices (Figures 3.248–3.251). Fully developed *Selenastrum bibraianum* cells are wider than *Selenastrum gracile*, but actively dividing cells can be very narrow (Figure 3.249). John, et al. (2011) state that the cells form tetrads and the colonies rarely contain more than 16 cells,. Most of the local specimens formed larger colonies (>30–40 cells), with cells joined along the convex wall, but not necessarily arranged in tetrads. Smaller colonies and solitary cells may be present in the same sample (Figures 3.250–3.251).

Selenastrum gracile cells are narrowly crescent-shaped, less strongly curved than *S. bibraianum*, with sharply pointed apices (Figures 3.252–3.254). The cells are joined centrally along the convex wall, forming fairly obvious tetrads. This species is much less frequent in plankton samples from local lakes.

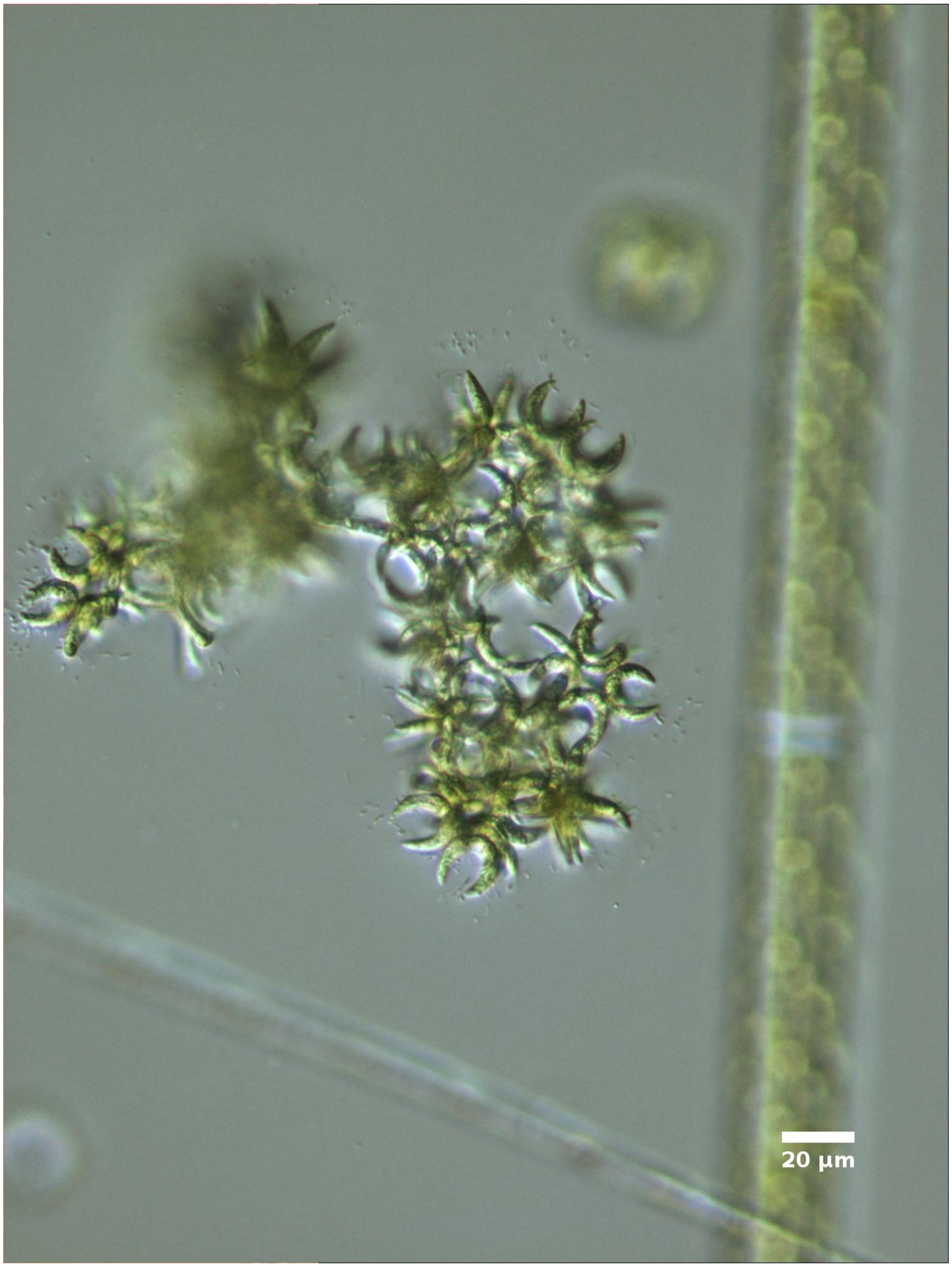

Figure 3.248: *Selenastrum bibraianum* (200x DIC), Sunday Lake, IWS water quality sampling site, Snohomish County, September 2, 2009.

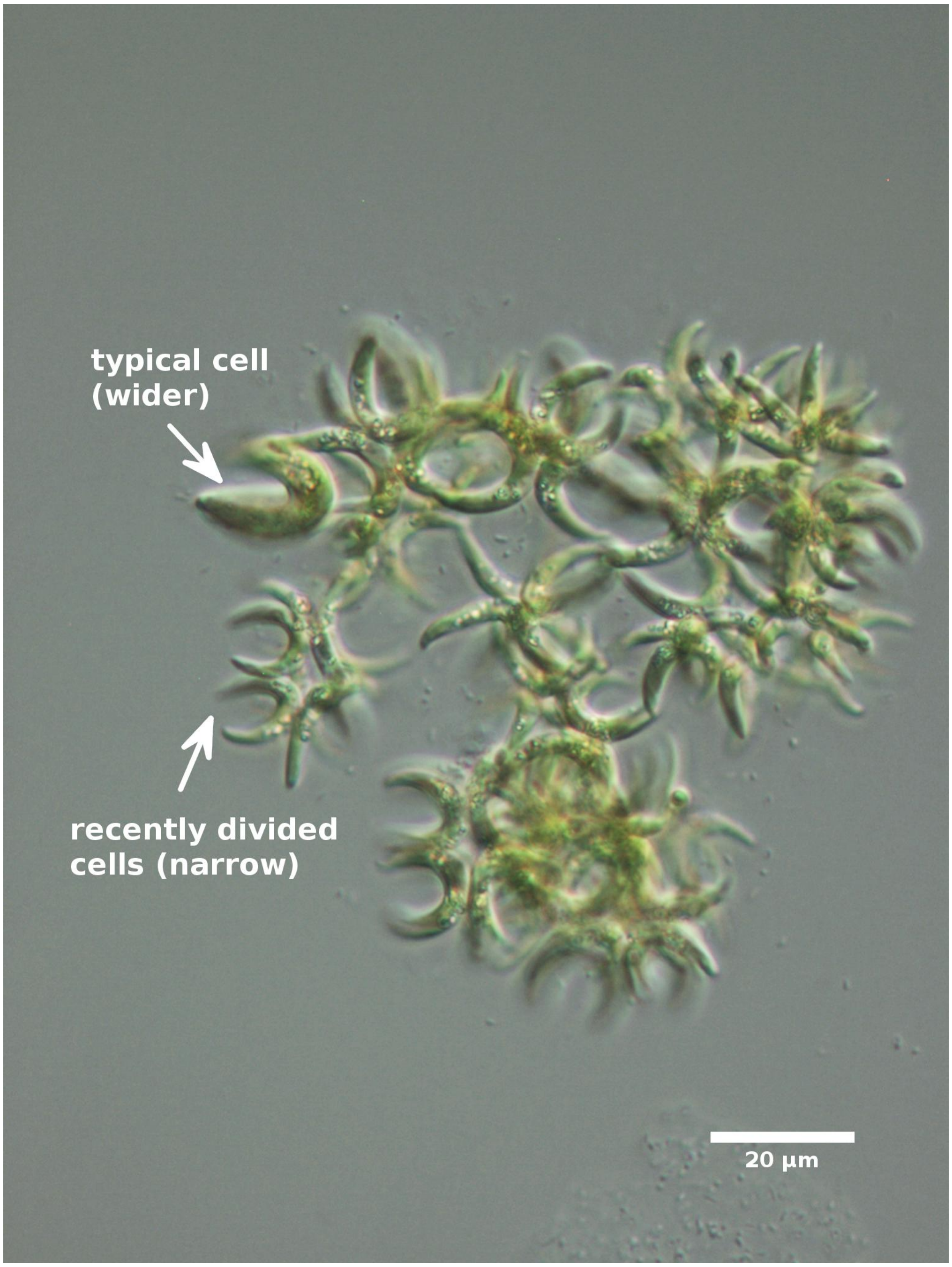

Figure 3.249: *Selenastrum bibraianum* (400x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, September 14, 2012.

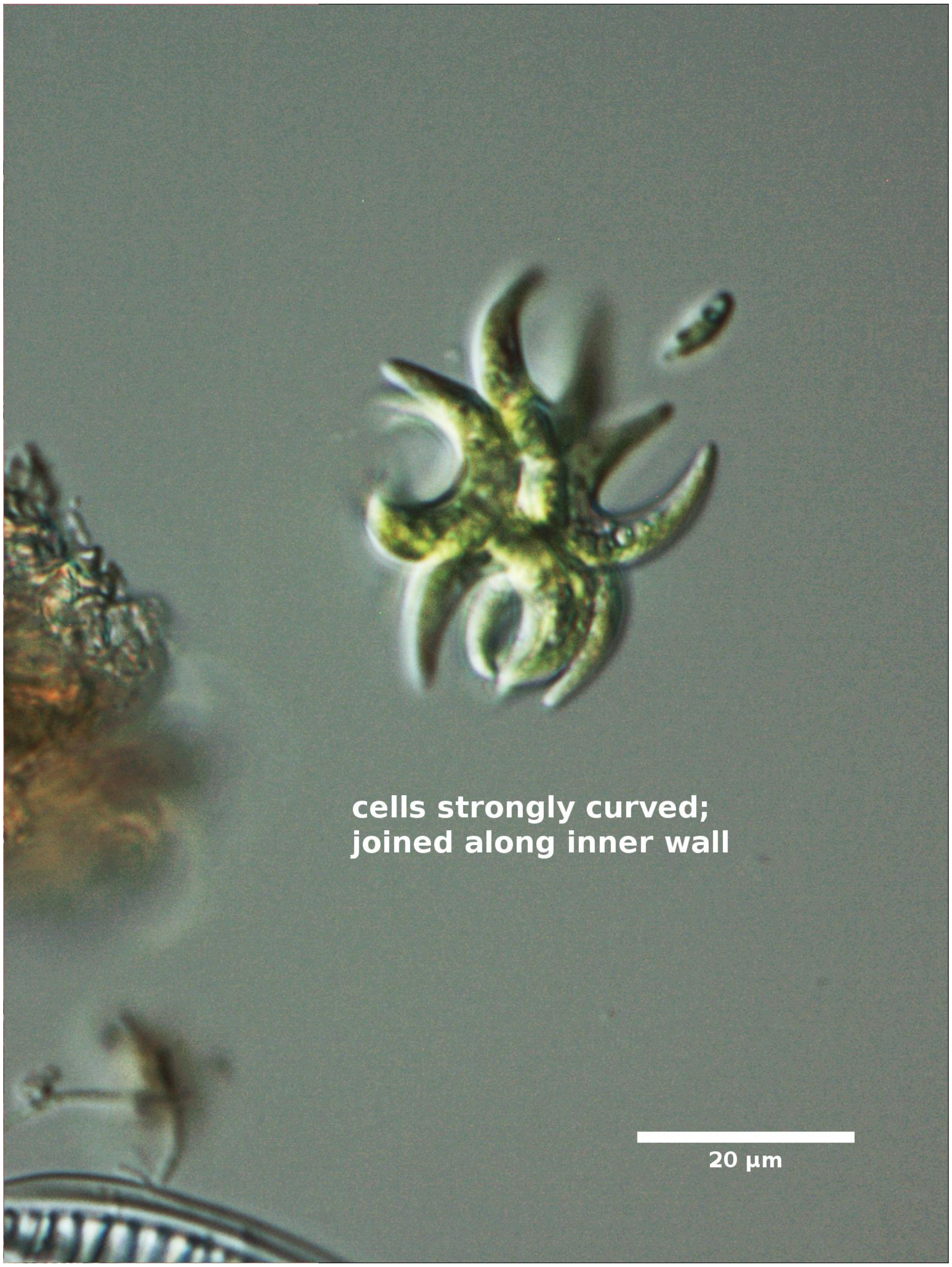

Figure 3.250: *Selenastrum bibraianum* (600x DIC), Sunday Lake, IWS water quality sampling site, Snohomish County, July 26, 2011.

Figure 3.251: *Selenastrum bibraianum* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, September 14, 2012.

Figure 3.252: *Selenastrum gracile* (600x DIC), small pond near Fairhaven College, Whatcom County, April 13, 2015.

Figure 3.253: *Selenastrum gracile* (600x DIC), small pond near Fairhaven College, Whatcom County, April 13, 2015.

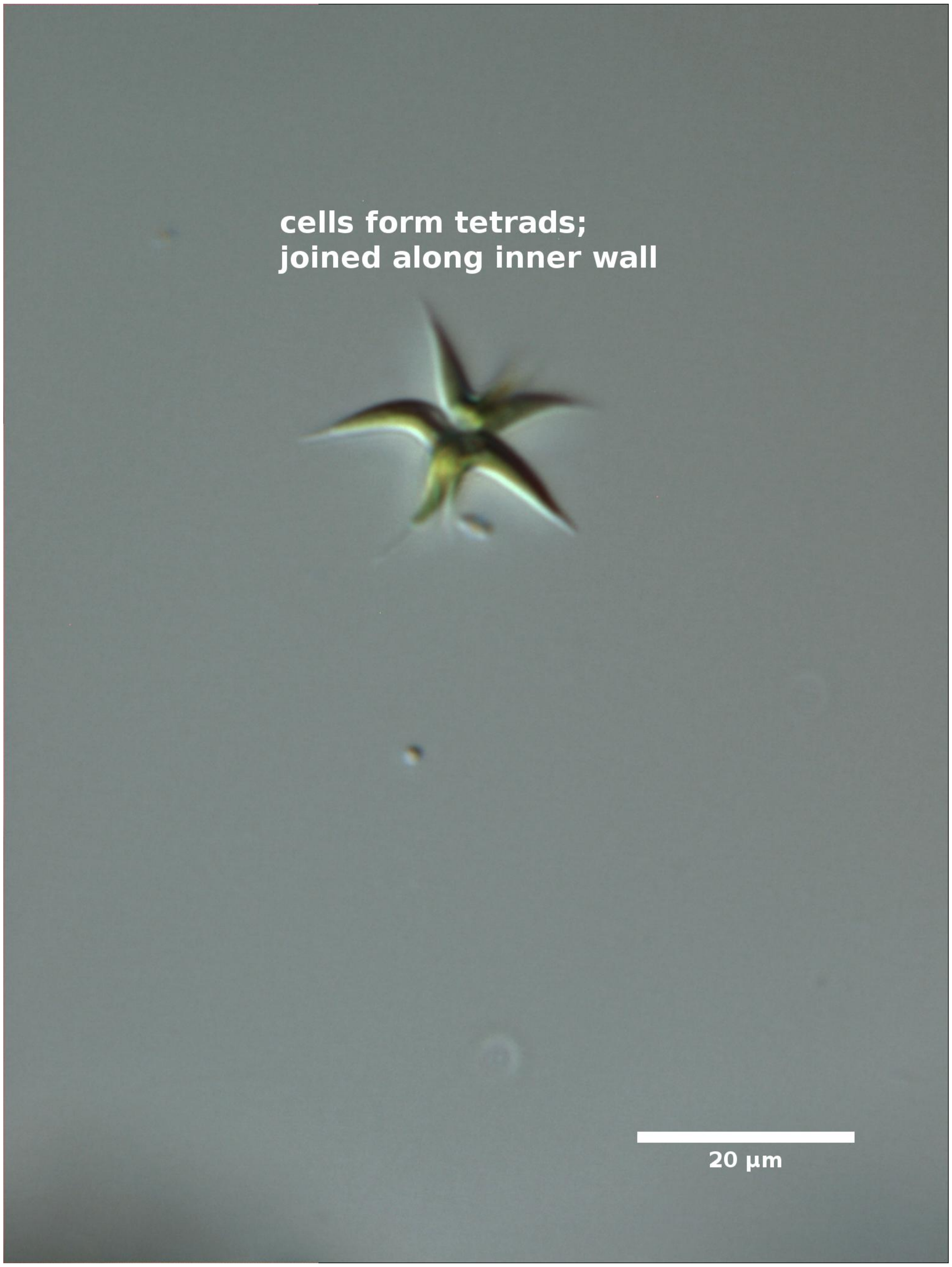

Figure 3.254: *Selenastrum gracile* (600x DIC), freshwater pond uphill from Mud Bay, Whatcom County, May 7, 2009.

3.34 *Sorastrum* Kützing

Local taxa
Sorastrum americanum (Bohlin) Schmidle;
Sorastrum spinulosum Nägeli

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Sorastrum americanum	min	6.2 μm	6.7 μm	135 μm^3
cells (spheroid)	med	10.7 μm	10.5 μm	610 μm^3
	max	20.9 μm	17.4 μm	3,980 μm^3
Sorastrum americanum	min	23.6 μm	–	
colonies‡	med	35.6 μm	–	
	max	53.1 μm	–	
Sorastrum spinulosum	min	10.1 μm	8.7 μm	522 μm^3
cells (spheroid)	med	11.9 μm	11.4 μm	867 μm^3
	max	16.2 μm	13.0 μm	1,790 μm^3
Sorastrum spinulosum	min	25.1 μm	–	
colonies‡	med	30.1 μm	–	
	max	37.9 μm	–	

†Calculated using original measurements, not summary values.
‡Colony biovolume can estimated using a spherical shape.

Description
Sorastrum colonies contain 4–32 cells with thick basal stalks and long or short, horn-like, apical spines (Figures 3.255–3.259). The cells are attached to each other by the basal stalks, forming distinctive three-dimensional, radiating colonies. *Sorastrum* is morphologically similar to *Pediastrum* (Section 3.28, page 424), but *Pediastrum* colonies are flat while *Sorastrum* colonies are spherical.

Sorastrum americanum colonies have wedge-shaped cells with 2–4 long apical spines per cell (Figures 3.255–3.257). The length and number of apical spines varies between cells, with young colonies often having relatively short spines. The individual cells are about equal in length and width, and the colonies are slightly less compact compared to *Sorastrum spinulosum*.

Sorastrum spinulosum forms dense, compact colonies, with broad, heart-shaped cells that have short, knob-like apical spines (Figures 3.258–3.259). The individual cells are usually slightly wider than their length, but this feature can be difficult to see unless the colony is flattened.

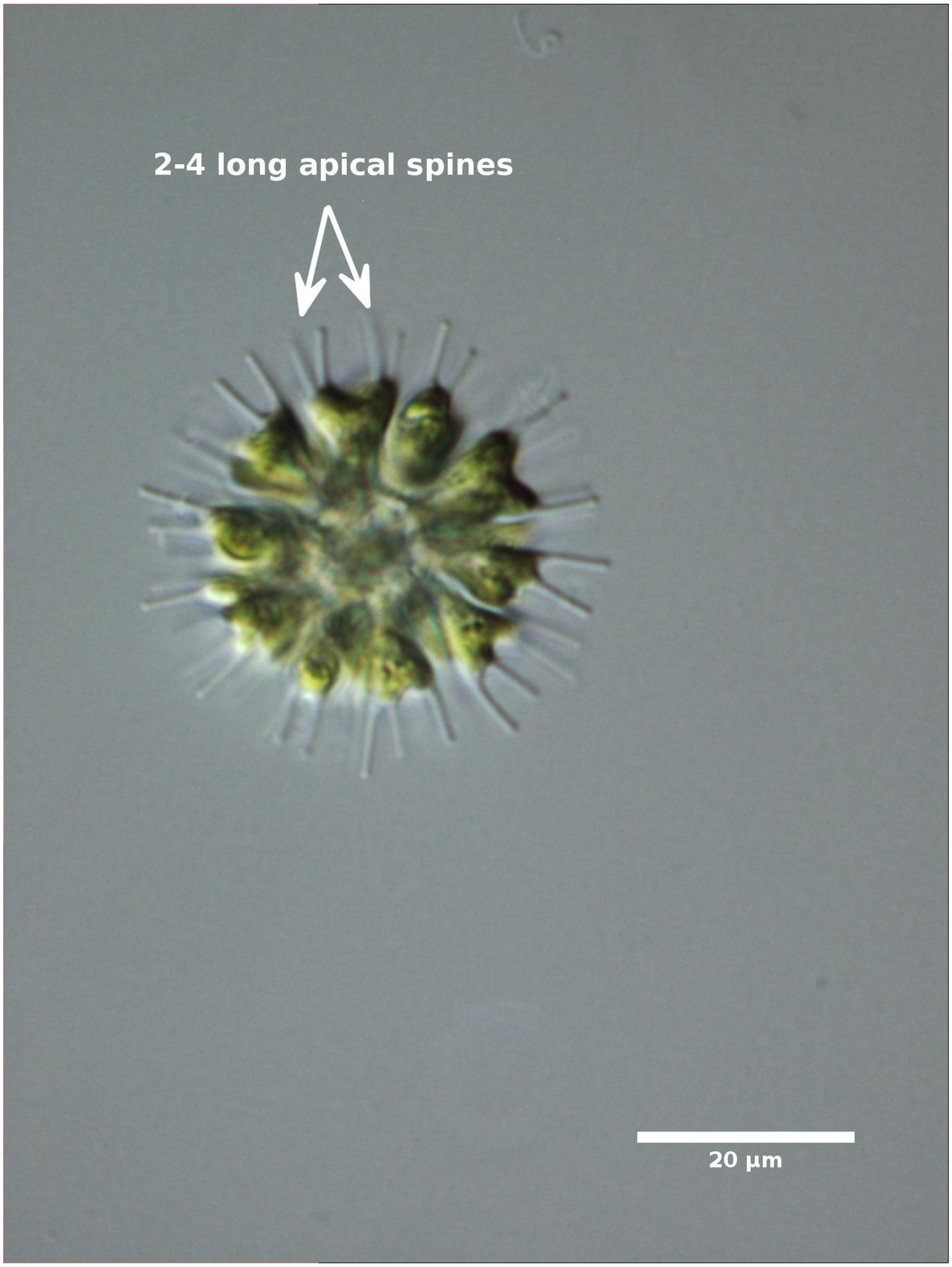

Figure 3.255: *Sorastrum americanum* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, May 7, 2009.

Figure 3.256: *Sorastrum americanum* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, September 12, 2012.

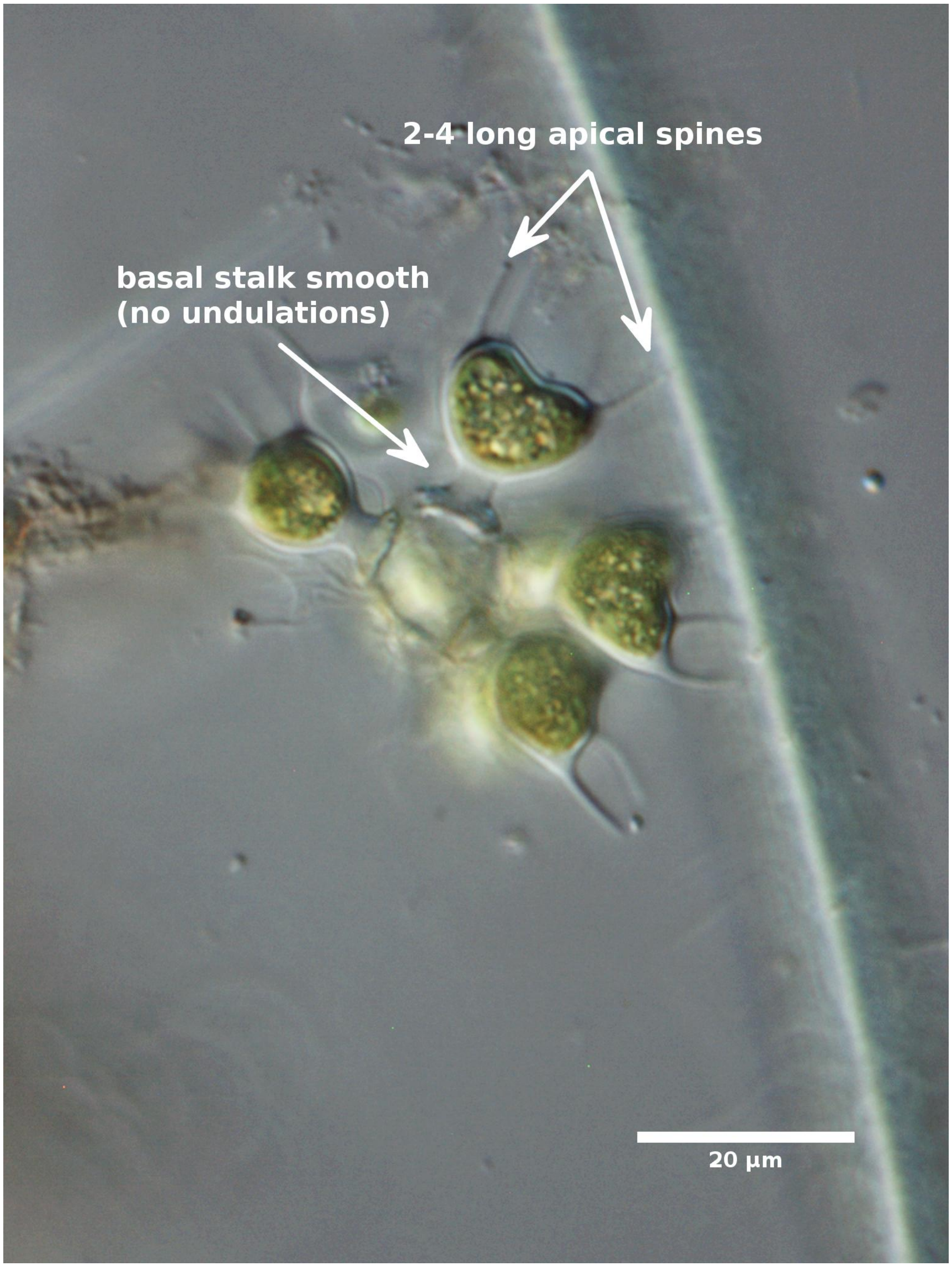

Figure 3.257: *Sorastrum americanum* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, September 21, 2012.

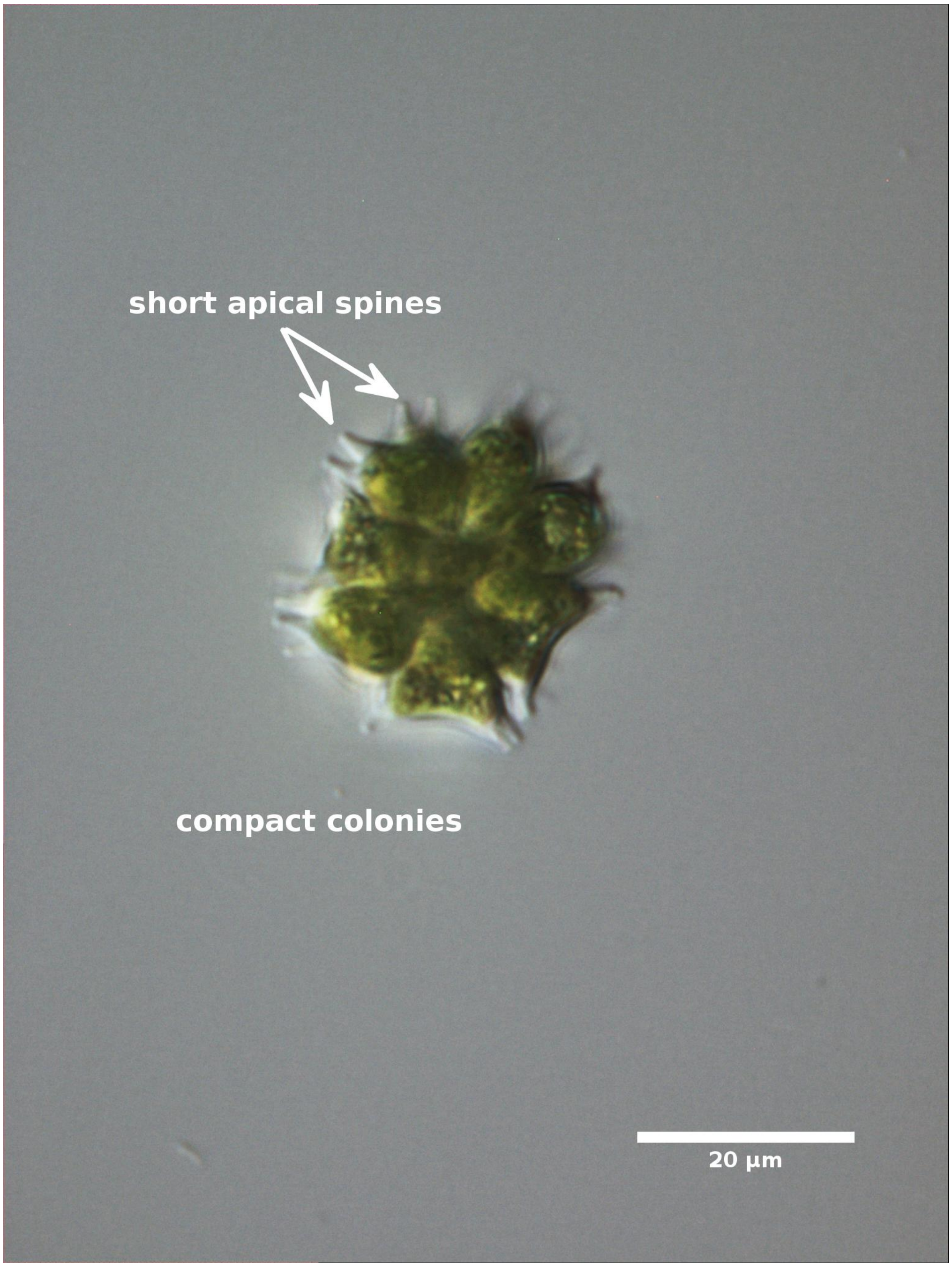

Figure 3.258: *Sorastrum spinulosum* (600x DIC), Whistle Lake, IWS water quality sampling site, Skagit County, July 21, 2011.

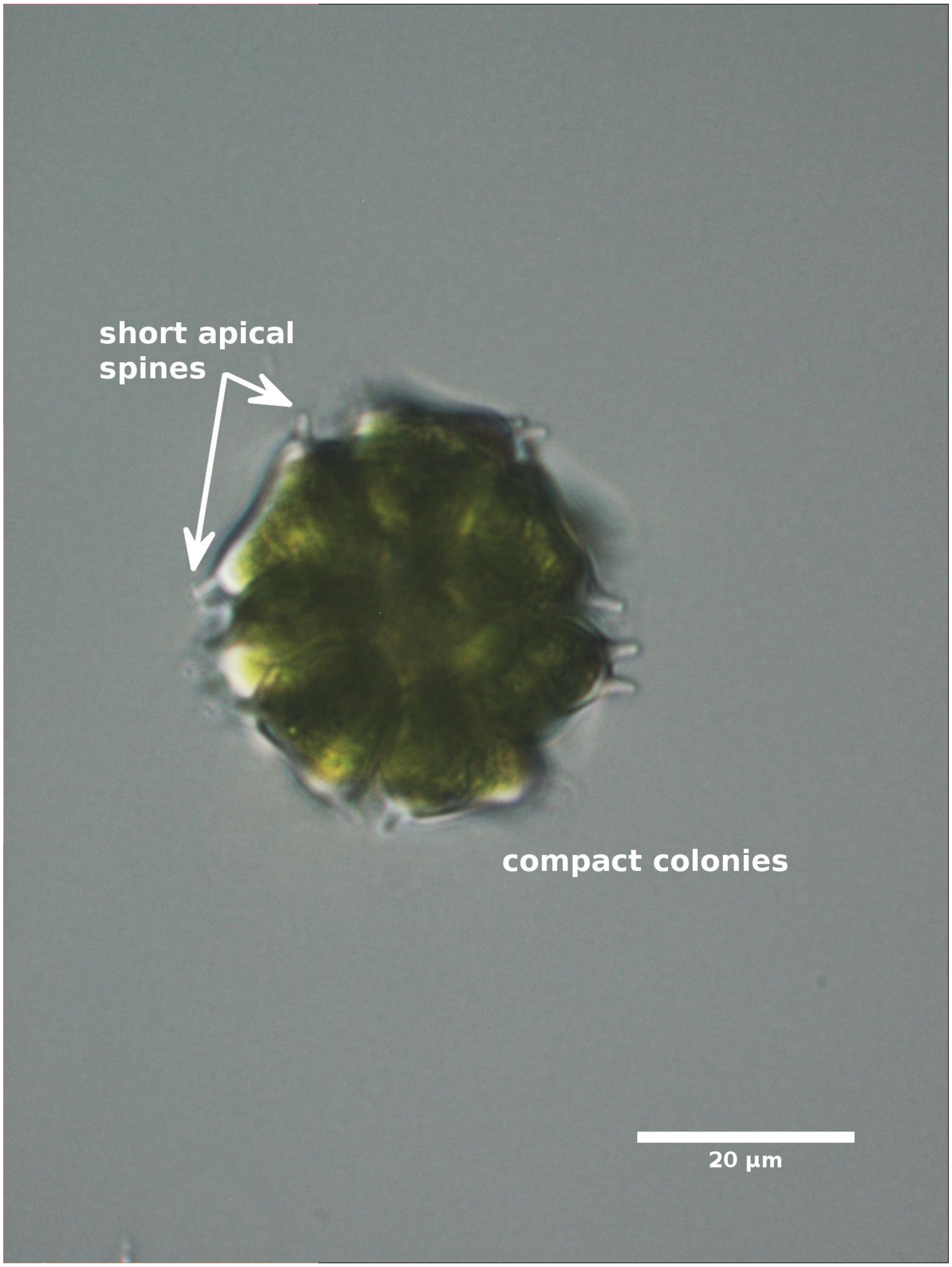

Figure 3.259: *Sorastrum spinulosum* (600x DIC), Heart Lake, IWS water quality sampling site, Skagit County, September 20, 2010.

3.35 *Sphaerocystis* Chodat

Local taxon
Sphaerocystis schroeteri Chodat

Abundance
Moderately common; may form very dense blooms.

Local measurements		Width	Length	Biovolume†
Sphaerocystis schroeteri	min	4.5 μm	4.6 μm	48.8 μm^3
cells (spheroid)	med	9.5 μm	9.5 μm	449 μm^3
	max	26.3 μm	27.4 μm	9,920 μm^3

†Calculated using original measurements, not summary values.

Description
Sphaerocystis schroeteri colonies contain 4–32 (or more) spherical cells enclosed in an unstratified mucilaginous colonial envelope (Figures 3.260–3.263). The colony often includes large, undivided mother cells as well as clusters of smaller daughter cells. Each cell contains a single parietal chloroplast with a single pyrenoid. As the cell ages, the chloroplast may become very dense, filling the cell and obscuring the chloroplast detail. When actively dividing, the size difference between cells is quite distinctive.

John, et al. (2011) question whether some (most?) specimens identified as *Sphaerocystis schroeteri* might actually be *Coenochloris fottii* (Hindák) Tsarenko. The differences are subtle and not easily distinguished using standard microscopy techniques, so we will include specimens fitting the general description for *Sphaerocystis schroeteri* in this section.

Compare *Sphaerocystis schroeteri* to *Chlorella* (Section 3.9, page 282), which does not form distinct colonies and has little if any mucilage surrounding the cells. Also compare specimens to *Asterococcus* (Section 3.6, page 245), which has stellate chloroplasts and stratified mucilage surrounding the cells and colony; *Gloeocystis* (Section 3.16, page 343), which has cup-shaped chloroplasts and stratified mucilage surrounding the cells and colony; and *Planktosphaeria* (Section 3.29, page 451), which is characterized by solitary cells surrounded by a firm, unstratified mucilage.

Figure 3.260: *Sphaerocystis schroeteri* (400x DIC), Heart Lake, IWS water quality sampling site, Skagit County, September 20, 2010.

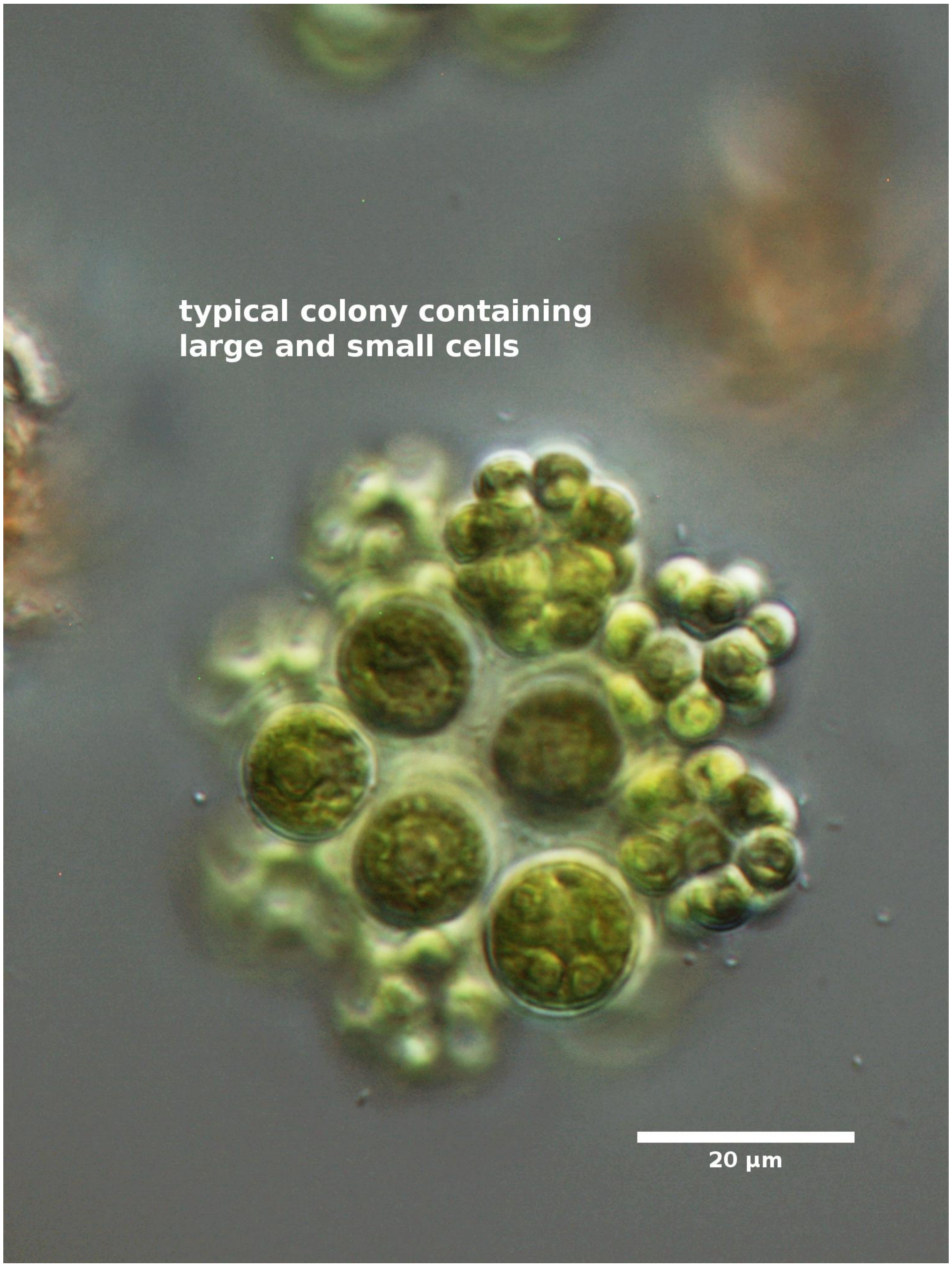

Figure 3.261: *Sphaerocystis schroeteri* (600x DIC), Lone Lake, IWS water quality sampling site, Island County, July 22, 2013.

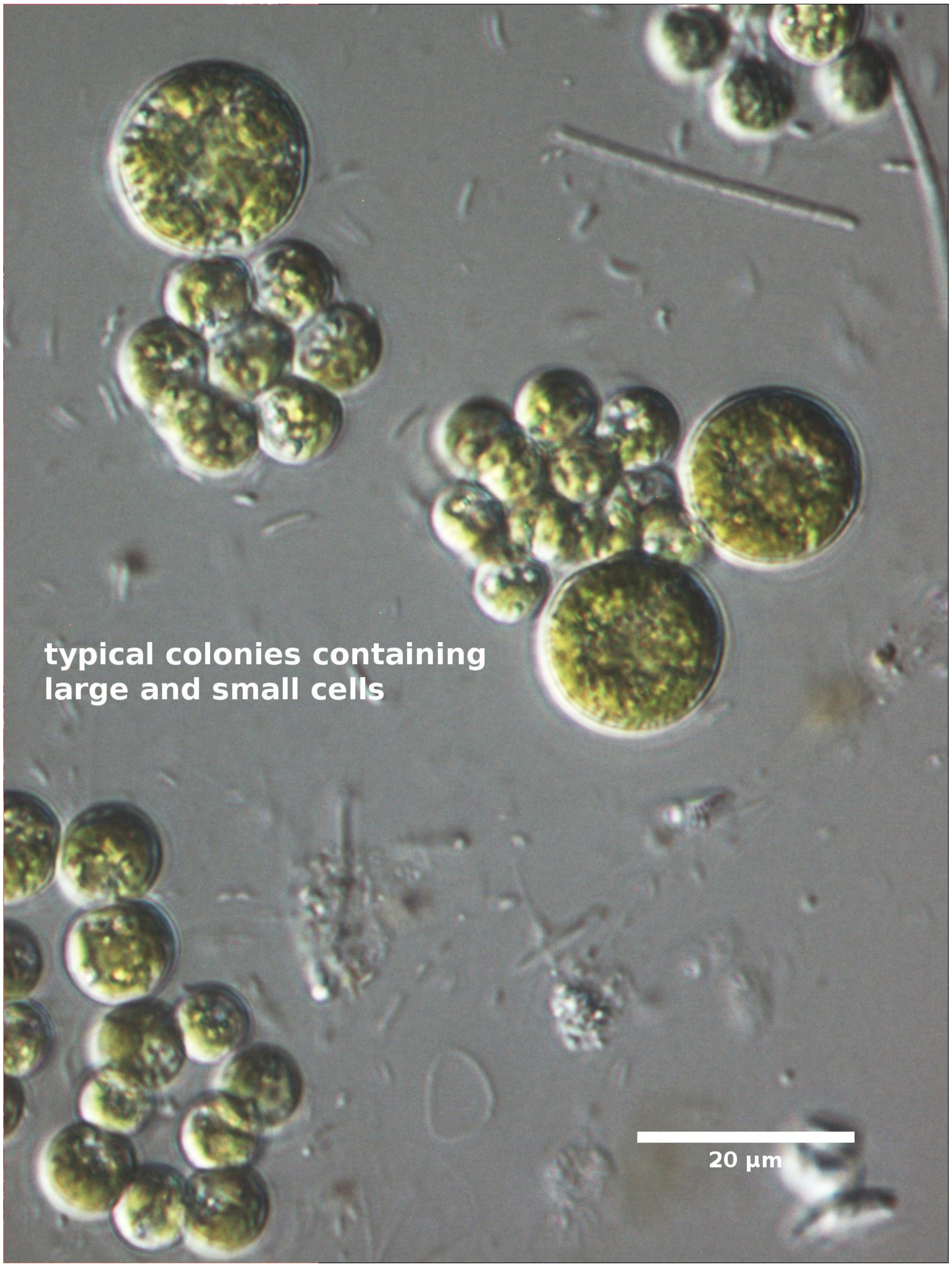

Figure 3.262: *Sphaerocystis schroeteri* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 12, 2010.

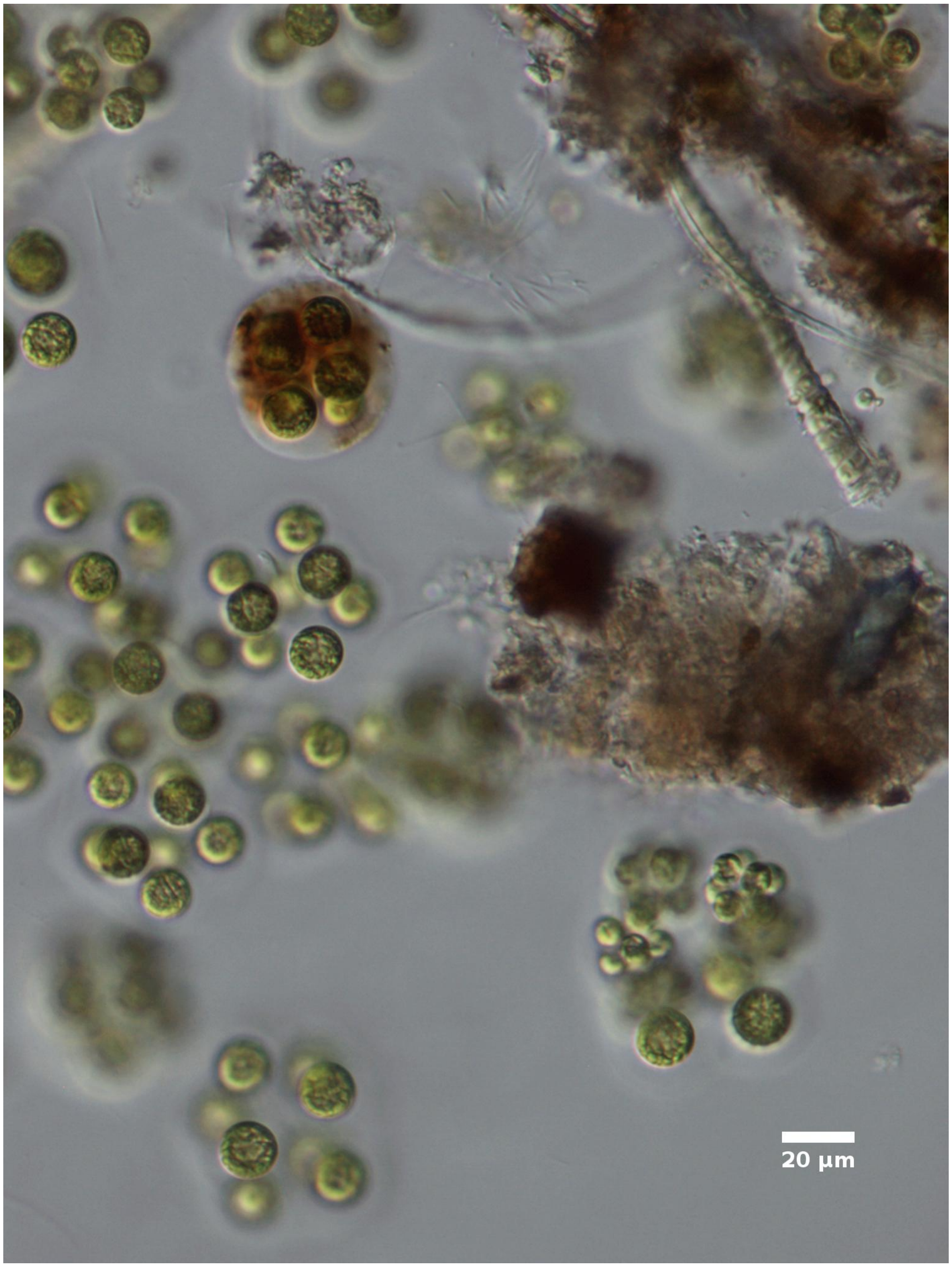

Figure 3.263: *Sphaerocystis schroeteri* bloom (200x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, July 8, 2013.

3.36 *Tetraedron* Kützing

Local taxa
Tetraedron caudatum (Corda) Hansgirg;
Tetraedron minimum (A. Braun) Hansgirg;
Tetraedron sp.

Abundance
Moderately common; rarely present in large numbers; easily overlooked.

Local measurements		Width	Length	Biovolume†
Tetraedron caudatum‡	min	–	–	–
cells (rectangular box)	med	12.0 μm	12.1 μm	697 μm^3
	max	–	–	–
Tetraedron minimum§	min	9.1 μm	9.9 μm	820 μm^3
cells (rectangular box)	med	10.1 μm	11.5 μm	1,160 μm^3
	max	13.6 μm	14.3 μm	2,640 μm^3
Tetraedron sp.1§	min	16.1 μm	22.1 μm	5,910 μm^3
cells (rectangular box)	med	19.5 μm	22.4 μm	8,400 μm^3
	max	24.5 μm	27.3 μm	16,400 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume was calculated assuming cell width/depth ratio of 2.5 (Olenina, et al., 2006) and was based on <5 cells.
§Biovolume was calculated assuming cell depth was equal to cell width.

Description
Many species originally in the genus *Tetraedron* have been moved out of Chlorophyta because they do not form starch. Check possible *Tetraedron* cells for starch formation using Lugol's iodine or look for pyrenoids that are visible in some species of *Tetraedron*. Compare specimens that lack pyrenoids and starch to *Goniochloris*, *Pseudostaurastrum*, and *Tetraedriella*.[20]

[20]See **Freshwater Algae in Northwest Washington, Volume IV. Chrysophyceae, Xanthophyceae, and Haptophyta**.

Tetraedron caudatum cells are solitary, 5-sided (star-shaped), and slightly flattened, with short spines at each corner (Figure 3.264). This species has only been collected from a small ornamental pond near Fairhaven College (Western Washington University).

Tetraedron minimum cells are solitary, 4-sided, and slightly flattened. The cells may have small knobs or spines at each corner, but lack extensive wall ornamentation (Figures 3.265-3.267). The sides of the cell range from concave to straight, or even slightly convex. The cell wall may be smooth or slightly bumpy; the apices may have short, blunt knobs, but not long spines. The cells usually have a central pyrenoid that is easy to see using light microscopy. This species is fairly common in local lakes, but its small size makes it easy to overlook.

Tetraedron sp.1 cells are solitary, more-or-less 4-sided, with ornate wall extensions that extend into short, highly branched arms (Figures 3.268–3.271). The cells match the general description for *Tetraedron planctonicum* G. M. Smith, which is still listed in the Chlorophyta on AlgaeBase. A very similar species, *Tetraedron limneticum* Borge, has been renamed *Pseudostaurastrum limneticum* Borge (Chodat) and moved to Heterokontophyta. *Pseudostaurastrum limneticum* should be distinguishable by the absence of starch (test with Lugol's iodine solution). Most of the local *Tetraedron* sp.1 specimens have been collected from high elevation lakes.

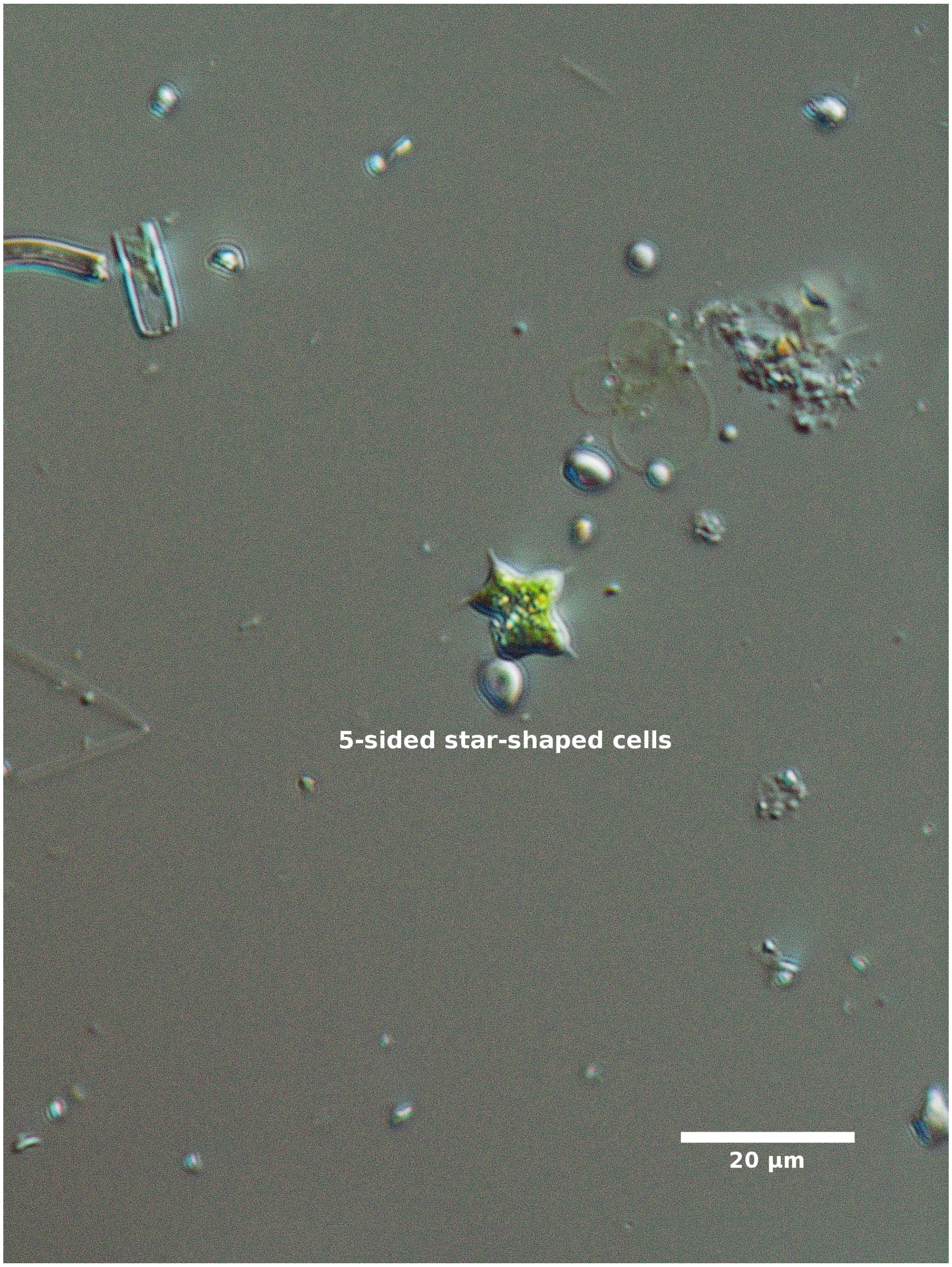

Figure 3.264: *Tetraedron caudatum* (600x DIC, small pond near Fairhaven College, Whatcom County, May 14, 2014.

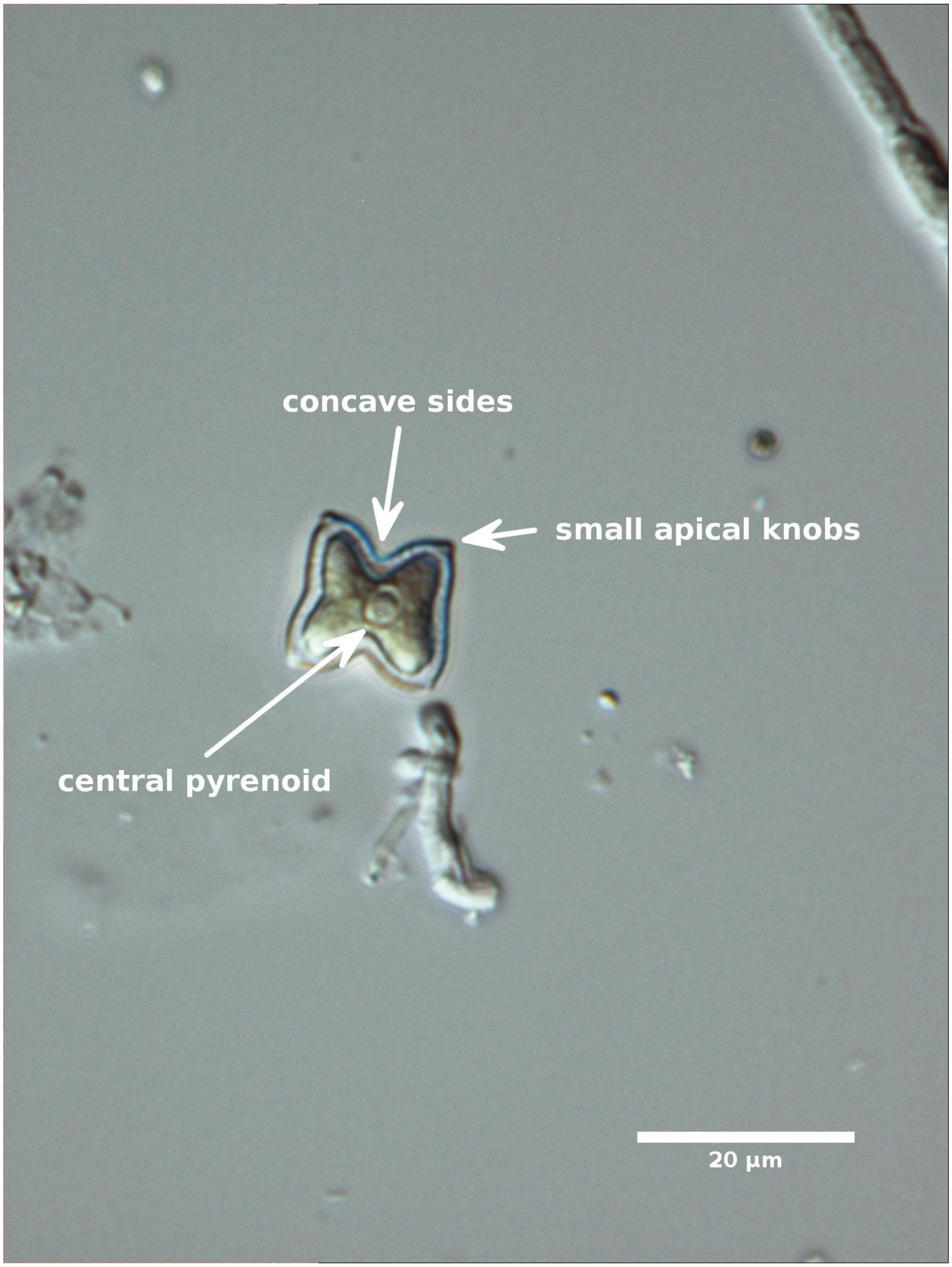

Figure 3.265: *Tetraedron minimum* in Lugol's iodine solution (600x DIC), Lake Campbell, IWS water quality sampling site, Skagit County, September 3, 2009.

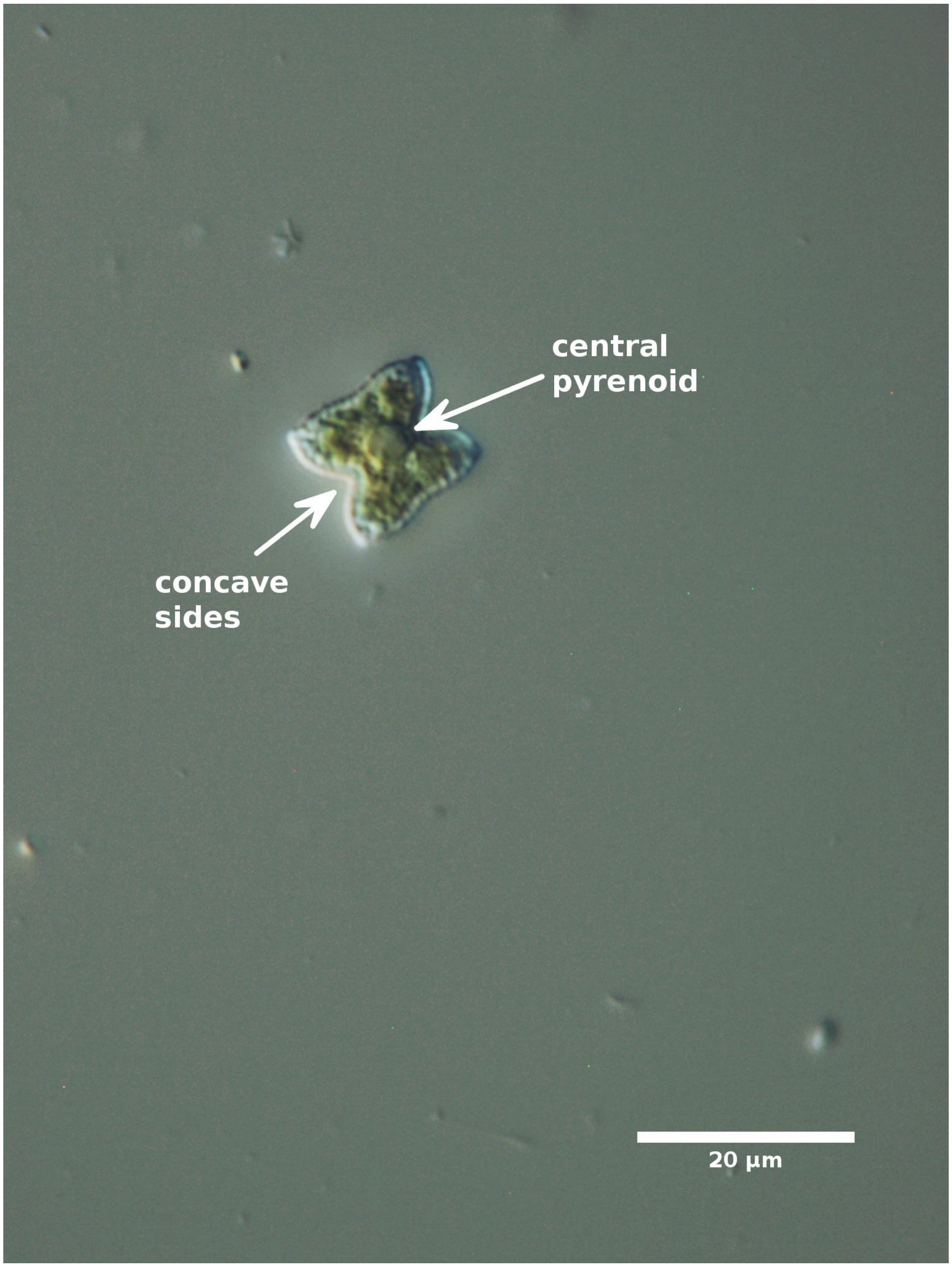

Figure 3.266: *Tetraedron minimum* (600x DIC), Heart Lake, IWS water quality sampling site, Skagit County, October 8, 2013.

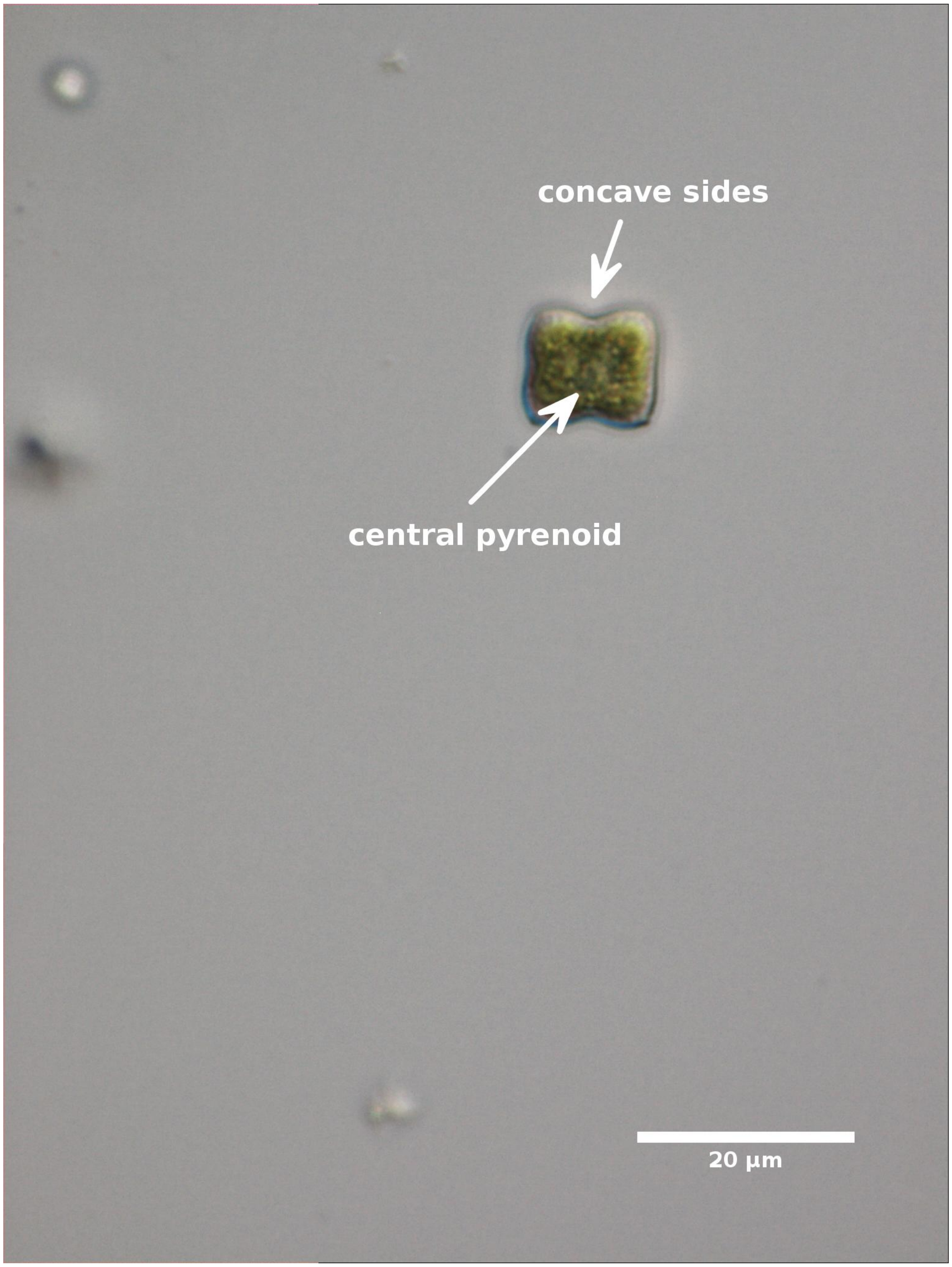

Figure 3.267: *Tetraedron minimum* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 12, 2008.

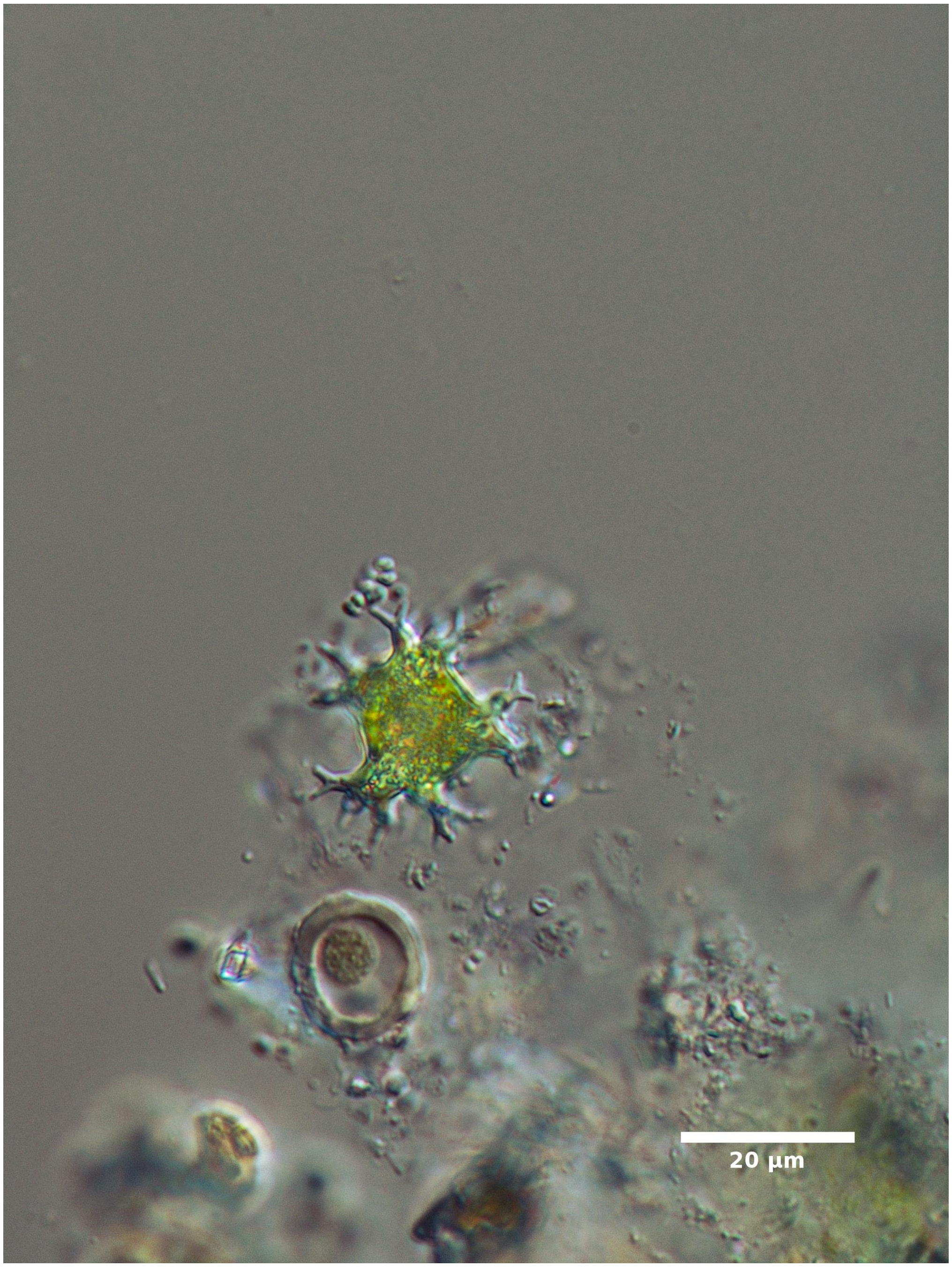

Figure 3.268: *Tetraedron* sp.1 (600x DIC), Bear Lake, IWS water quality sampling site, Snohomish County, July 25, 2014.

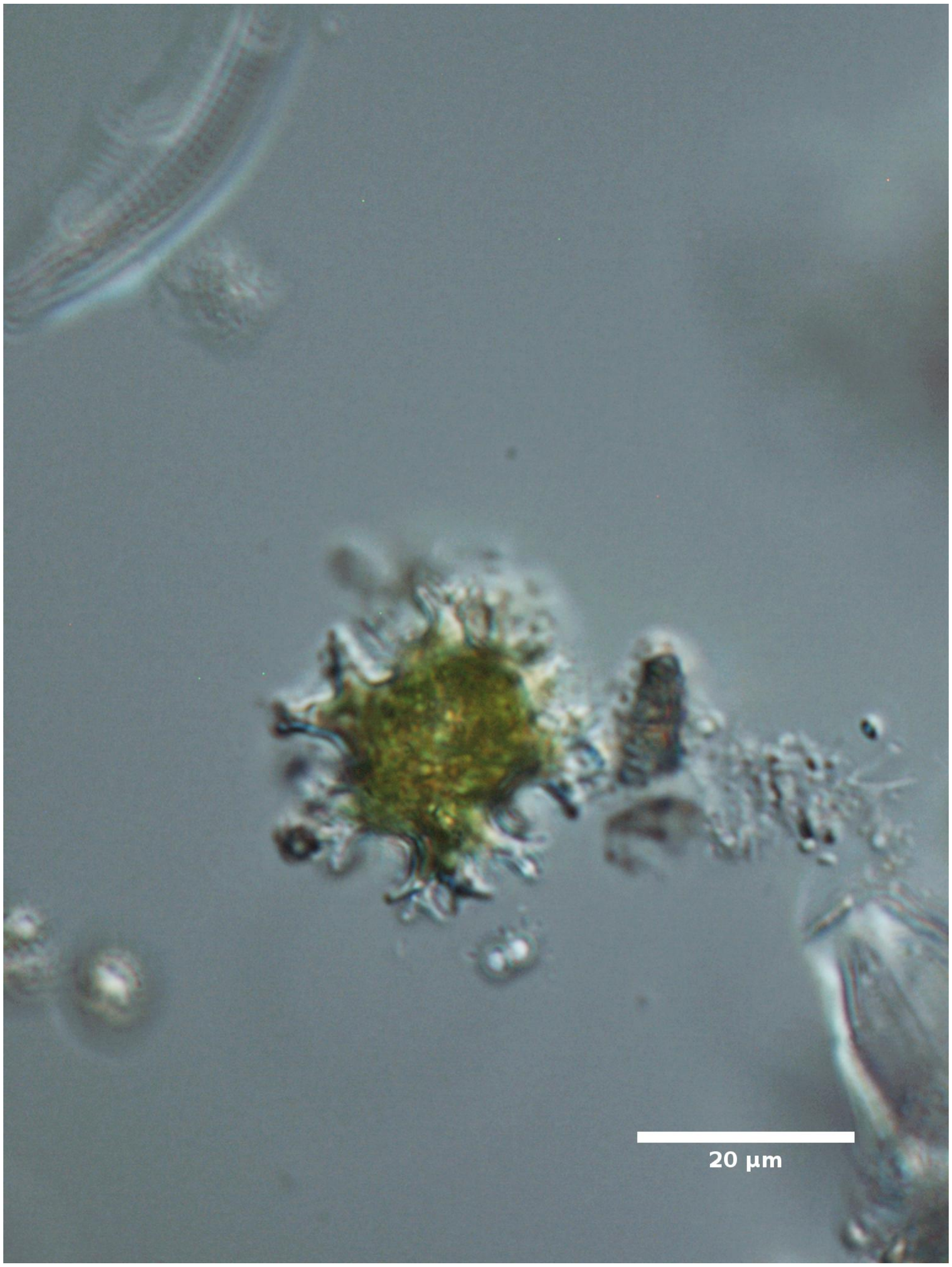

Figure 3.269: *Tetraedron* sp.1 (600x DIC), Lake Evan, IWS water quality sampling site, Snohomish County, August 24, 2012.

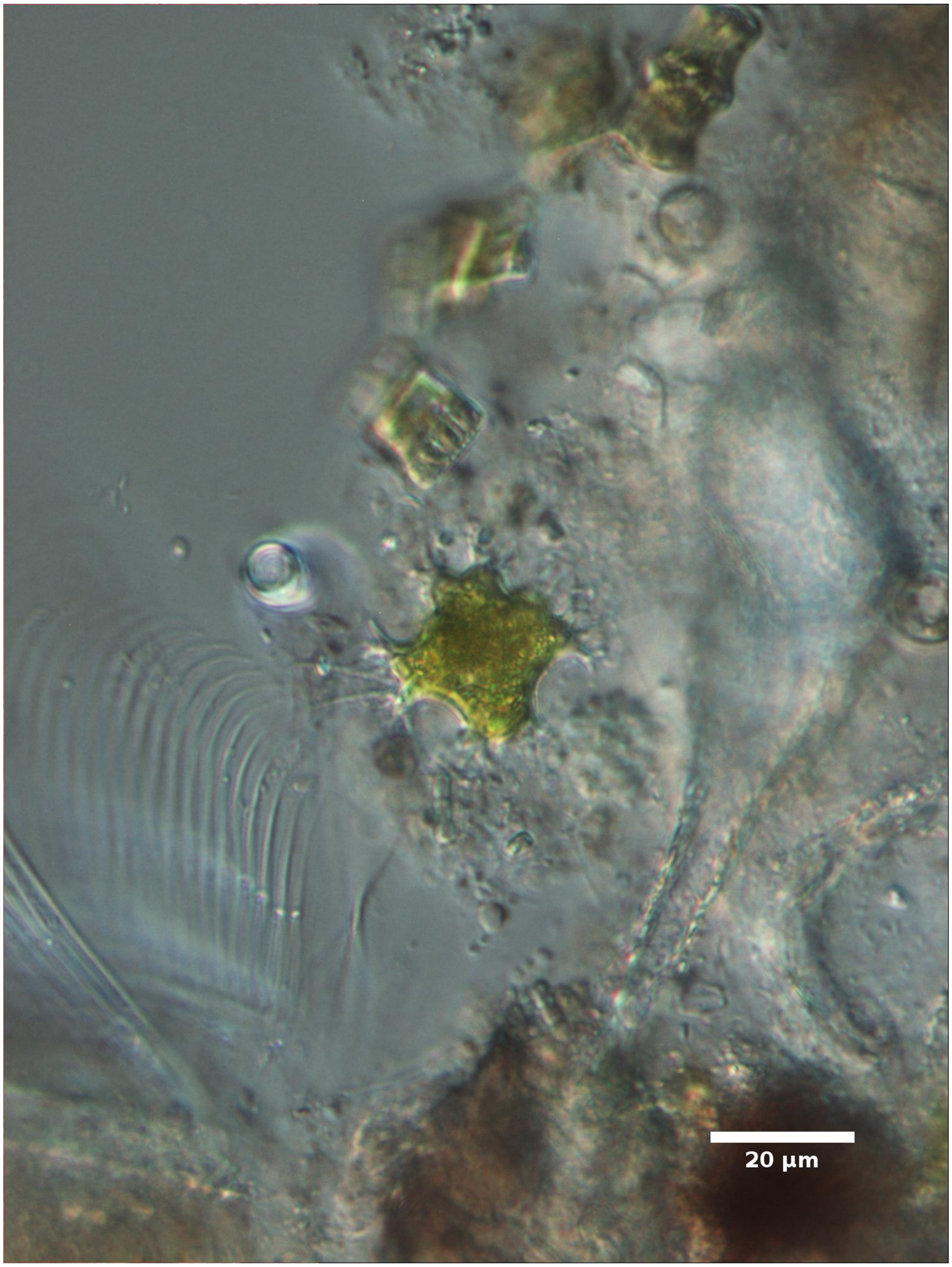

Figure 3.270: *Tetraedron* sp.1 (400x DIC), Highwood Lake, IWS water quality sampling site, Whatcom County, October 7, 2012.

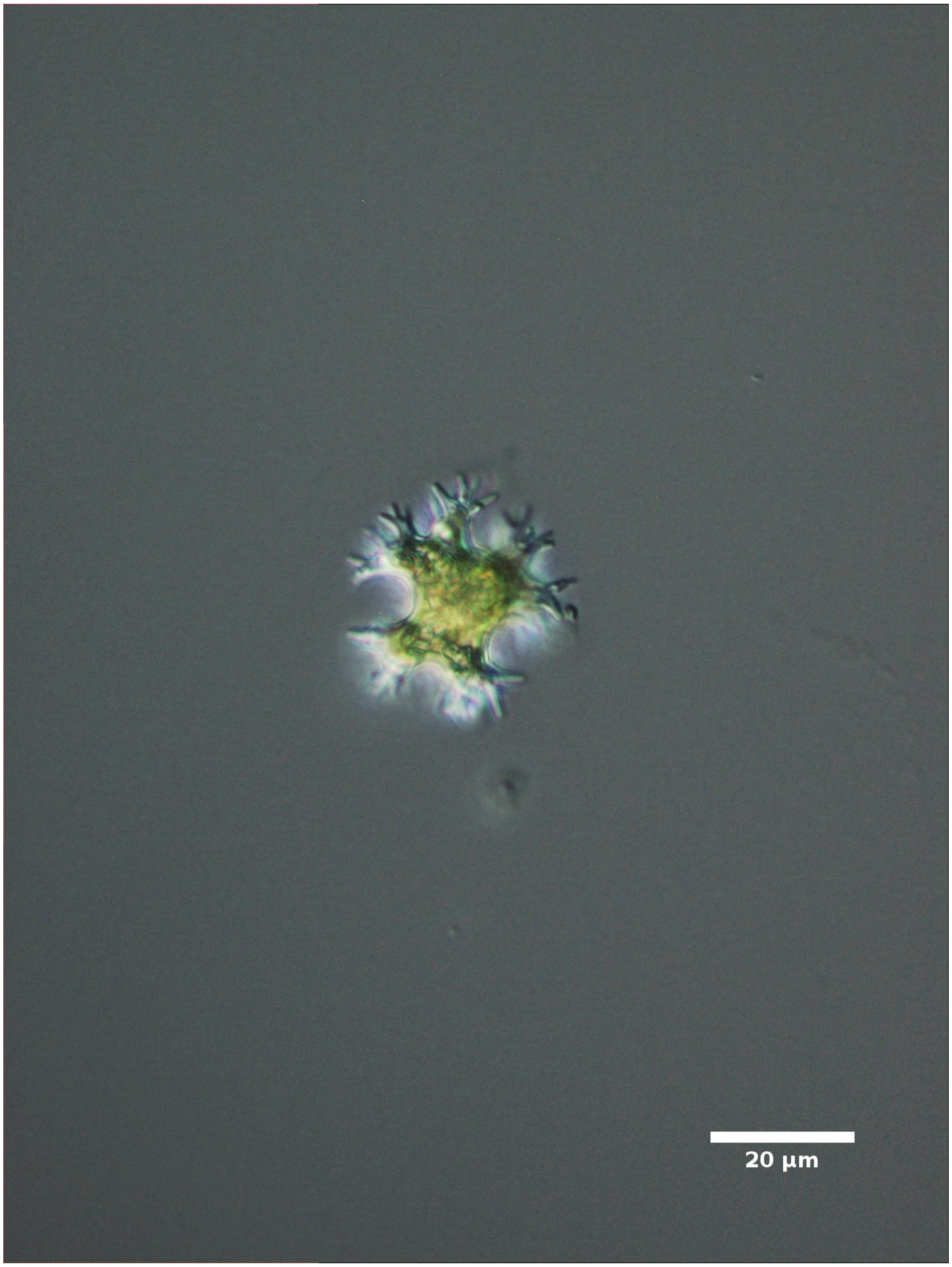

Figure 3.271: *Tetraedron* sp.1 (400x DIC), Highwood Lake, IWS water quality sampling site, Whatcom County, September 30, 2010.

3.37 *Tetraspora* Link ex Desvaux

Local taxa

Tetraspora gelatinosa (Vaucher) Desvaux;
Tetraspora lacustris Lemmermann
(=*Pseudosphaerocystis lacustris* [Lemmermann] Nováková);
Tetraspora lemmermannii Fott

Abundance

Moderately common in plankton samples and along shorelines; very common in shallow flowing water; may form planktonic blooms; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Tetraspora gelatinosa	min	7.5 μm	8.0 μm	236 μm^3
cells (spheroid)	med	9.1 μm	9.3 μm	399 μm^3
	max	10.9 μm	11.1 μm	691 μm^3
Tetraspora lacustris	min	7.2 μm	7.8 μm	212 μm^3
cells (spheroid)	med	9.2 μm	9.7 μm	434 μm^3
	max	11.0 μm	11.3 μm	716 μm^3
Tetraspora lemmermannii	min	5.6 μm	6.1 μm	100 μm^3
cells (spheroid)	med	7.4 μm	8.1 μm	224 μm^3
	max	9.0 μm	9.3 μm	394 μm^3

†Calculated using original measurements, not summary values.

Description

Tetraspora cells are spherical or slightly oval, and usually form 4-cell subgroups that are embedded in a homogeneous colonial mucilage (Figures 3.272–3.283). The cells have 2 long, thread-like pseudocilia that extend beyond the margin of the colonial mucilage. The cells have a cup-shaped chloroplast and lack eyespots.

Tetraspora belongs to the order **Tetrasporales**, which contains nonmotile cells that are related to the motile **Volvocales** (e.g., *Volvox*, Section 2.13, page 134). Although *Tetraspora* cells are nonmotile in the vegetative state, the cells have long pseudocilia that look like flagella. Other members of the **Tetrasporales** include *Apiocystis* (Section 3.5, page 240), *Asterococcus* (Section 3.6, page 245), *Paulschulzia* (Section 3.27, page 421), and *Schizochlamys* (Section 3.31, page 465).

Tetraspora gelatinosa is common in slow moving ditches and streams, less common in lakes, and rarely planktonic. The cells are enclosed in a homogeneous colonial mucilage (Figures 3.272–3.275). The colonies are often very large (macroscopic), forming slimy amorphous masses containing hundreds of cells. Within the colony the cells are usually arranged in distinct 4-cell subgroups.

The most common *planktonic* species, *Tetraspora lacustris*, forms small (microscopic) colonies of about 4–32 cells, with the cells arranged int distinct 4-cell subgroups. The colonies are surrounded by a thin, nearly invisible, colonial mucilage (Figures 3.276–3.280). The mucilage is distinctly layered or stratified, but there may be several 4-cell groups enclosed in an expanded mucilage envelope that was associated with the original mother cell (Figure 3.279). Cells resembling *Tetraspora lacustris* that have an eyespot may be a nonmotile form of *Chlamydomonas* (Section 2.3, page 35).

Tetraspora lemmermannii colonies resemble *Tetraspora gelatinosa*, but the colonies are smaller ($<500\ \mu$m), with fewer cells, and more likely to be planktonic (Figures 3.281–3.283). The individual cells form 4-cell subgroups inside the homogeneous colonial mucilage.

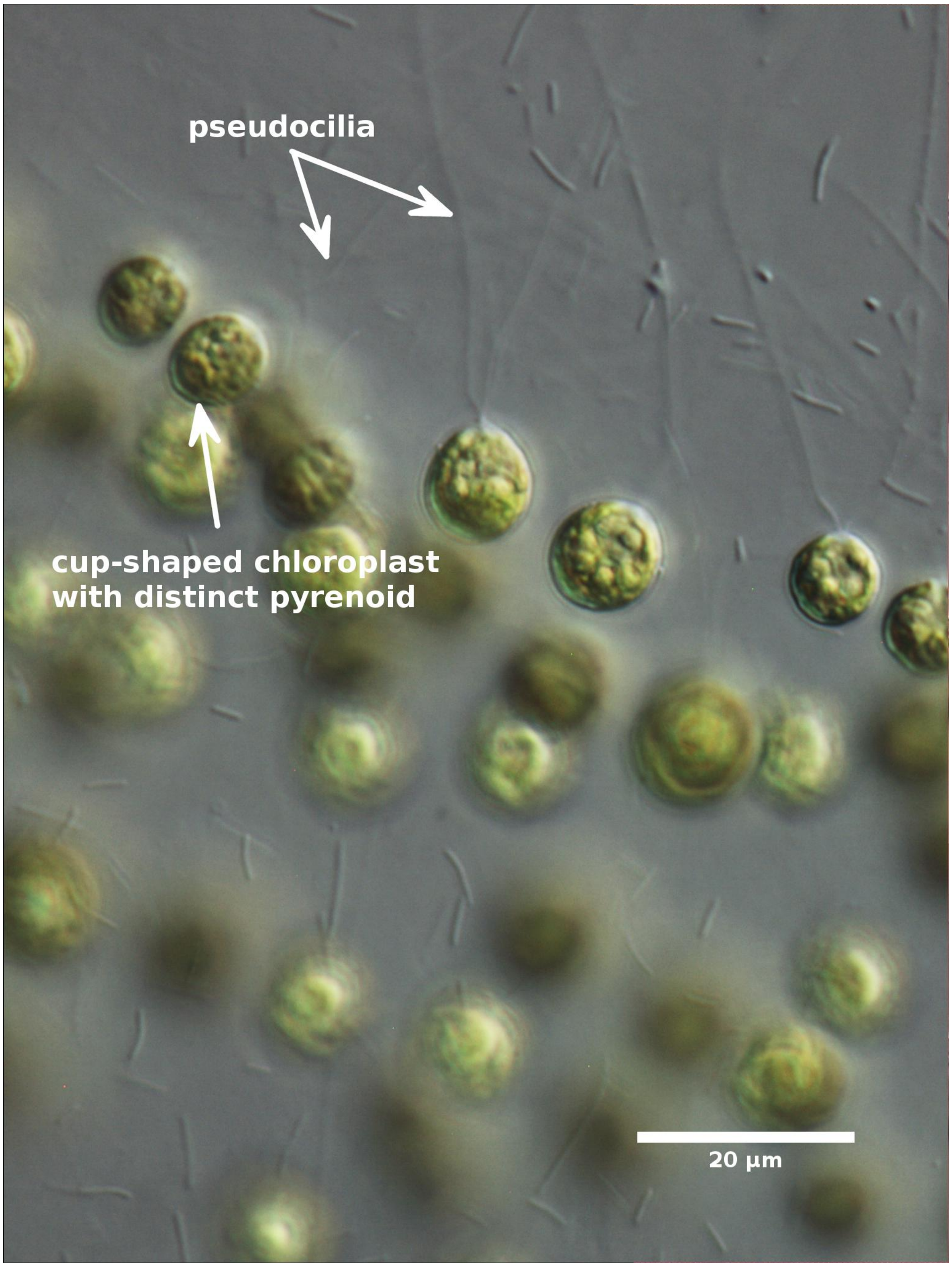

Figure 3.272: *Tetraspora gelatinosa* (600x DIC), Cedar Lake, IWS water quality sampling site, Whatcom County, April 9, 2012.

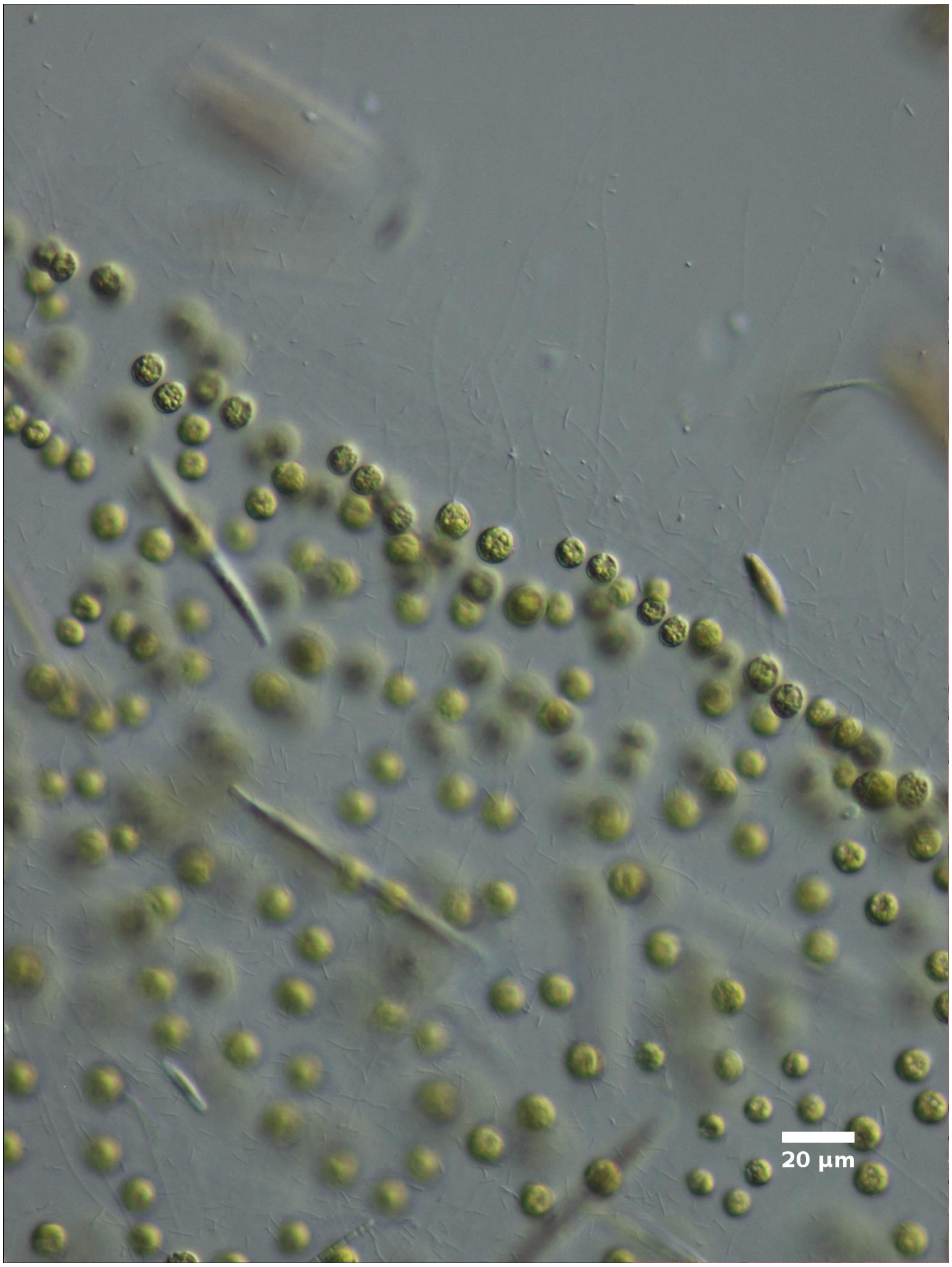

Figure 3.273: *Tetraspora gelatinosa* (200x DIC), Cedar Lake, IWS water quality sampling site, Whatcom County, April 9, 2012.

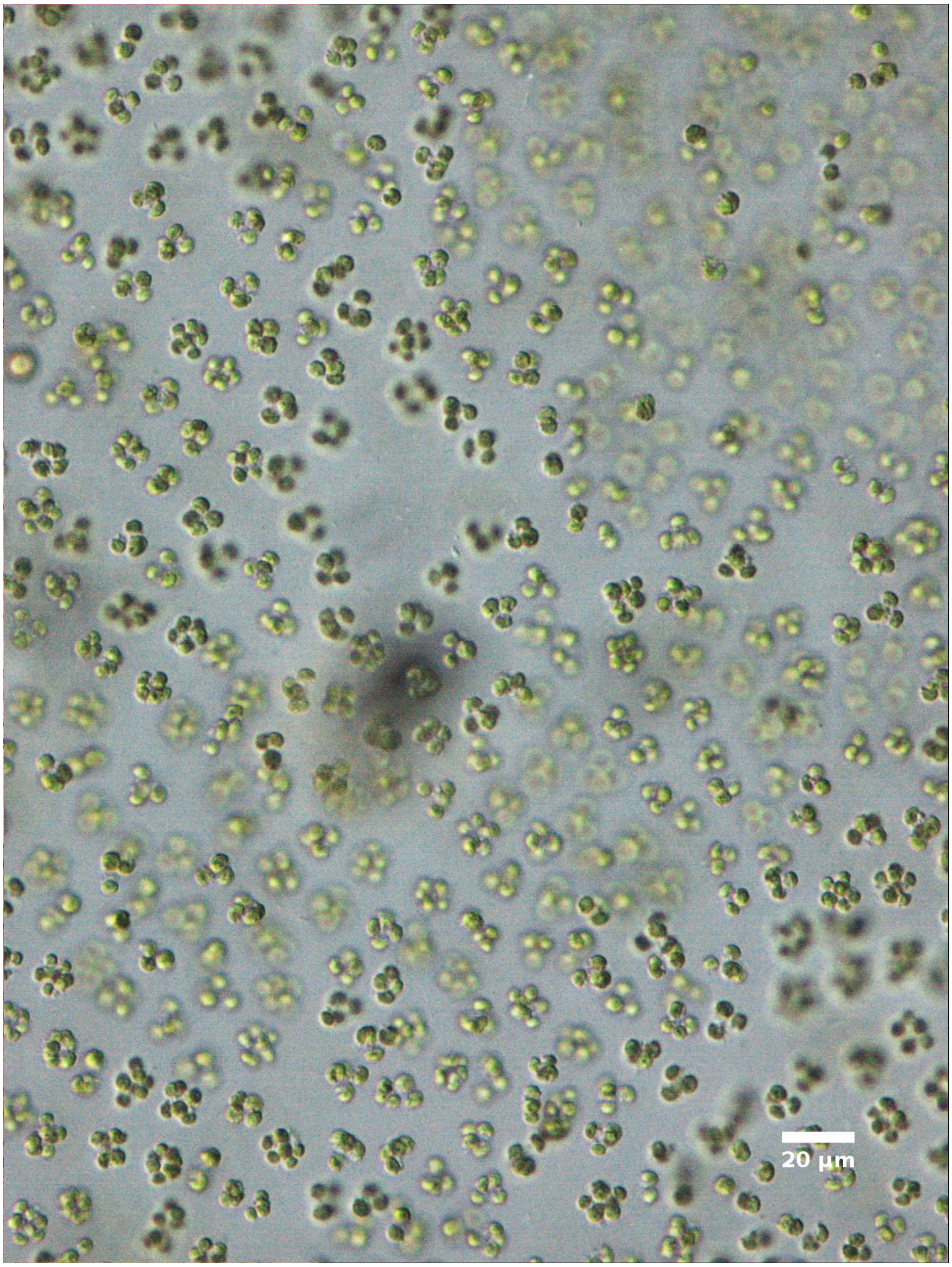

Figure 3.274: *Tetraspora gelatinosa* (200x DIC), Lake Geneva, IWS water quality sampling site, Whatcom County, April 5, 2011.

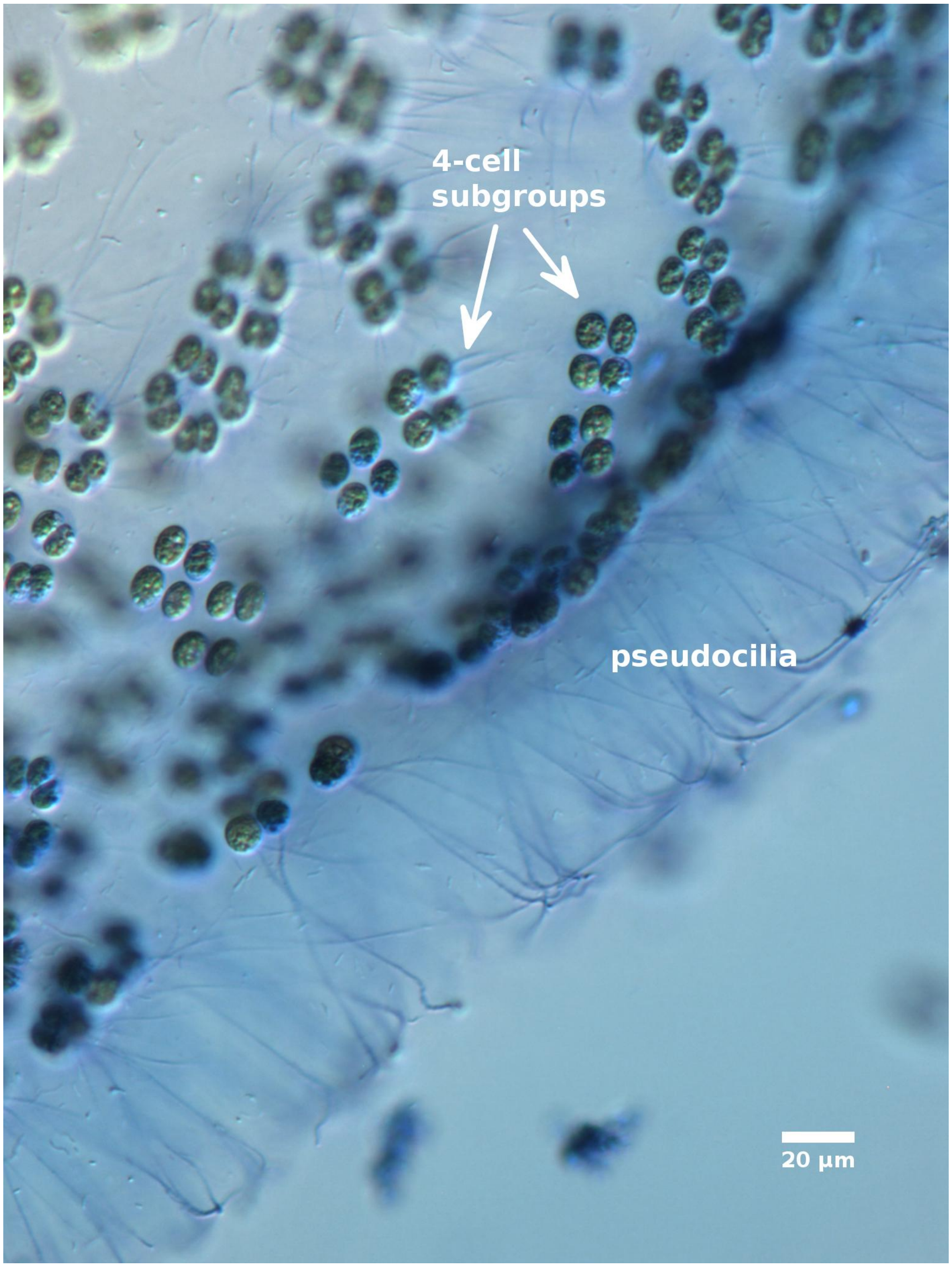

Figure 3.275: *Tetraspora gelatinosa* stained with methylene blue (200x DIC), Barclay Lake outlet stream, North Cascades along Hwy 2, July 22, 2013.

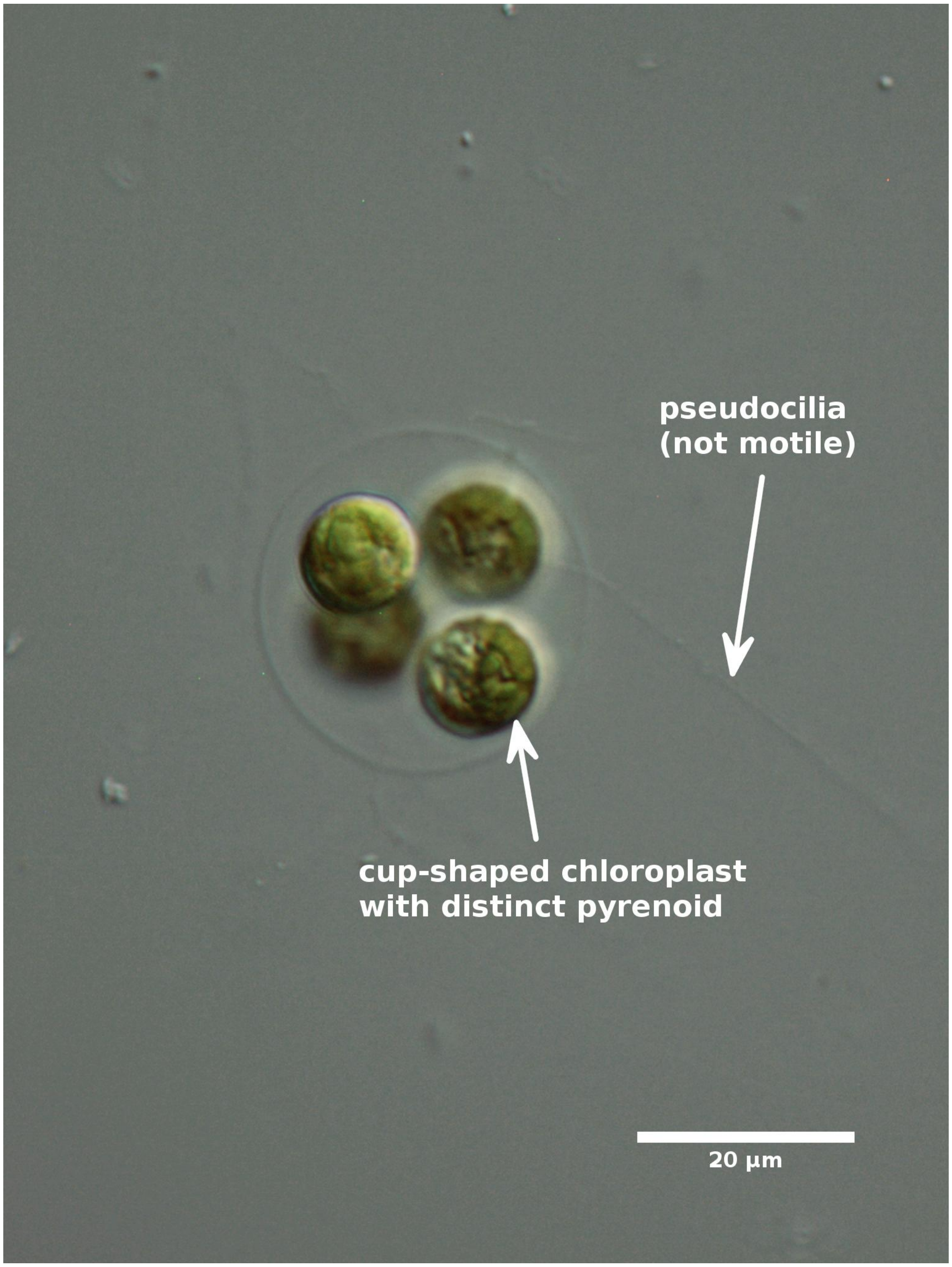

Figure 3.276: *Tetraspora lacustris* (600x DIC), Lake Padden, IWS water quality sampling site, Whatcom County, October 26, 2012.

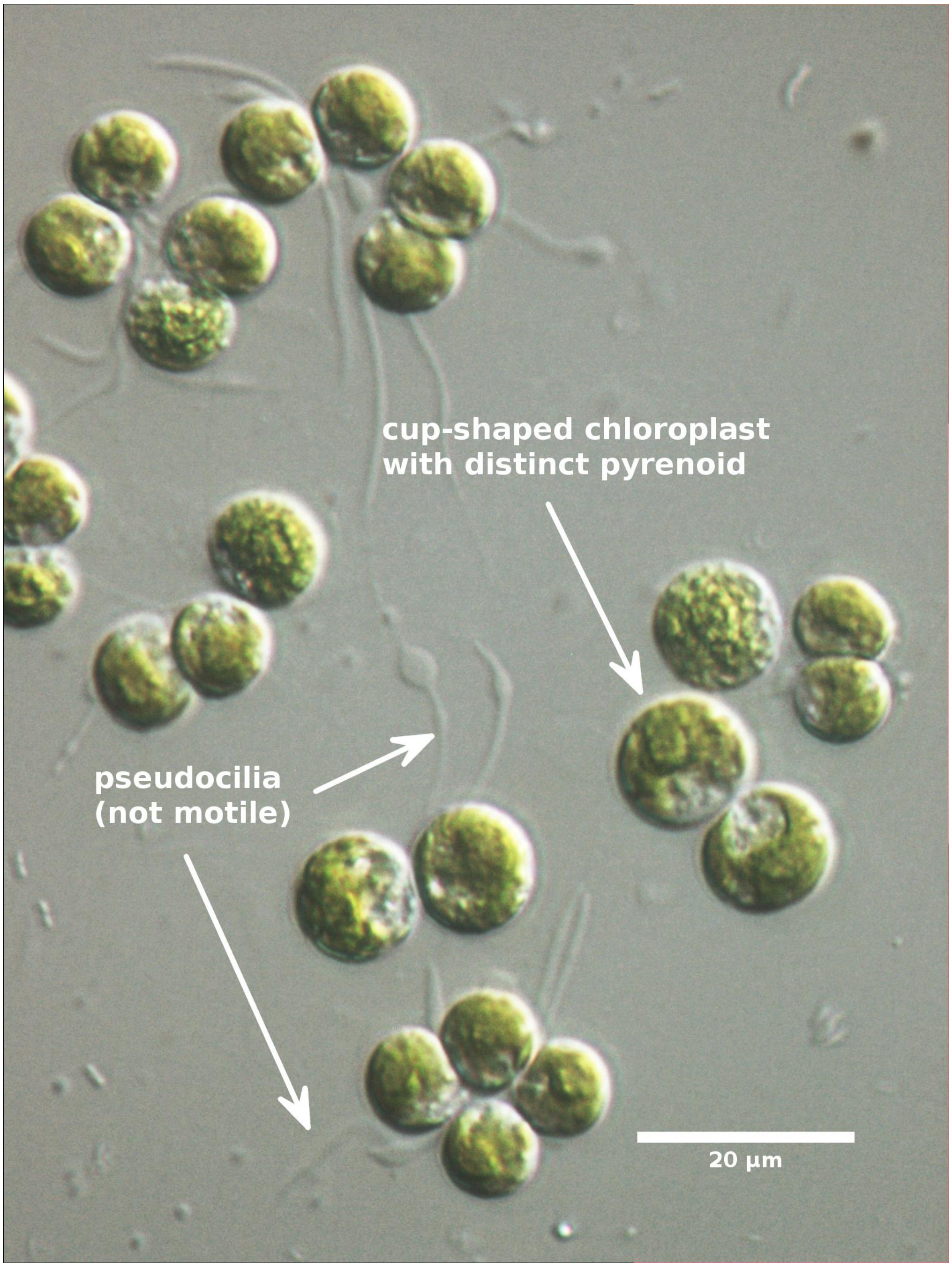

Figure 3.277: *Tetraspora lacustris* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 12, 2010.

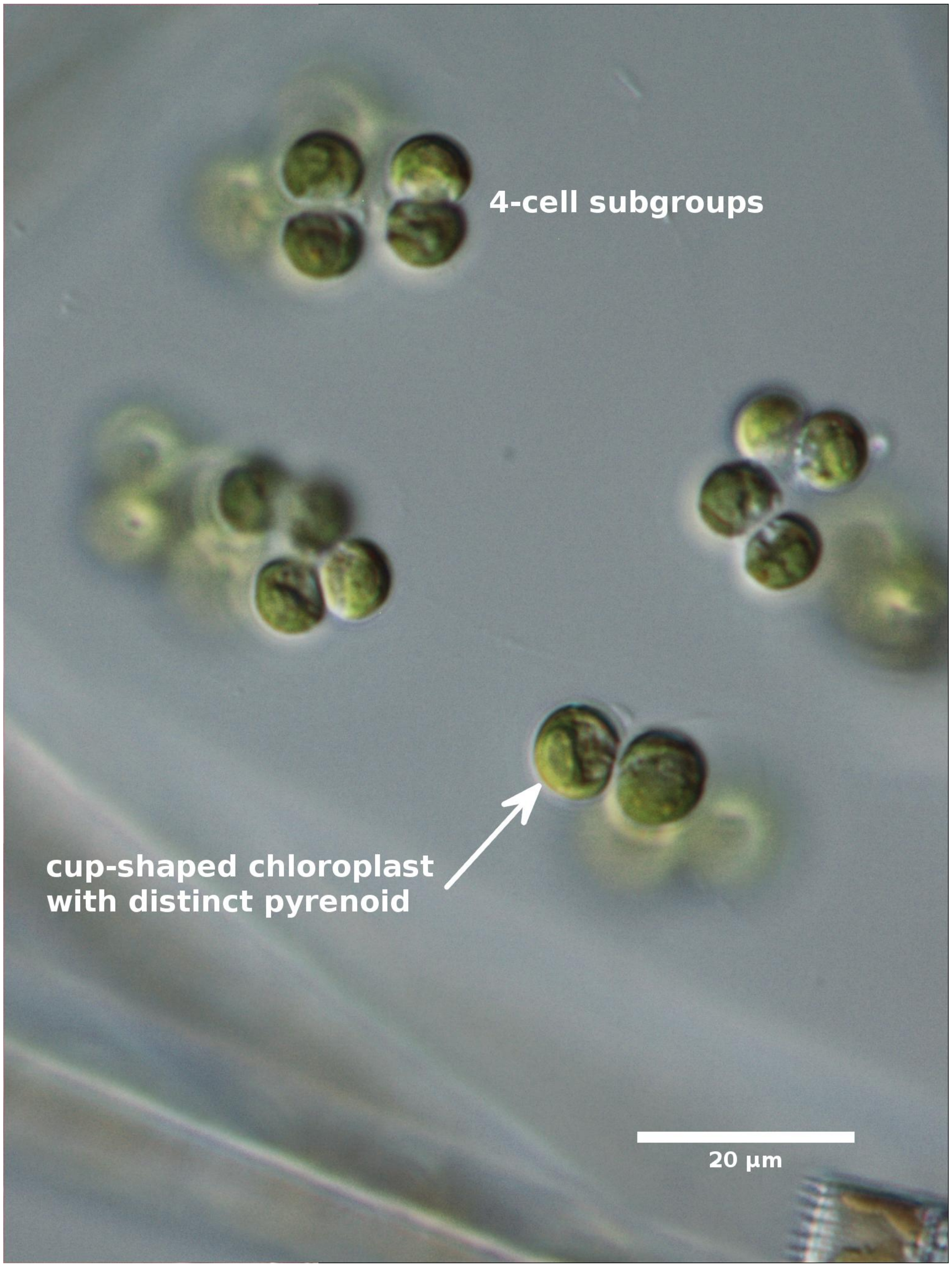

Figure 3.278: *Tetraspora lacustris* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, December 3, 2009.

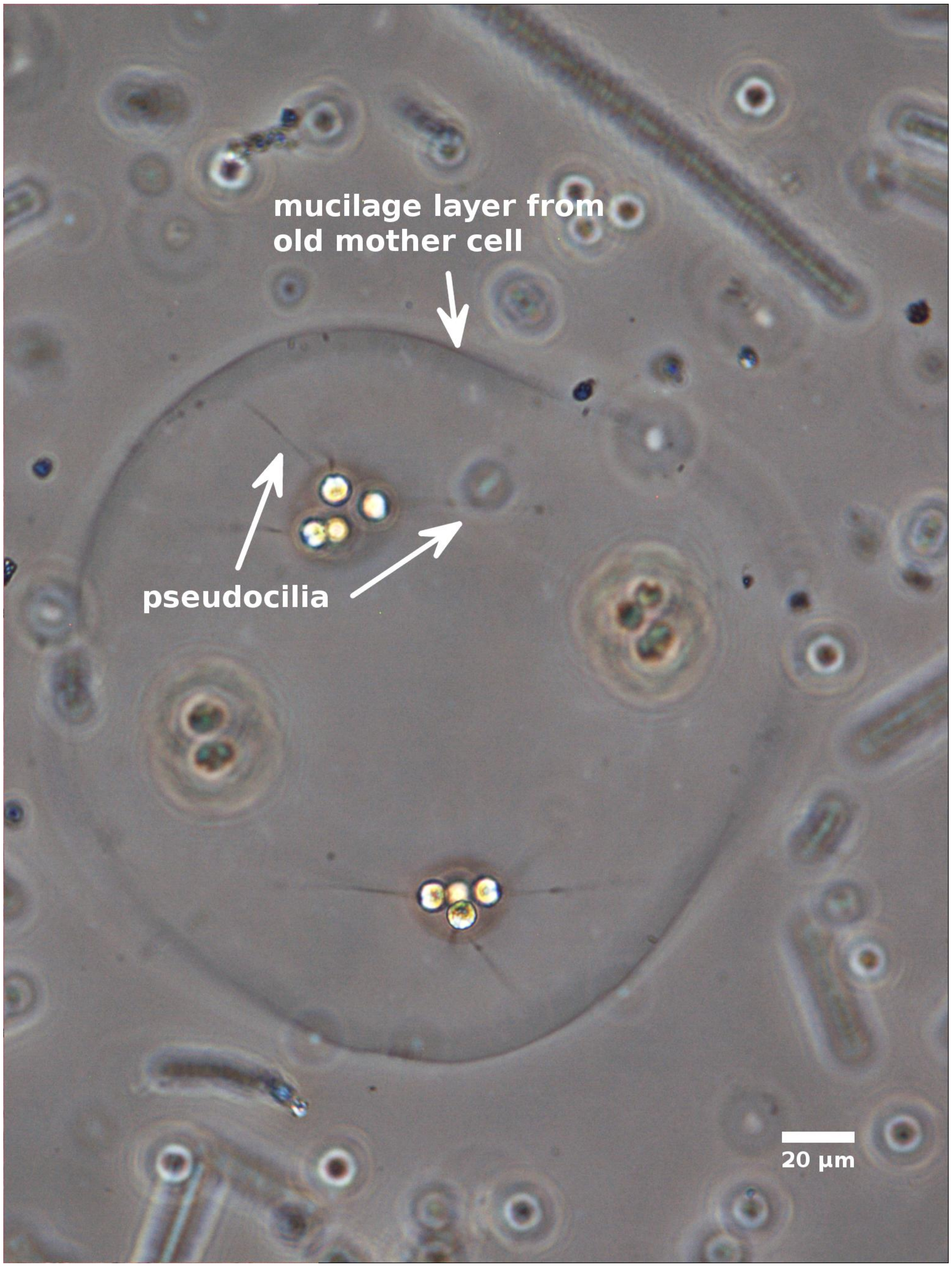

Figure 3.279: *Tetraspora lacustris* (200x phase contrast), Heart Lake, IWS water quality sampling site, Skagit County, August 25, 2009.

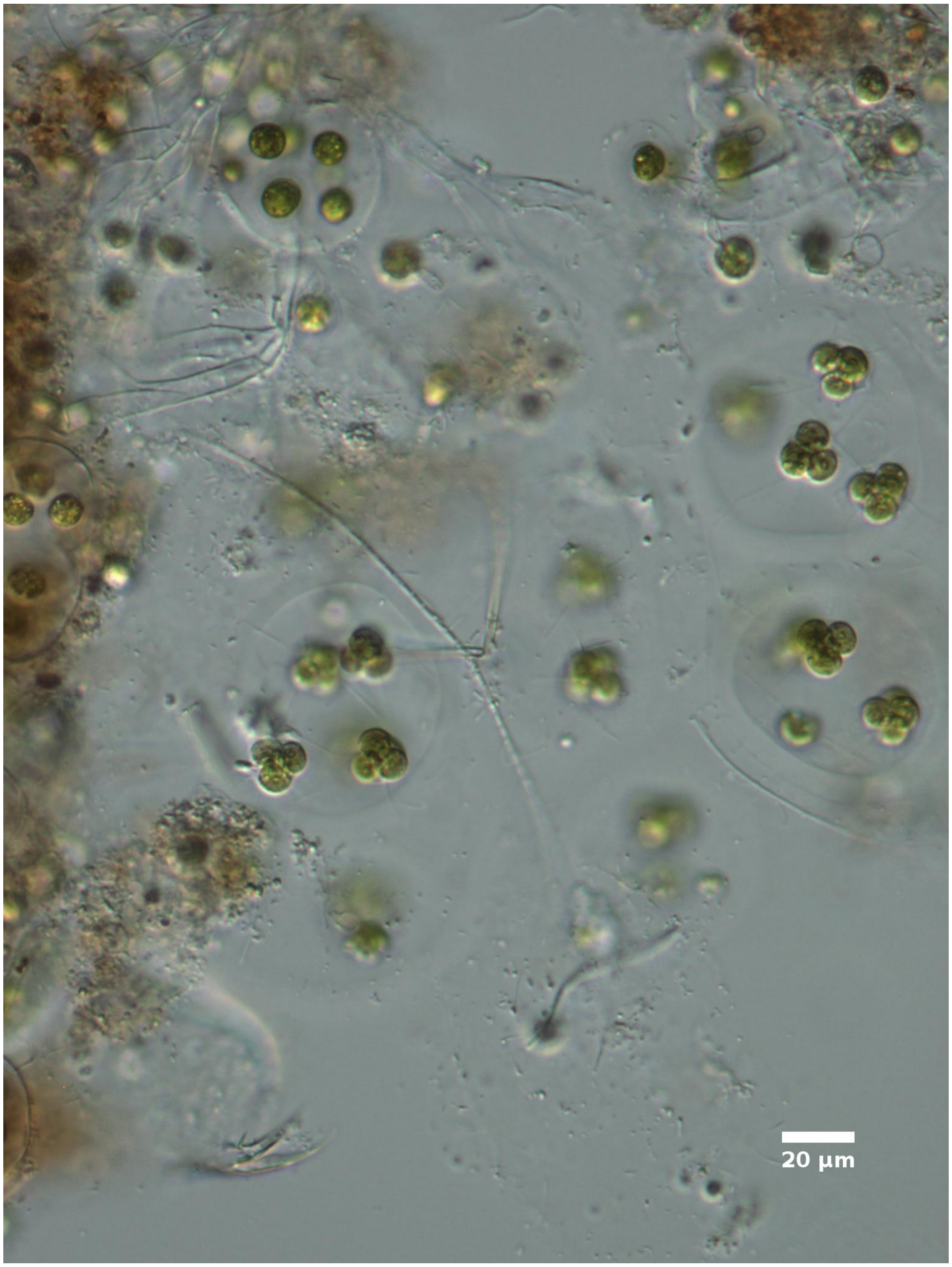

Figure 3.280: *Tetraspora lacustris* bloom (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, May 31, 2013.

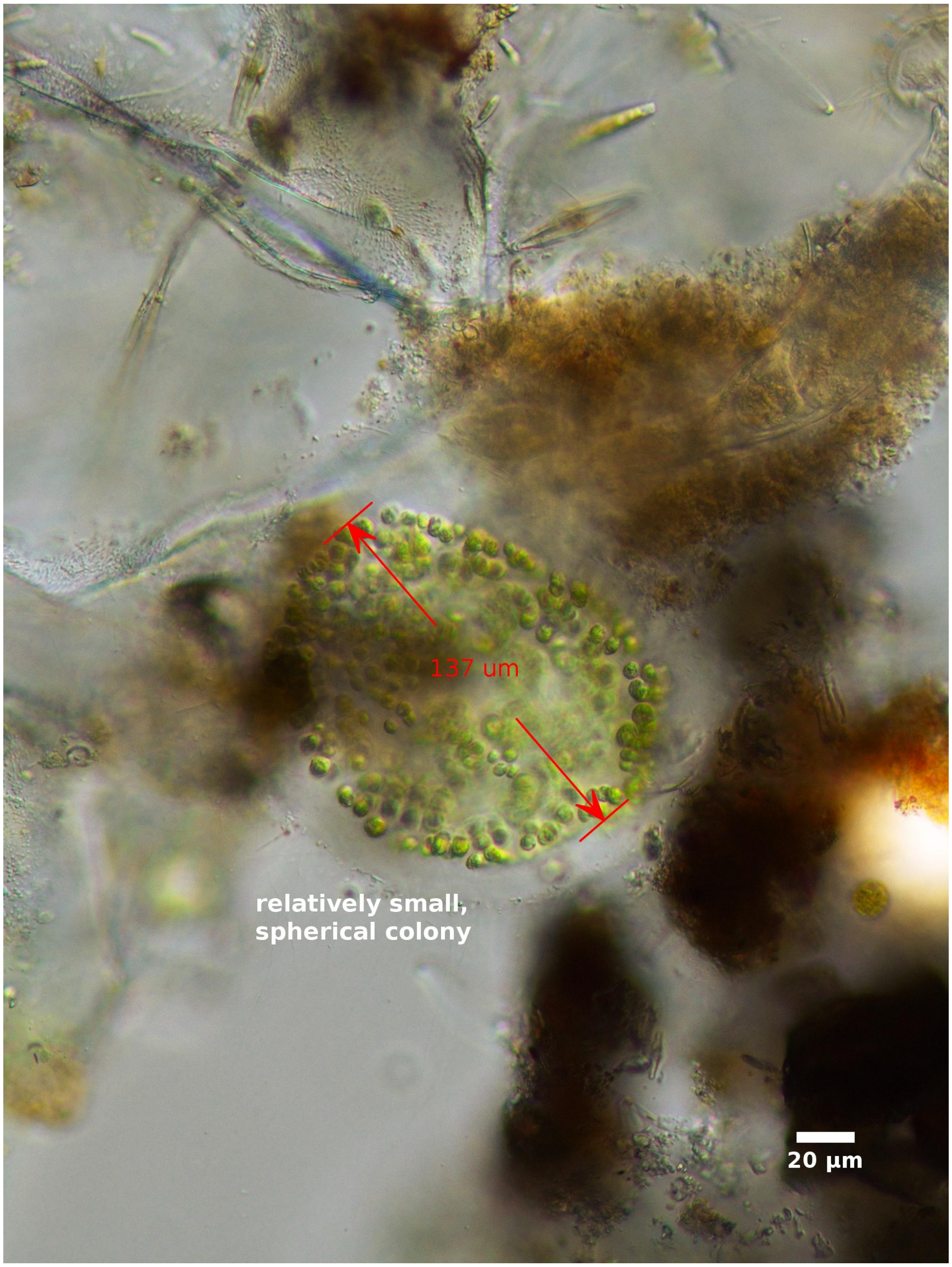

Figure 3.281: *Tetraspora lemmermannii* (200x DIC), Canyon Lake, IWS water quality sampling site, Whatcom County, August 16, 2014.

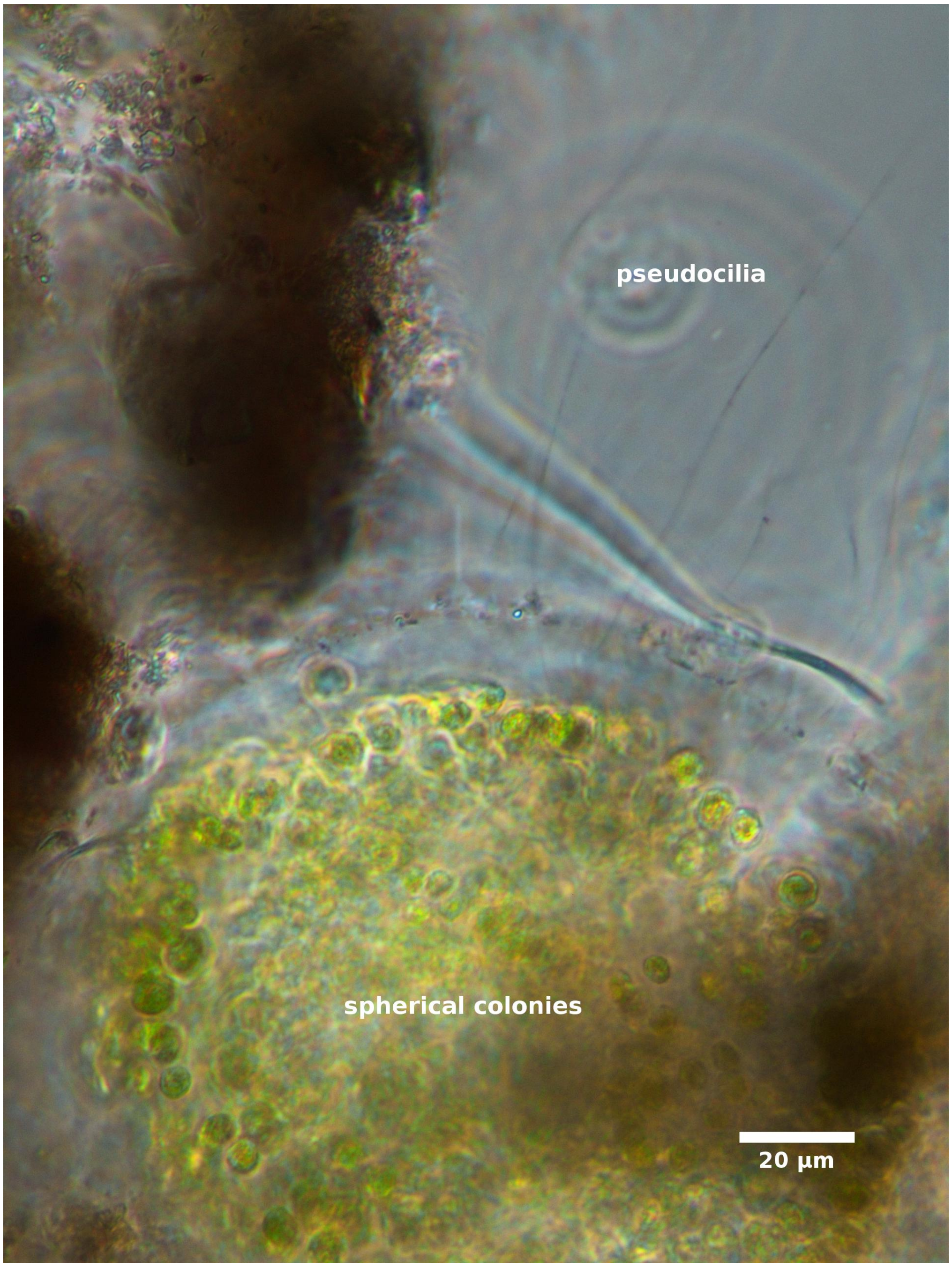

Figure 3.282: *Tetraspora lemmermannii* (400x phase contrast), Canyon Lake, IWS water quality sampling site, Whatcom County, August 16, 2014.

Figure 3.283: *Tetraspora lemmermannii* (600x DIC), Canyon Lake, IWS water quality sampling site, Whatcom County, August 16, 2014.

3.38 *Treubaria* C. Bernard

Local taxon
Treubaria setigera (Archer) G. M. Smith?

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Treubaria setigera?‡	min	–	–	–
cells (spheroid)	med	19.6 μm	19.9 μm	4,000 μm^3
	max	–	–	–

†Calculated using original measurements, not summary values.
‡Biovolume estimate based on <5 cells.

Description
Treubaria cells are solitary, with long spine-like projections extending out in three or more angles from the cell (Figure 3.284). The cell walls are otherwise smooth. Young cells have a single cup-shaped parietal chloroplast containing a single pyrenoid.

Treubaria setigera cells have three spine-like projections, so the sample from Sunday Lake was tentatively identified as this species. AlgaeBase shows images of a provisional species that was collected in northwest Washington (*Treubaria schmidlei* (Schröder) Fott & Kovácik) that resemble the Sunday Lake specimen.

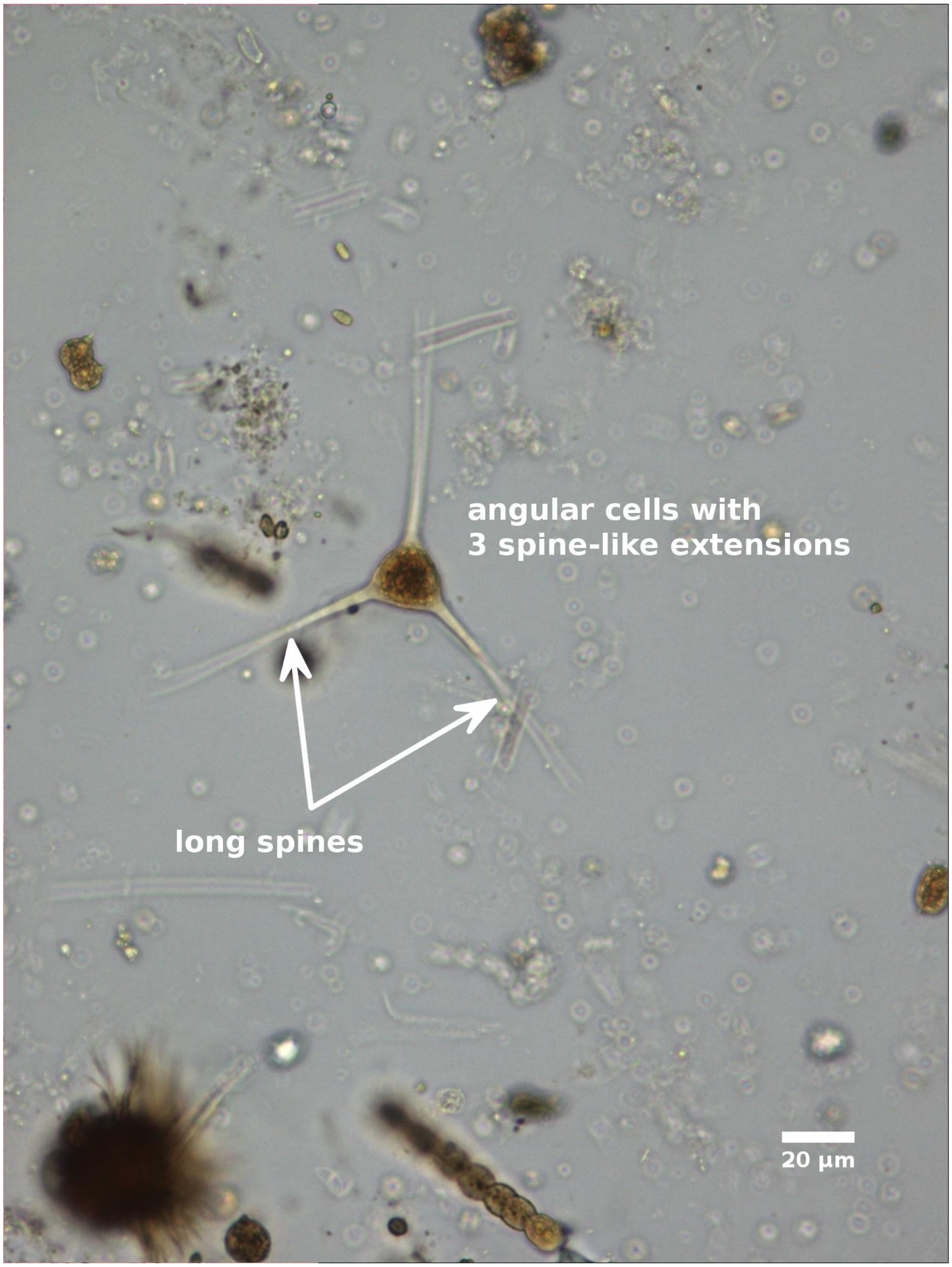

Figure 3.284: *Treubaria setigera*? in Lugol's iodine solution (200x brightfield), Sunday Lake, IWS water quality sampling site, Snohomish County, September 10, 2009.

3.39 *Westella* De Wildeman

Local taxon
Westella botryoides (West) De Wildeman

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Westella botryoides	min	6.0 μm	6.2 μm	123 μm^3
cells (spheroid)	med	6.4 μm	6.7 μm	148 μm^3
	max	7.8 μm	7.8 μm	248 μm^3

†Calculated using original measurements, not summary values.

Description
Westella botryoides cells are nearly spherical, with a cup-shaped chloroplast that contains one or more pyrenoids (Figures 3.285–3.287). The cells are arranged in groups of 4, forming small ($\leq$16 cells), irregular colonies. The cell groups are loosely connected in the center of the colony by fragments of old mother cell walls.

Westella botryoides resembles *Botryosphaerella* (Section 3.7, page 254), especially *Botryosphaerella sudetica* (Figures 3.84–3.86). *Botryosphaerella* colonies usually contain >16 cells, the cells are not arranged in 4-cell subgroups, and are joined by mucilage strands rather than old cell wall fragments.

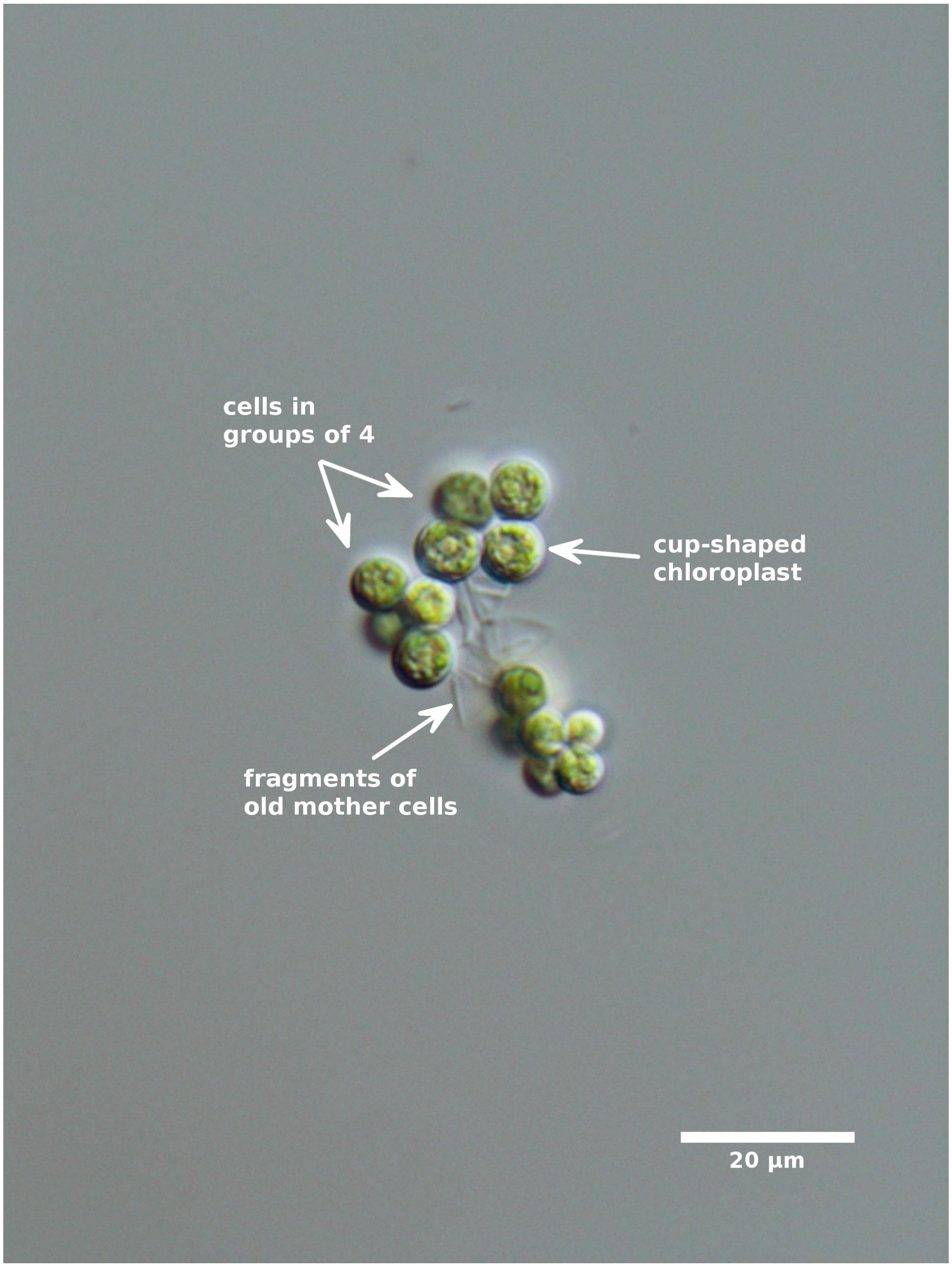

Figure 3.285: *Westella botryoides* (600x DIC), Grandy Lake, IWS water quality sampling site, Skagit County, July 7, 2015.

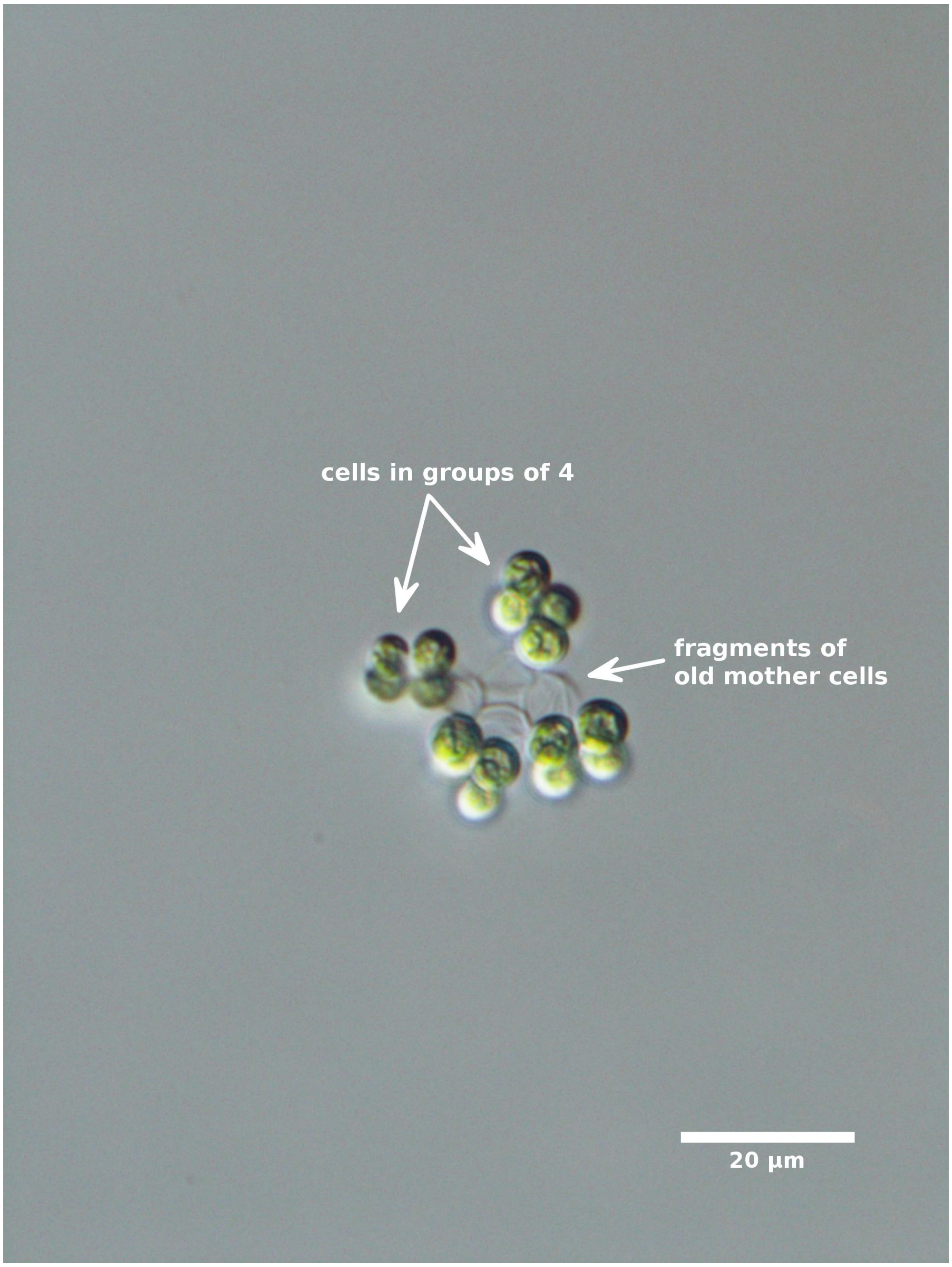

Figure 3.286: *Westella botryoides* (600x DIC), Grandy Lake, IWS water quality sampling site, Skagit County, July 7, 2015.

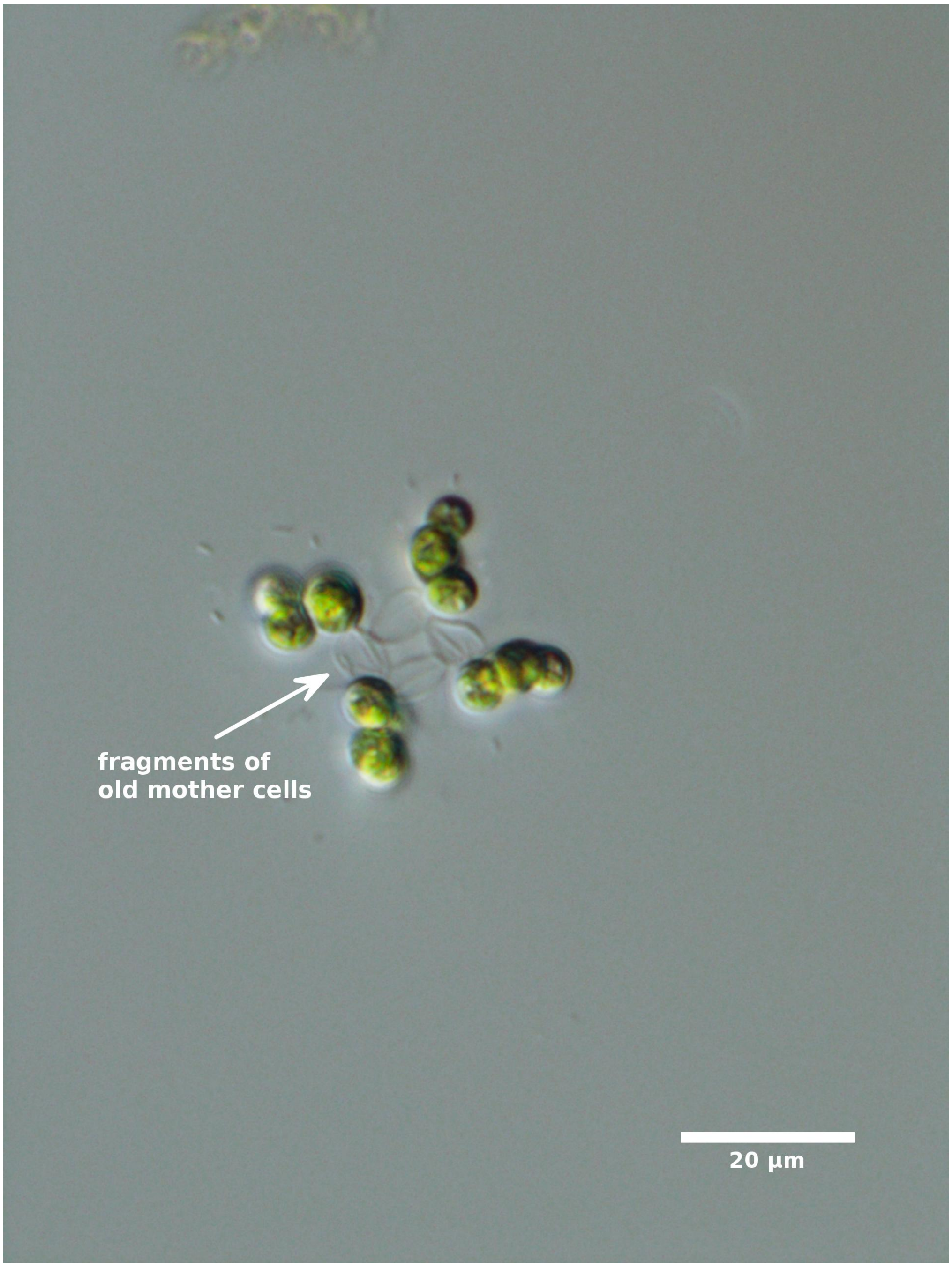

Figure 3.287: *Westella botryoides* (600x DIC), Grandy Lake, IWS water quality sampling site, Skagit County, July 7, 2015.

Chapter 4

Filamentous Chlorophyta

The key on page 532 will help you identify filamentous Chlorophyta, including taxa that form pseudofilaments (cells not actually joined end-to-end). For motile Chlorophyta, go to page 16; for solitary and colonial nonmotile Chlorophyta, go to page 161; and for filamentous Rhodophyta go to page 755.

Although there are many species of filamentous Chlorophyta, most are found attached to solid surfaces in flowing water rather than in the water column of lakes and ponds. When filamentous species are found in the water column, the samples are often from vegetated near-shore areas or have washed into the lake from tributaries. Most of the specimens in this algae guide were collected in lakes and ponds, so the taxa in this chapter do not provide a complete representation of the diversity of algae in Northwest Washington streams.

Filamentous Chlorophyta are quite diverse and there are not many generalizations that apply other than the filamentous structure. Many of the taxa have unique features that allow you to identify the genus, but most are difficult to identify to species unless reproductive structures are present.

Many of the filamentous Chlorophyta produce motile vegetative cells (zoospores) and motile reproductive cells (gametes) that resemble single-cell motile green taxa such as *Chlamydomonas*. When motile cells are produced, the filamentous vegetative cells are usually still be present in the sample, providing helpful clues for distinguishing the taxa. For a good illustration of the variation between vegetative and reproductive cells, see the *Draparnaldia* images from Cedar Lake (Section 4.8, page 589).

This chapter does not include solitary or filamentous desmids, which are abundant and diverse in northwest Washington lakes and bogs (Figures 3.1 and 4.1, pages 160 and 531). The desmids have been placed in a separate algal division (Charophyta) that will be described in **Freshwater Algae in Northwest Washington, Volume III. Desmids**. Many older taxonomic guides include desmids in the division Chlorophyta because the cells are bright green and form starch, so they stain dark purple or brown in Lugol's iodine solution. This chapter **does** include *Mougeotia*, *Spirogyra*, and *Zygnema*, which are in the division Charophyta because the cells form conjugation bridges during sexual reproduction, similar to desmids. Except for this feature, *Mougeotia*, *Spirogyra*, and *Zygnema* are visibly similar to other filamentous Chlorophyta.

Figure 4.1: Examples of local filamentous desmids (see **Freshwater Algae in Northwest Washington, Volume III. Desmids**).

Table 4.1: Key to the Filamentous Chlorophyta

A Cells form net-like or indistinct filaments; filamentous structure may not be obvious	
A.1 Cells epiphytic	
A.1a Cells form flat, disk-like colonies	*Coleochaete* (page 583)
A.1b Cells spherical; often solitary; usually with hair-like setae	*Chaetosphaeridium* (page 570)
A.1c Cells ±cylindrical or irregular; rarely solitary; usually with hair-like setae	*Aphanochaete* (page 536)
A.2 Cells not epiphytic	
A.2a Cells cylindrical, in open, net-like colony	*Hydrodictyon* (page 624)
A.2b Cells elliptical or fusiform; solitary or small colonies in lens-shaped mucilage	*Elakatothrix* (page 327)
B Cells form distinct pseudofilaments; filamentous structure obvious; often surrounded by mucilage	Go to page 533
C Cells form distinct, unbranched filaments	Go to page 533
D Cells form distinct, branched filaments	Go to page 534

continued on next page

Table 4.1: Key to the Filamentous Chlorophyta, continued

B Cells form distinct pseudofilaments; filamentous structure obvious; often surrounded by mucilage	
B.1 Cells oval or elliptical, forming widely separated pairs; mucilage thick and striated	*Binuclearia* (page 550)
B.2 Cells long and cylindrical; filaments very short; chloroplast plate-like, mucilage indistinct	*Gloeotila* (page 619)
B.3 Cells spherical, bead-like, or compressed and lens-shaped; mucilage usually distinct	*Radiofilum* (page 680)
B.4 Cells adjacent or separated and paired; elliptical or rounded and cylindrical; mucilage variable, but not striated (⇒difficult group!)	*Geminella* (page 601)
C Cells form distinct, unbranched filaments	
C.1 Cells with wide or narrow ribbon-like chloroplasts containing distinct pyrenoids; with or without mucilage layer around filament	
C.1a Cells with 1 or more spiraling chloroplasts	*Spirogyra* (page 691)
C.1b Cells with 1 wide, flat chloroplast	*Mougeotia* (page 655)
C.2 Cells with paired, central, stellate chloroplasts	*Zygnema* (page 749)
C.3 Cells with chloroplasts forming a partial or complete central band; filaments lack mucilage layer (cell walls may be thick and stratified)	

continued on next page

Table 4.1: Key to the Filamentous Chlorophyta, continued

	C.3a Cells cylindrical; length $\geq$ width; chloroplast forms a wide incomplete band (saddle-shaped)	*Klebsormidium* (page 630)
	C.3b Cells cylindrical; length $\leq$ width; chloroplast usually forms narrow complete band (ring-shaped); cells often $\gg$15 μm wide	*Ulothrix* (page 737)
	C.4 Cells with net-like chloroplasts; filaments lack mucilage layer (cell walls may be thick and stratified)	
	C.4a Cells with H-segmented end walls (may be inconspicuous); cell wall often thick or stratified	*Microspora* (page 636)
	C.4b Cells without H-segments; some cells in filament will have folded end wall caps; expanded oogonia often present	*Oedogonium* (page 661)
D	Cells form distinct, branched filaments	
	D.1 Filaments bright orange from carotenoids; not planktonic; attached to damp trees, cliff walls, bridges	*Trentepohlia* (page 732)
	D.2 Filaments sparsely branched; very large cells (length >100 μm)	
	D.2a Filaments flexible; cells 100–500 μm long; filaments often encrusted with epiphytes	*Cladophora* (page 575)

continued on next page

Table 4.1: Key to the Filamentous Chlorophyta, continued

D.2b Filaments coarse; cells often >1000 μm long; filaments contain dark akinetes	*Pithophora* (page 676)
D.3 Filaments highly branched, may have setae or hair-like multi-cellular extensions	
D.3a Primary (axial) cells and secondary (branch) cells similar; cells with 1–2 long setae that are expanded at the base	*Bulbochaete* (page 553)
D.3b Primary (axial) cells form parallel strands of sparsely branched filaments; secondary (branch) cells short, tufted, sometimes forming multi-cellular extensions	*Chaetophora* (page 560)
D.3c Primary (axial) cells large, barrel-shaped, with band-like chloroplast; secondary (branch) cells thin, tapering, with long, multi-cellular extension	*Draparnaldia* (page 589)
D.4 Filaments highly branched; lacking setae or multi-cellular extensions	
D.4a Primary (axial) and secondary (branch) cells similar; filaments comprised of narrow cylindrical cells (<5 μm wide)	*Microthamnion* (page 650)
D.4b Primary (axial) cells large, cylindrical, occasionally forming rhizoids; secondary (branch) cells narrow, tapering to bluntly pointed apex	*Stigeoclonium* (page 722)

4.1 *Aphanochaete* A. Braun

Local taxa

Aphanochaete polychaete (Hansgirg) F. E. Fritsch;
Aphanochaete repens A. Braun;
Aphanochaete vermiculoides Wolle;
Aphanochaete sp.1

Abundance

Infrequently collected in plankton samples; moderately common epiphyte.

Local measurements		Width	Length	Biovolume†
Aphanochaete polychaete	min	7.1 μm	8.4 μm	224 μm^3
cells (spheroid)	med	8.8 μm	9.4 μm	409 μm^3
	max	10.4 μm	12.3 μm	487 μm^3
Aphanochaete repens	min	4.0 μm	6.7 μm	111 μm^3
cells (cylinder)	med	8.2 μm	11.6 μm	531 μm^3
	max	10.5 μm	27.4 μm	1,480 μm^3
Aphanochaete vermiculoides	min	4.8 μm	15.8 μm	416 μm^3
cells (cylinder)	med	6.2 μm	23.5 μm	678 μm^3
	max	7.9 μm	33.4 μm	1,250 μm^3
Aphanochaete sp.1	min	11.9 μm	14.7 μm	1,390 μm^3
cells (cylinder)	med	16.8 μm	20.7 μm	3,180 μm^3
	max	28.1 μm	37.2 μm	11,600 μm^3

†Calculated using original measurements, not summary values.

Description

Aphanochaete is an epiphyte that grows on filamentous algae or other aquatic plants. The individual cells range from nearly spherical to long and cylindrical, forming short, highly branched, irregular filaments (Figures 4.2–4.13). The filament may consist of a single pad-like cell attached to the host plant, making the filamentous structure difficult to see. Each cell has a parietal chloroplast with one or more pyrenoids; the cell may also have one or more long hair-like seta.

Aphanochaete polychaete (Figures 4.2–4.4) has short, spherical or cubical cells that are attached to their host along the entire cell length. Many cells have several hair-like setae, which distinguishes this species from *Aphanochaete repens*, which has cells with a single seta.

Aphanochaete repens (Figures 4.5–4.9) is characterized by cylindrical cells that are usually longer than wide and are attached to their host along the entire cell length. Most cells have one long, hair-like seta.

Aphanochaete vermiculoides (Figures 4.10–4.11) cells are comparatively long and narrow. The filaments are distinctively arched, maintaining only a few points of contact with the host plant, which distinguishes this species from other species of *Aphanochaete*. Dillard (1989b) describes the species as having short cells (4–7 $\times$ 5–8 μm); local specimens have cells that are much longer than their width.

Aphanochaete sp.1 has large, spherical, club-shaped, or cubical cells with one or more hair-like setae (Figures 4.12–4.13). The cells form irregular, creeping, epiphytic filaments enclosed in a diffuse mucilage. This species resembles *Aphanochaete polychaete*, but the cells are larger than the dimensions listed by John, et al. (2011), and *Aphanochaete polychaete* filaments are not enclosed in a distinct mucilage layer. *Aphanochaete* sp.1 also resembles *Aphanochaete pilosissima* Schmidle, which has spherical cells enclosed in a diffuse mucilage, but *Aphanochaete pilosissima* has much smaller cells ($\approx$4 μm wide; John, et al., 2011) and the basal sheath surrounding the setae should be fringed.

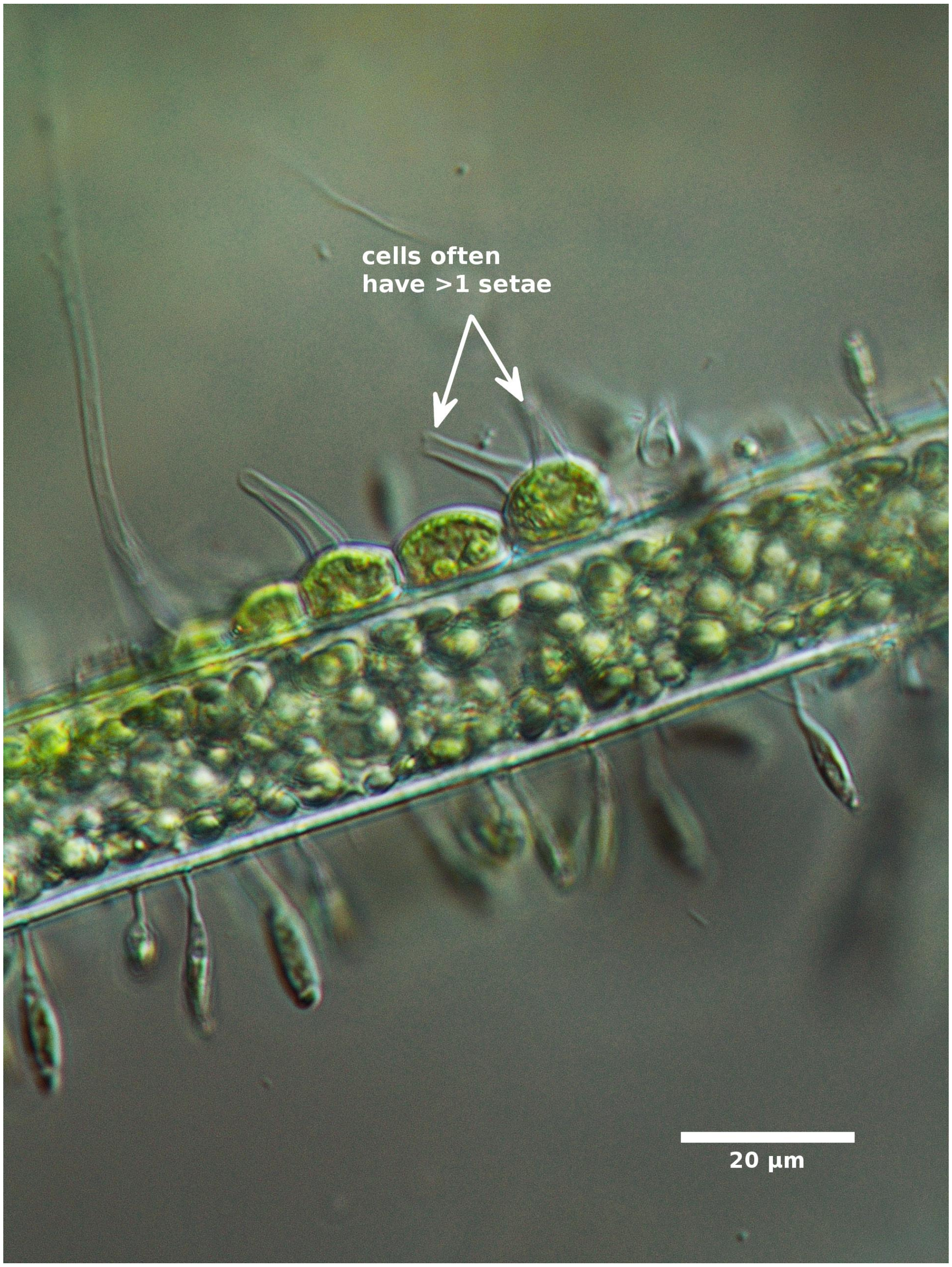

Figure 4.2: *Aphanochaete polychaete* (600x DIC), small pond near Fairhaven College, Whatcom County, June 4, 2014.

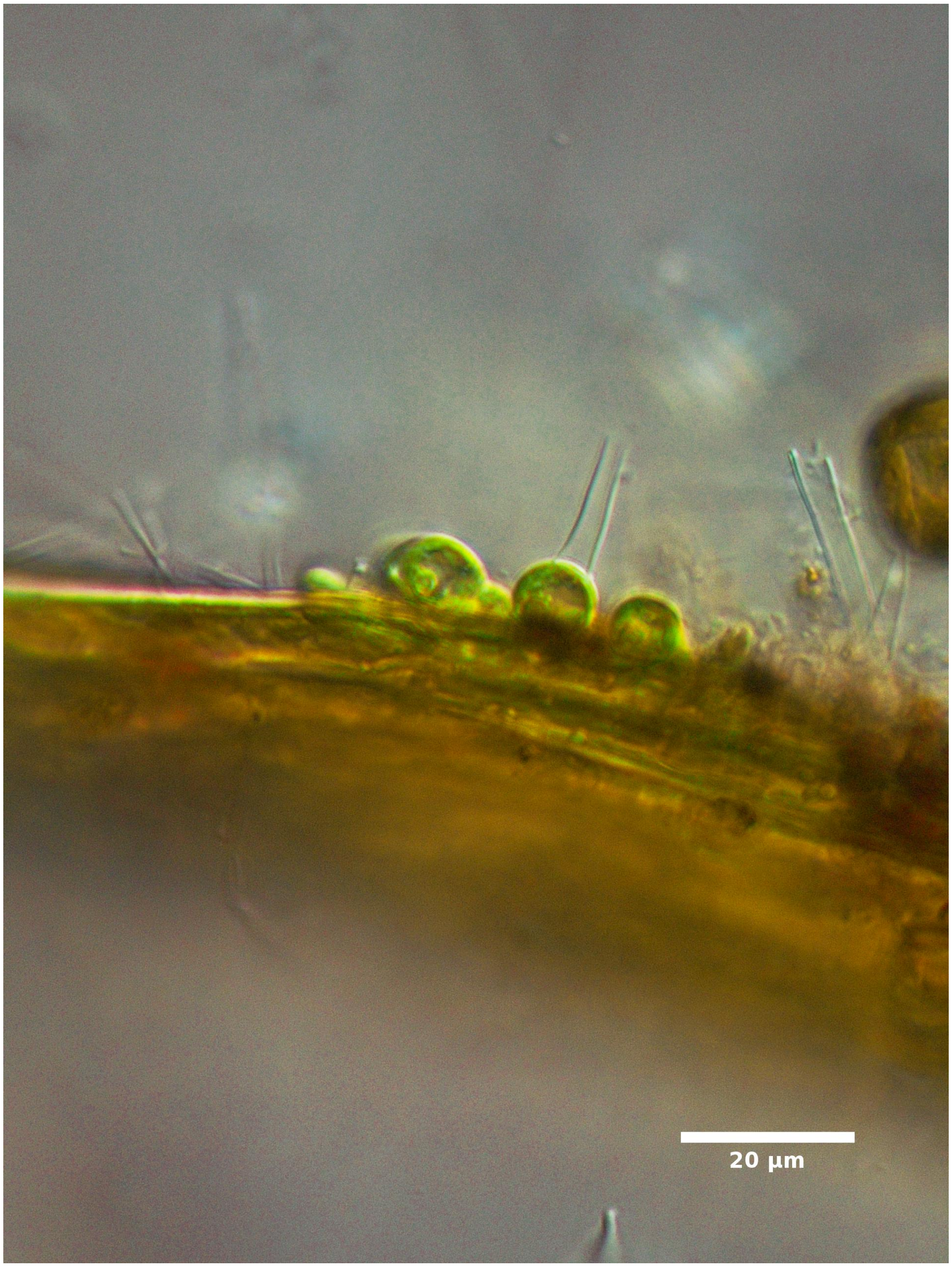

Figure 4.3: *Aphanochaete polychaete* (600x DIC), small pond near Fairhaven College, Whatcom County, April 14, 2014.

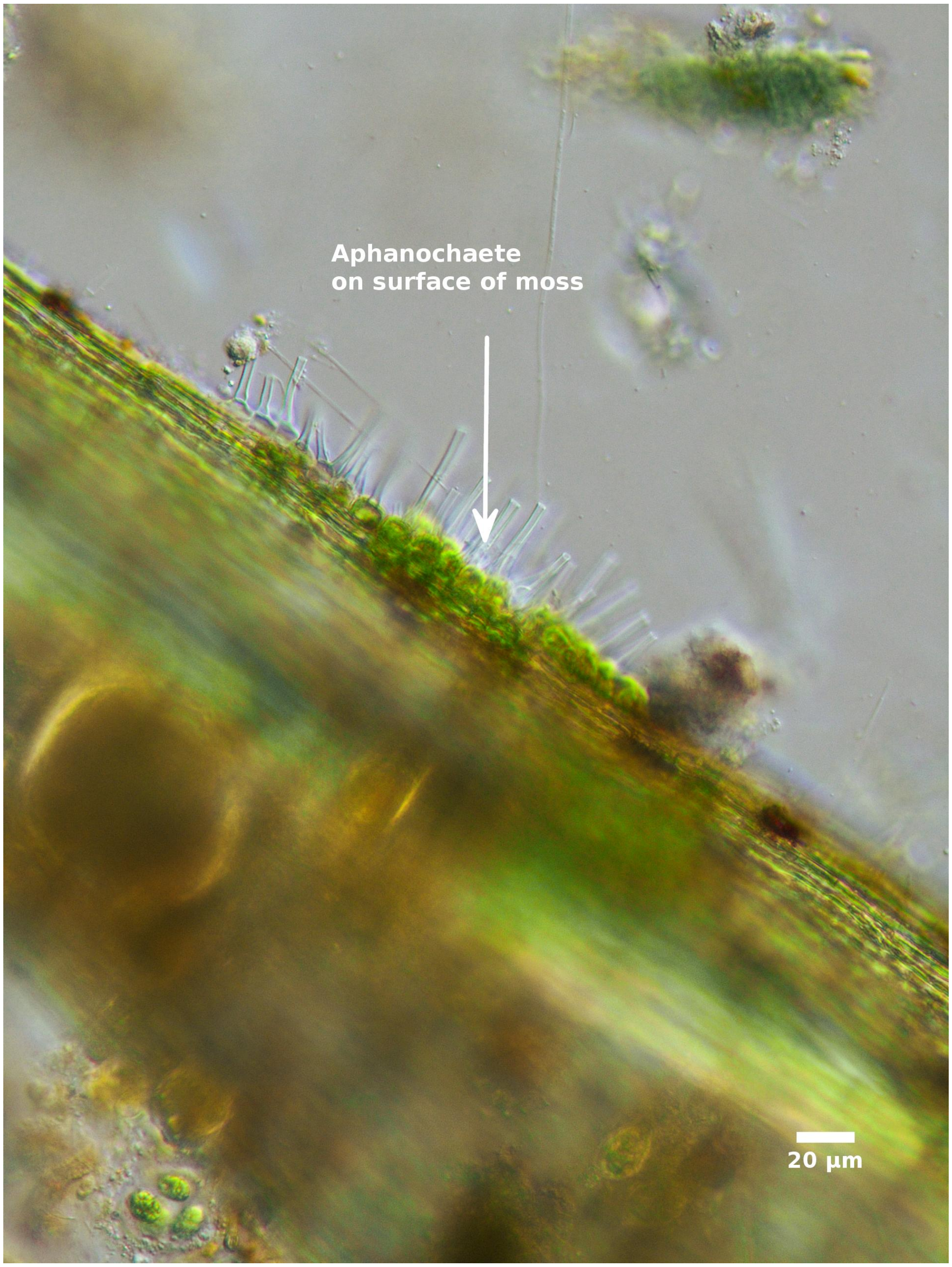

Figure 4.4: *Aphanochaete polychaete* (200x DIC), small pond near Fairhaven College, Whatcom County, April 14, 2014.

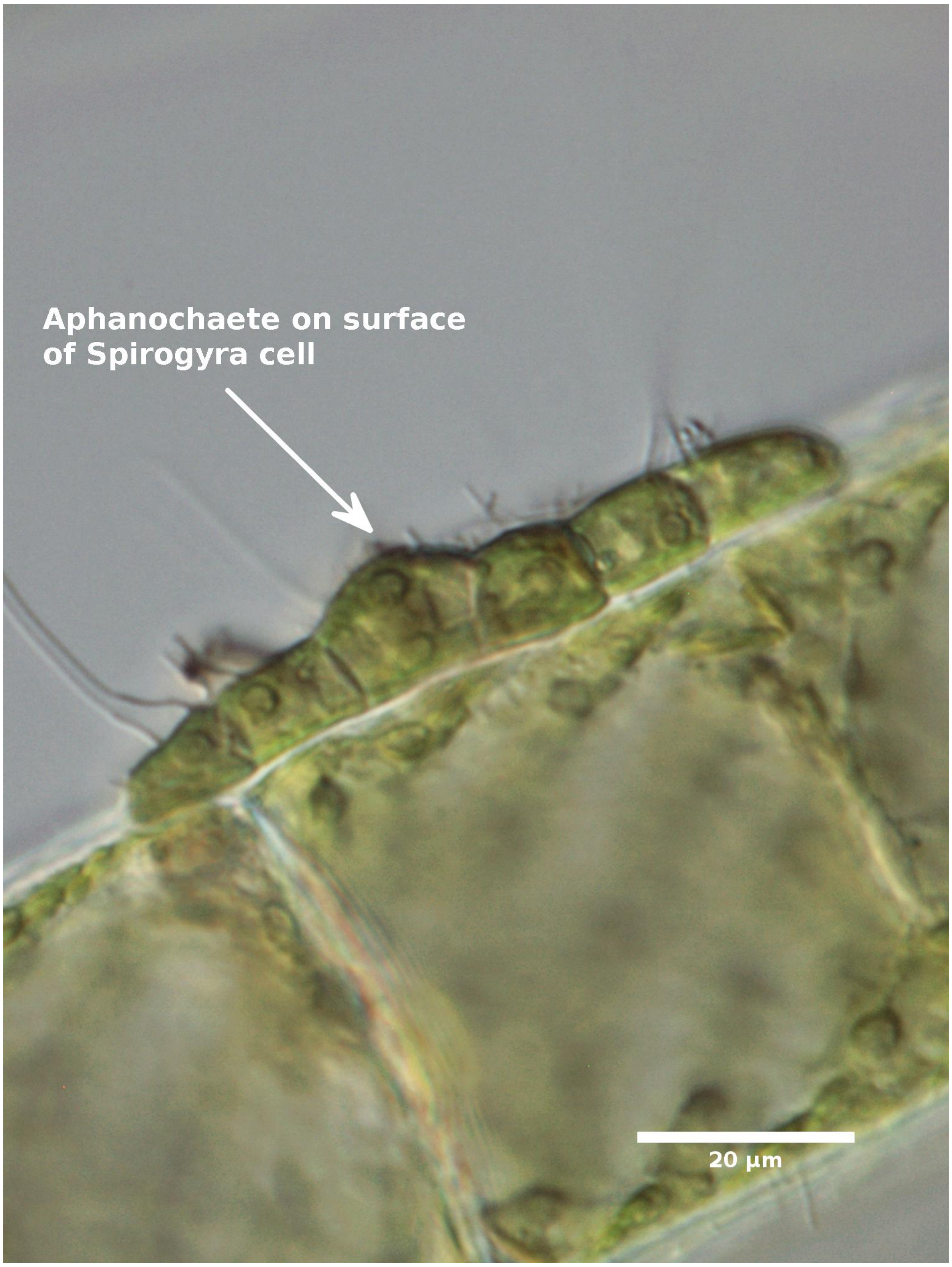

Figure 4.5: *Aphanochaete repens* (600x DIC), Upper Highlands Reservoir, Skagit County, May 2, 2013.

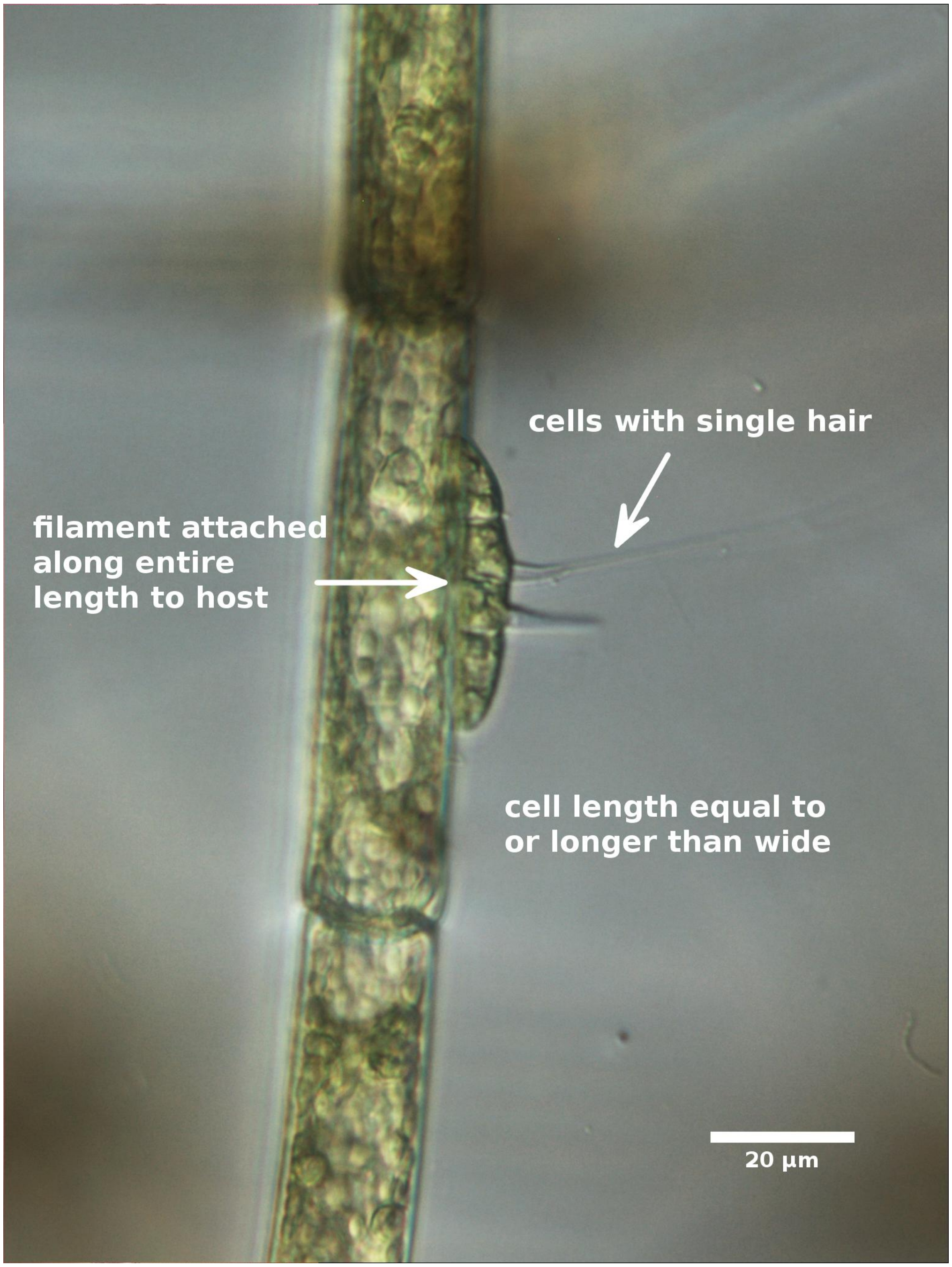

Figure 4.6: *Aphanochaete repens* (400x DIC), Lake Fazon, IWS water quality sampling site, Whatcom County, September 21, 2010.

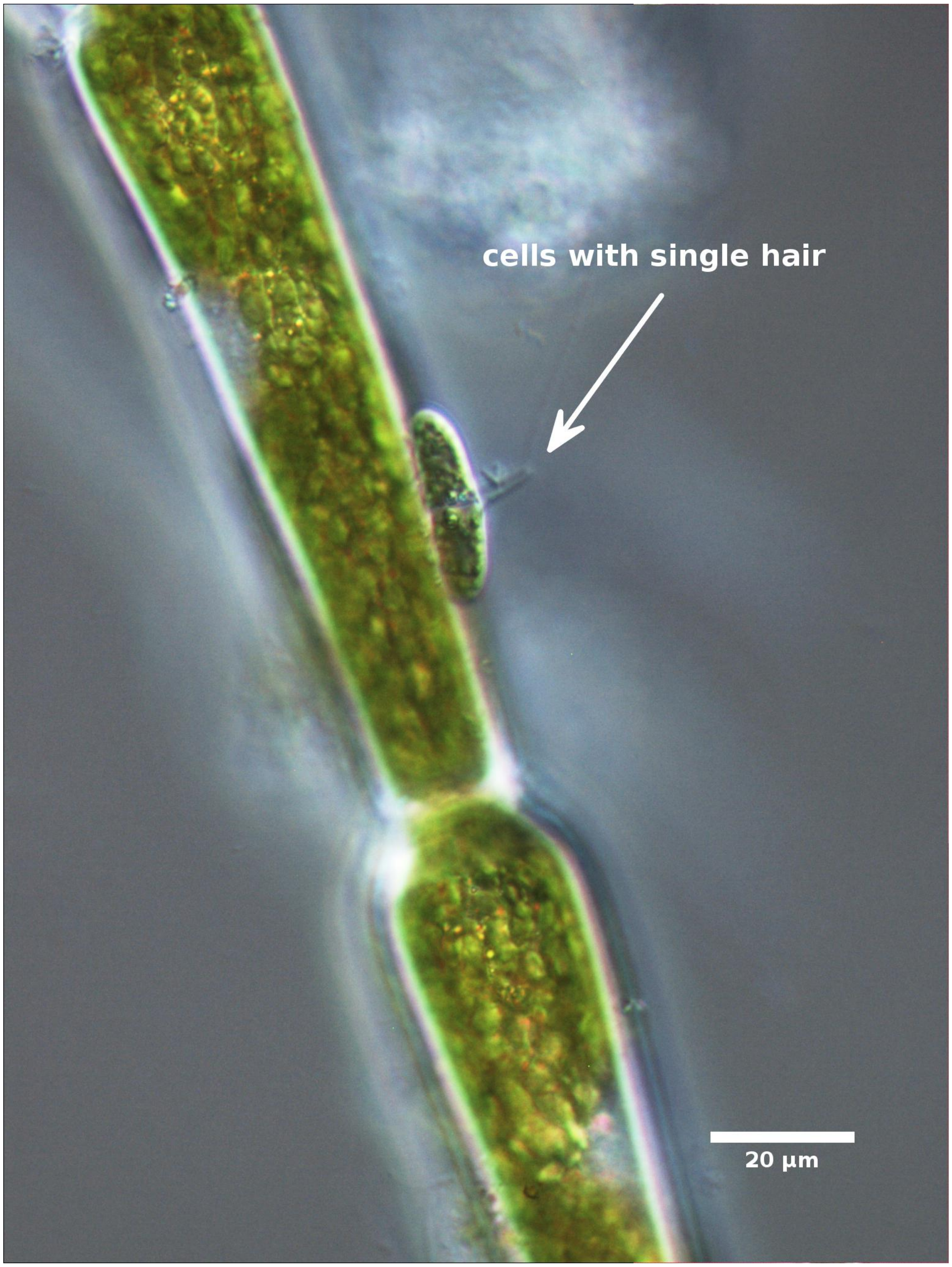

Figure 4.7: *Aphanochaete repens* (400x DIC), Sunset Pond, IWS water quality sampling site, Whatcom County, August 19, 2009.

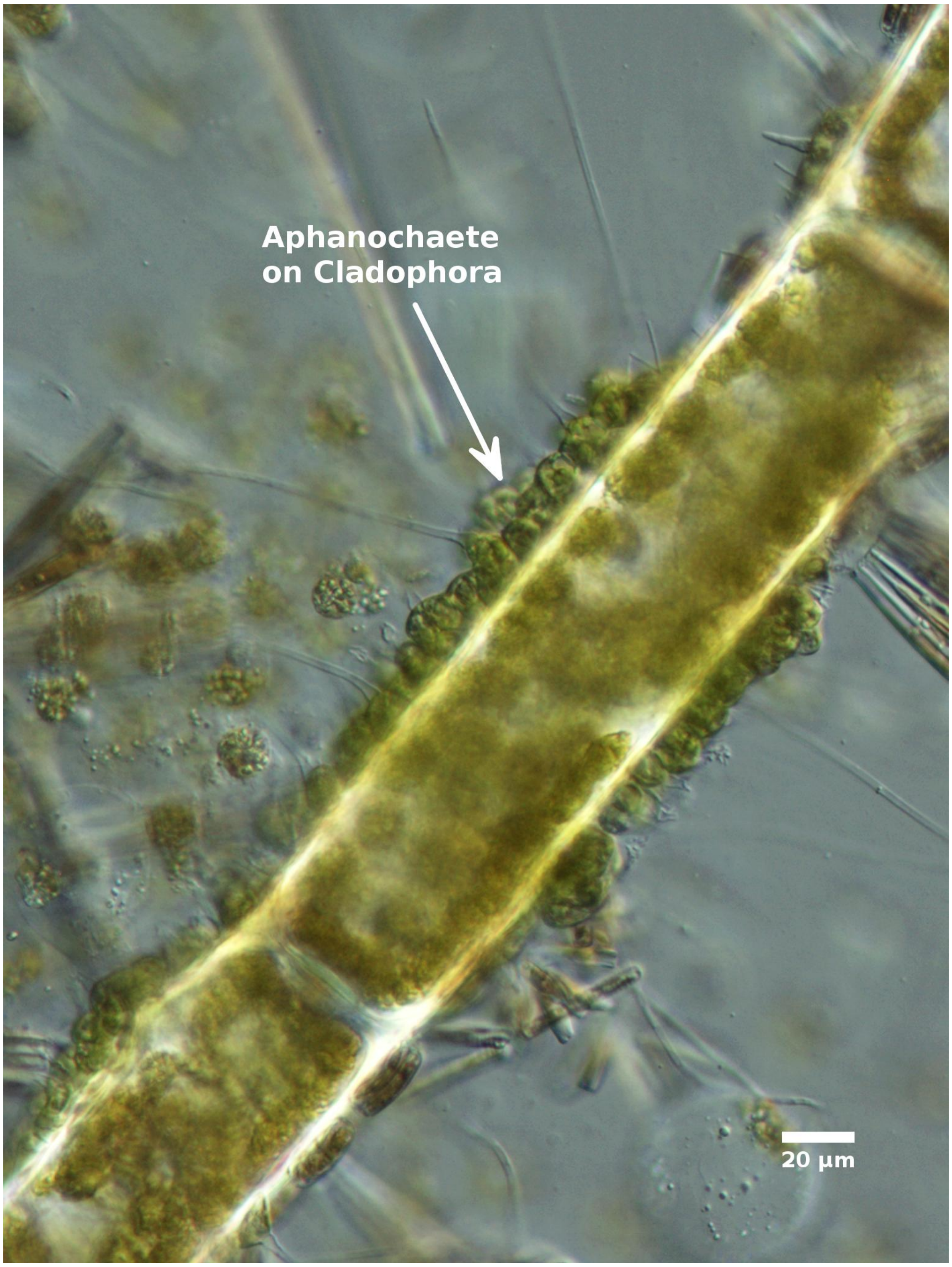

Figure 4.8: *Aphanochaete repens* (200x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, April 4, 2013.

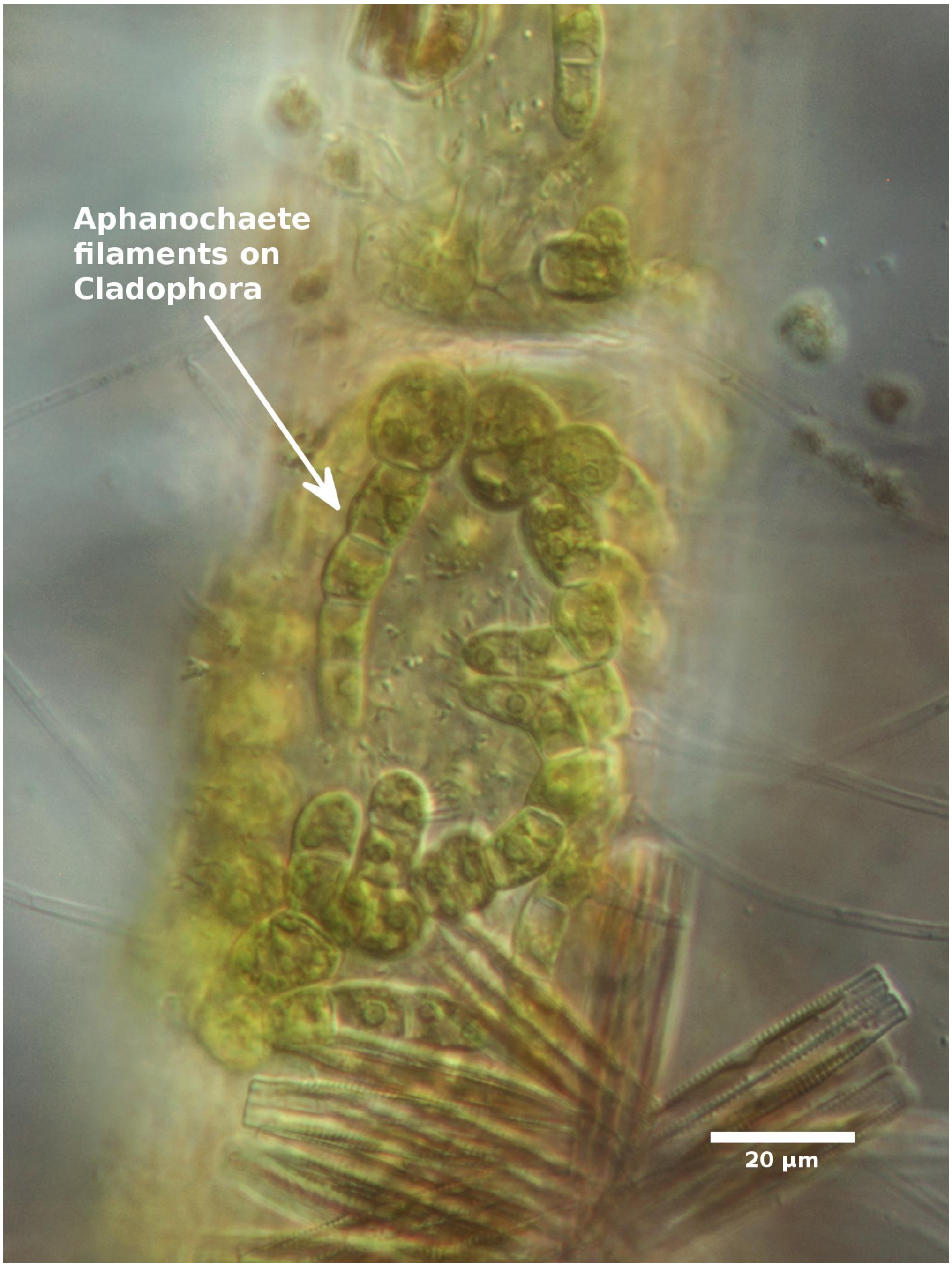

Figure 4.9: *Aphanochaete repens* (400x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, April 4, 2013.

Figure 4.10: *Aphanochaete vermiculoides* (200x DIC), Myrtle Lake, IWS water quality sampling site, Snohomish County, August 22, 2012.

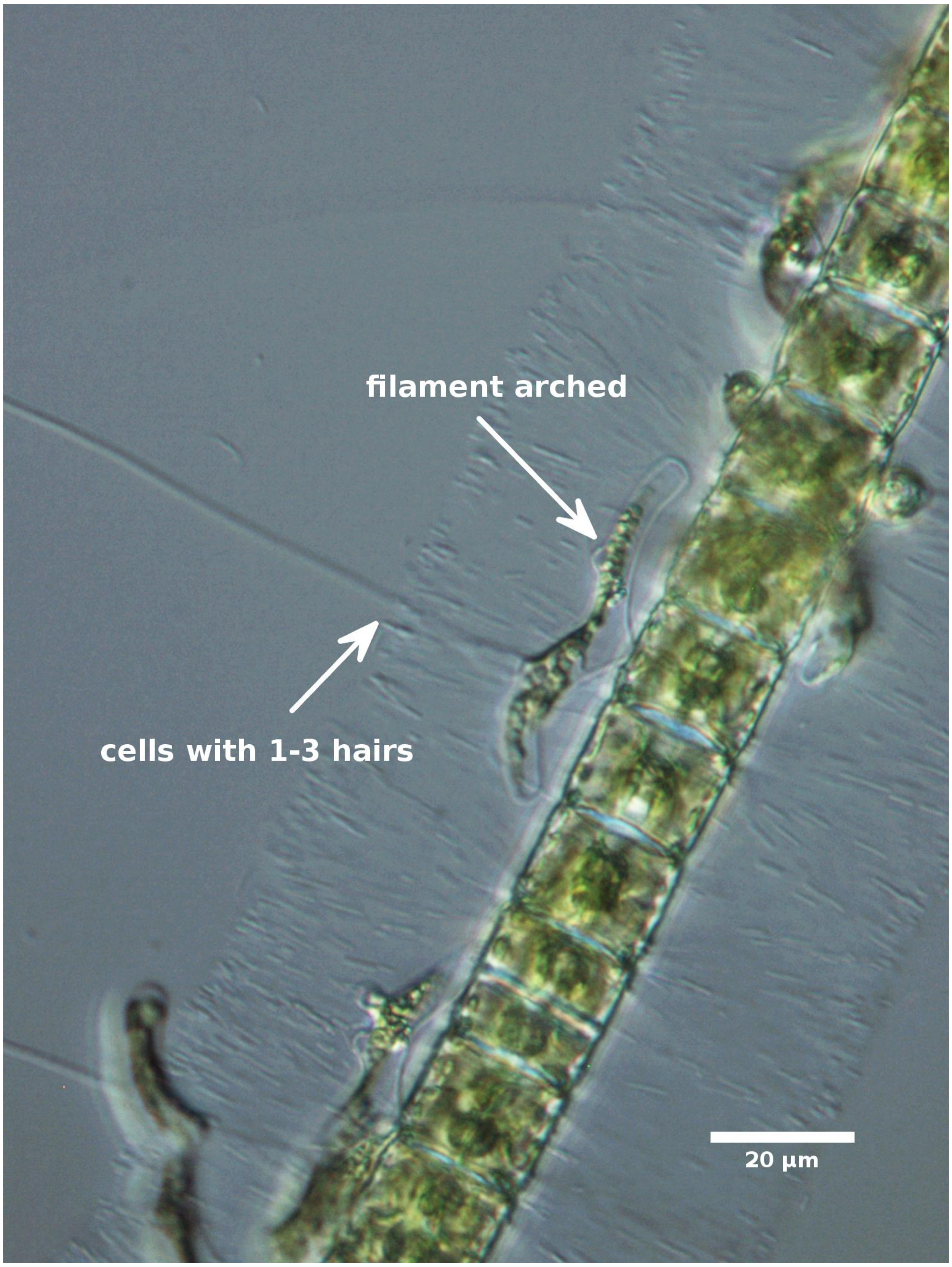

Figure 4.11: *Aphanochaete vermiculoides* (400x DIC), Myrtle Lake, IWS water quality sampling site, Snohomish County, August 22, 2012.

Figure 4.12: *Aphanochaete* sp.1 (600x DIC), small lake north of Sultan, Snohomish County, April 27, 2015.

Figure 4.13: *Aphanochaete* sp.1 (200x DIC), small lake north of Sultan, Snohomish County, May 1, 2015.

4.2 *Binuclearia* Wittrock

Local taxon
Binuclearia tectorum (Kützing) Beger ex Wichmann

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Binuclearia tectorum	min	5.4 μm	5.6 μm	97.7 μm^3
cells (spheroid)	med	6.1 μm	9.1 μm	174 μm^3
	max	6.7 μm	11.9 μm	280 μm^3

†Calculated using original measurements, not summary values.

Description
Binuclearia filaments are unbranched, and contain widely-spaced oval or elliptical cells that are enclosed in thick, striated mucilage (Figures 4.14–4.15). The cells form pairs immediately after division, but this feature becomes less obvious as the cell walls thicken, becoming mucilaginous and striated. The filaments are usually attached to solid substrates, but may become dislodged and planktonic. This species is associated with acidic water and *Sphagnum* bogs (John, et al., 2011); the local specimens were collected in Bear Lake, a boggy, high elevation lake in the North Cascades.

Figure 4.14: *Binuclearia tectorum* (600x DIC), Bear Lake, IWS water quality sampling site, Snohomish County, July 22, 2015.

Figure 4.15: *Binuclearia tectorum* (600x DIC), Bear Lake, IWS water quality sampling site, Snohomish County, July 22, 2015.

4.3 *Bulbochaete* C. Agardh

Local taxa
Bulbochaete spp.

Abundance
Infrequently collected in plankton samples; moderately common in flowing water and along shoreline.

Local measurements		Width	Length	Biovolume†
Bulbochaete spp.‡	min	11.7 μm	18.3 μm	1,970 μm^3
cells (cylinder)	med	17.6 μm	24.8 μm	5,940 μm^3
	max	25.1 μm	74.0 μm	33,300 μm^3

†Calculated using original measurements, not summary values.
‡Cell dimensions represent multiple species.

Description
Bulbochaete filaments are easily identified by the distinctive hair-like setae attached to most cell (Figures 4.16–4.21). The setae are long, thin, and expanded at the base. The terminal cells have two setae; cells making up the branched filaments will each have one seta. The chloroplasts are large, parietal, and contain several distinct pyrenoids. The filaments are usually attached to solid substrates by means of a specialized holdfast cell (Figure 4.16).

Bulbochaete is closely related to *Oedogonium* (Section 4.16, page 661). Like *Oedogonium*, the filaments form distinctive female reproductive cells called oogonia (Figure 4.20) and male reproductive cells called anthridia (Figure 4.21). Even when these cells are present, there are so many different species of *Bulbochaete* that it is difficult to identify the species correctly.

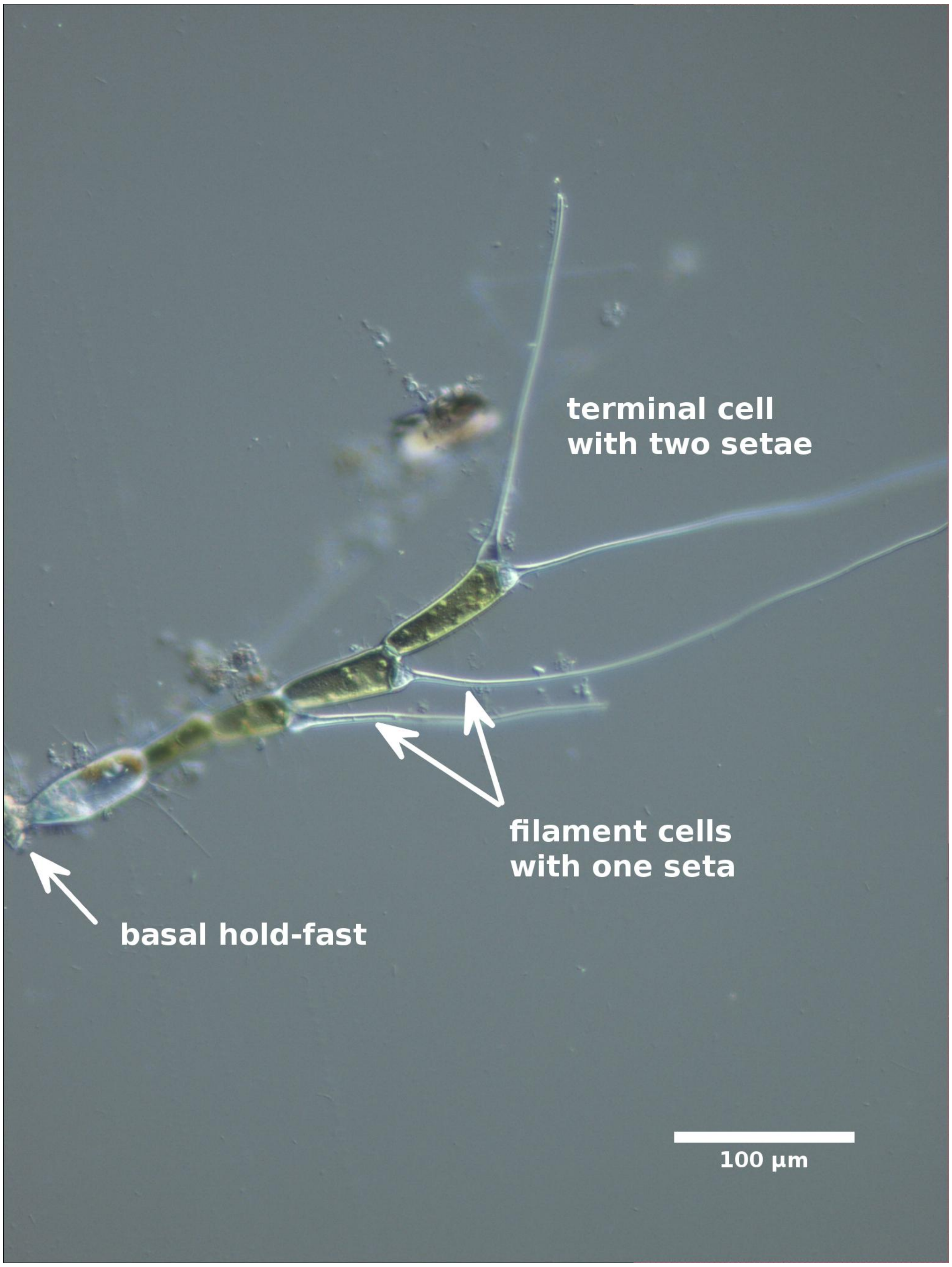

Figure 4.16: *Bulbochaete* (100x DIC), Lake Padden, IWS water quality sampling site, Whatcom County, August 20, 2008.

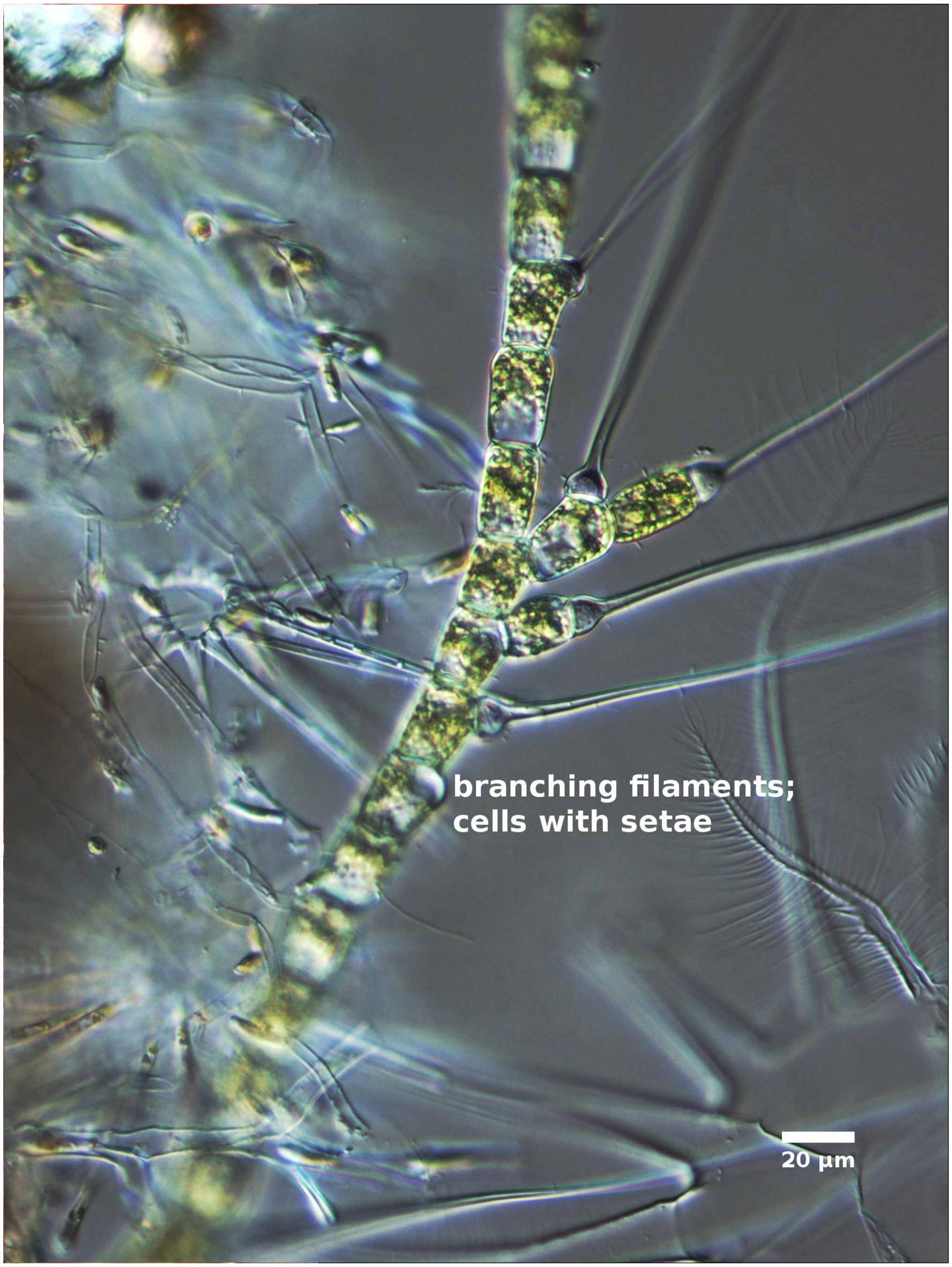

Figure 4.17: *Bulbochaete* (200x DIC), Big Lake, IWS water quality sampling site, Skagit County, May 21, 2009.

Figure 4.18: *Bulbochaete* (200x DIC), small pond near Lake Anderson, North Cascades along Hwy 20, August 31, 2012.

Figure 4.19: *Bulbochaete* (100x DIC), small pond near Lake Anderson, North Cascades along Hwy 20, August 31, 2012.

Figure 4.20: *Bulbochaete* oogonium (600x DIC), small pond near Lake Anderson, North Cascades along Hwy 20, September 3, 2012.

Figure 4.21: *Bulbochaete* anthridium (400x DIC), small pond near Lake Anderson, North Cascades along Hwy 20, September 3, 2012.

4.4 *Chaetophora* Schrank

Local taxa
Chaetophora elegans (Roth) C. Agardh;
Chaetophora incrassata Hazen = (*Chaetophora lobata* Schrank)

Abundance
Infrequently collected in plankton samples; moderately common in flowing water and along shoreline; may form dense, macroscopic colonies or mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Chaetophora elegans	min	7.1 μm	13.5 μm	534 μm^3
cells (cylinder)	med	9.0 μm	17.9 μm	1,200 μm^3
	max	10.6 μm	31.3 μm	2,310 μm^3
Chaetophora incrassata	min	7.3 μm	10.1 μm	628 μm^3
cells (cylinder)	med	11.0 μm	44.3 μm	3,760 μm^3
	max	17.7 μm	84.2 μm	19,200 μm^3

†Calculated using original measurements, not summary values.

Description
Chaetophora filaments form macroscopic colonies attached to solid substrates in flowing water and along shorelines (Figures 4.22–4.29). The individual cells have a parietal chloroplast and one or more pyrenoids; apical cells may form a long, hair-like extension. The filaments are highly branched and are surrounded by thick, soft mucilage that may not be visible without staining. *Chaetophora* taxonomy is difficult because environmental conditions affects the cell and filament morphology. In particular, phosphorus limitation influences the growth of the apical hair-like extensions (John, et al., 2011).

Chaetophora filaments resemble *Draparnaldia* (Section 4.8, page 589) and *Stigeoclonium* (Section 4.20, page 722). *Draparnaldia* has highly differentiated primary (axial) and secondary (branch) filaments, and usually appears dense and tufted. The *Draparnaldia* axial filament is unmistakable, consisting of large, barrel-shaped cells with a deeply incised, band-shaped parietal chloroplast.

Stigeoclonium filaments may be slightly differentiated into axial and branch filaments, and some of the filaments may form root-like rhizoids, but the axial filament will not consist of large, barrel-shaped axial cells, and the plant doesn't look tufted.

Chaetophora elegans forms spherical or hemispherical colonies of radiating filaments that are usually attached to woody substrates (Figures 4.22–4.24). The filaments branch repeatedly along their entire length, tapering gradually into acutely pointed apical cells. The apical cells may form a long, hair-like extension.

Chaetophora incrassata forms dense, irregular colonies (not spherical or hemispherical) with a central (axial) bundle of parallel, sparsely-branched, filaments; and tufted, densely branched lateral (branch) filaments (Figures 4.25–4.29). The lateral filaments end in untapered, bluntly rounded cells that may form a long, hair-like extension. This species has been renamed *Chaetophora lobata*, but most keys still list it as *C. incrassata*.

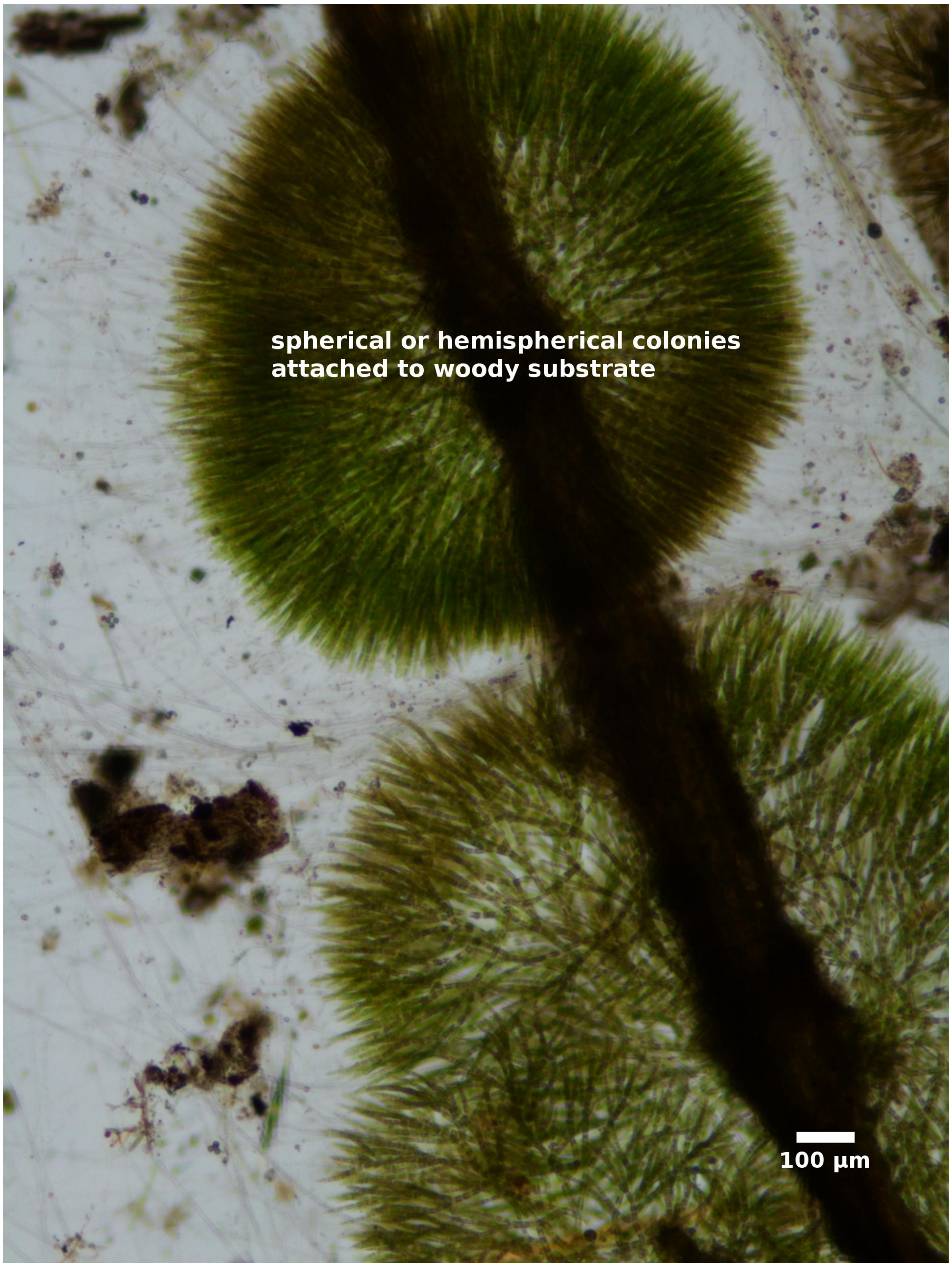

Figure 4.22: *Chaetophora elegans* (40x brightfield), small storm water treatment pond, Whatcom County, May 11, 2015.

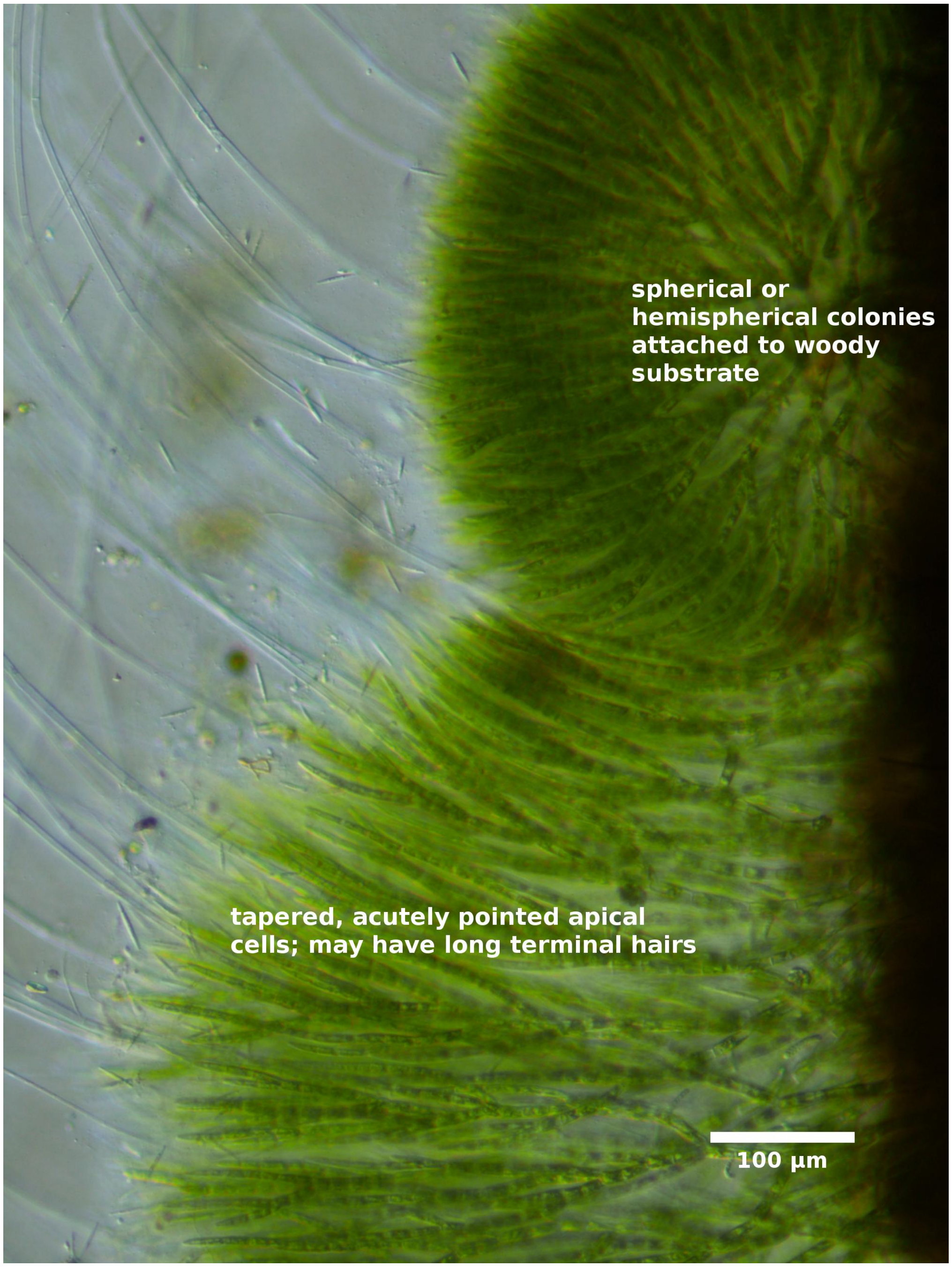

Figure 4.23: *Chaetophora elegans* (100x DIC), small storm water treatment pond, Whatcom County, May 11, 2015.

Figure 4.24: *Chaetophora elegans* (200x DIC), small storm water treatment pond, Whatcom County, May 11, 2015.

Figure 4.25: *Chaetophora incrassata* (40x brightfield), Lake Sutherland, Olympic Peninsula, May 20, 2013.

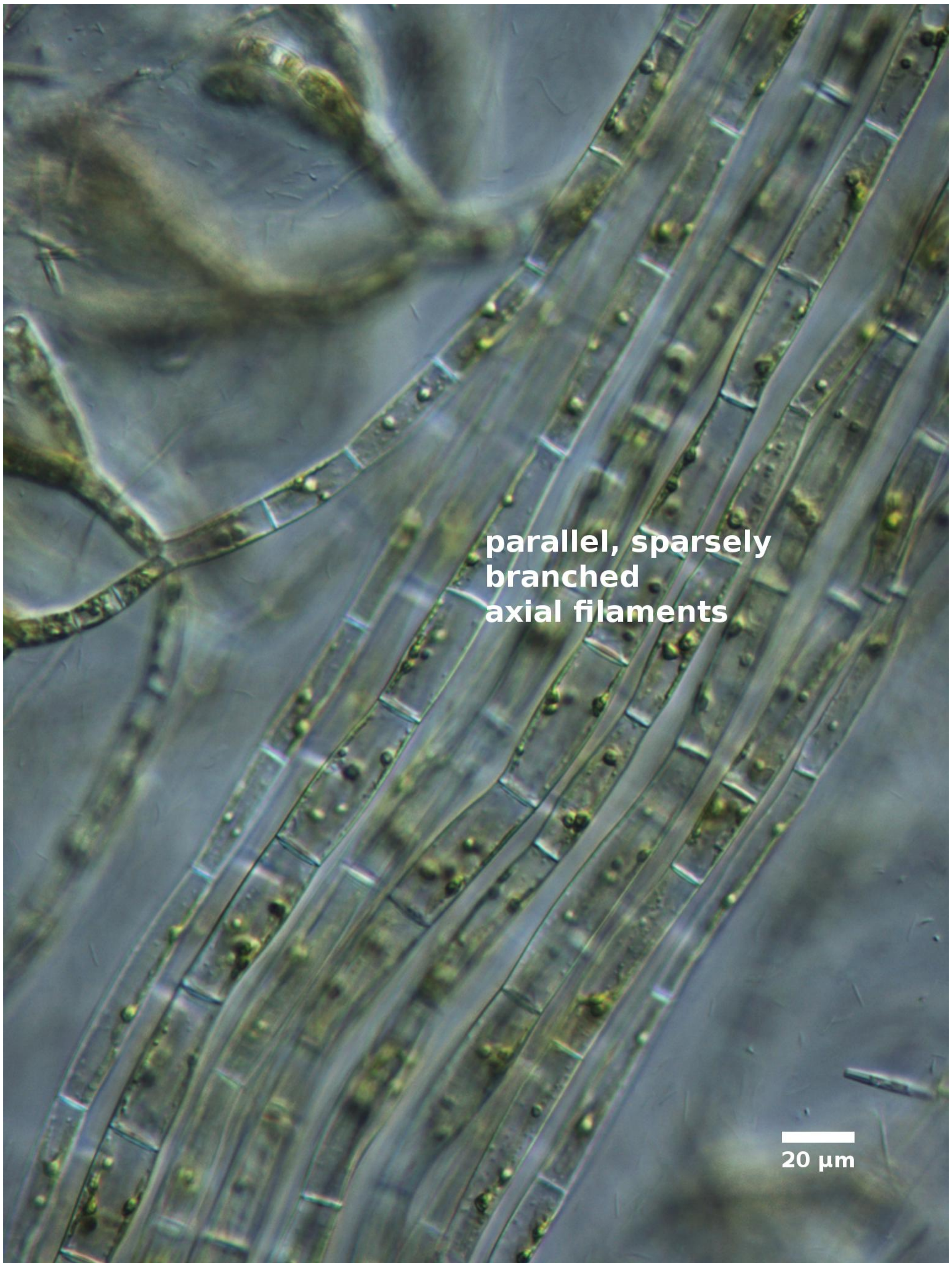

Figure 4.26: *Chaetophora incrassata* (100x DIC), Lake Sutherland, Olympic Peninsula, May 20, 2013.

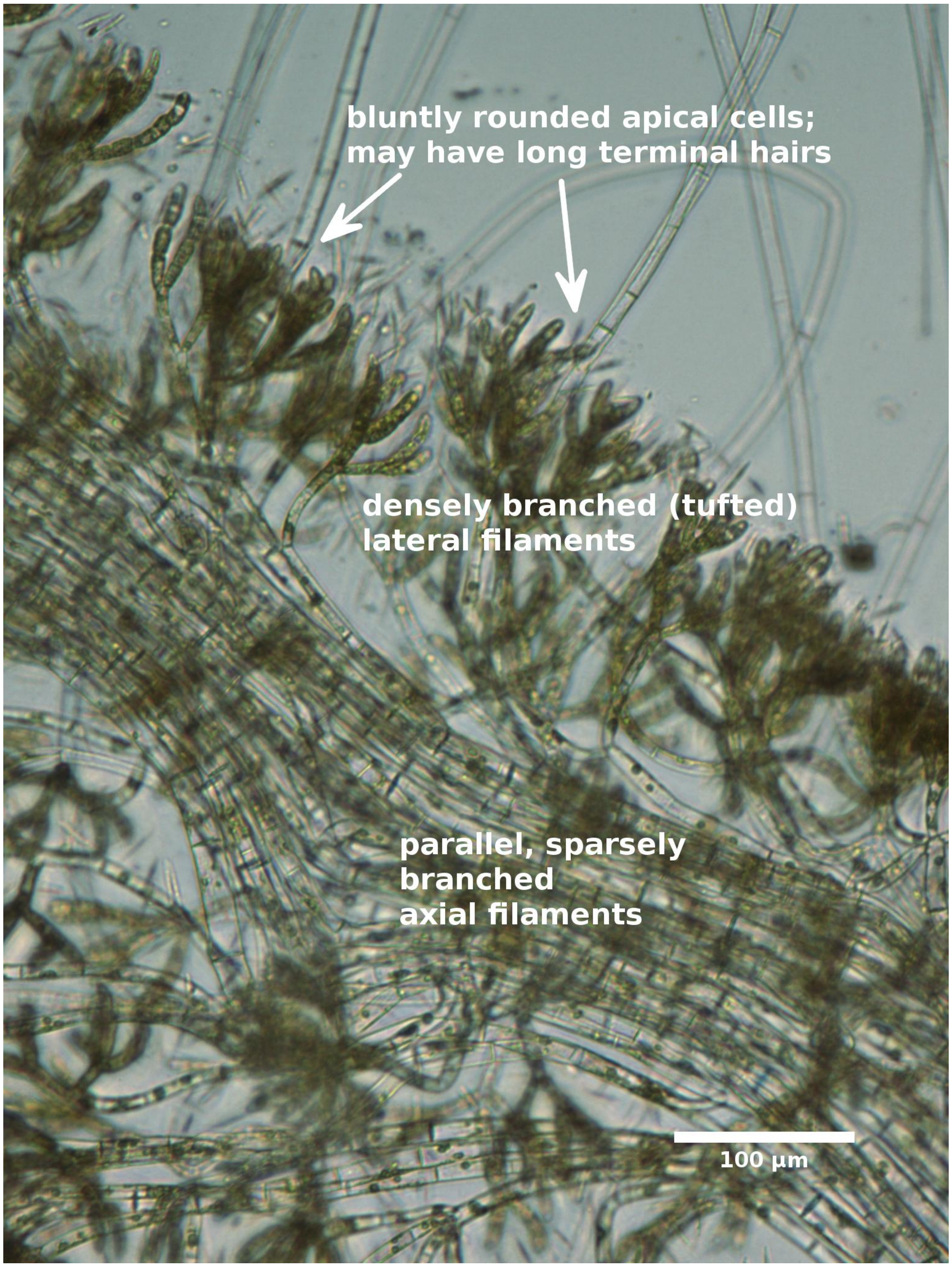

Figure 4.27: *Chaetophora incrassata* (100x DIC), Lake Sutherland, Olympic Peninsula, May 20, 2013.

Figure 4.28: *Chaetophora incrassata* (200x DIC), small freshwater pond, Whatcom County, May 2, 2013.

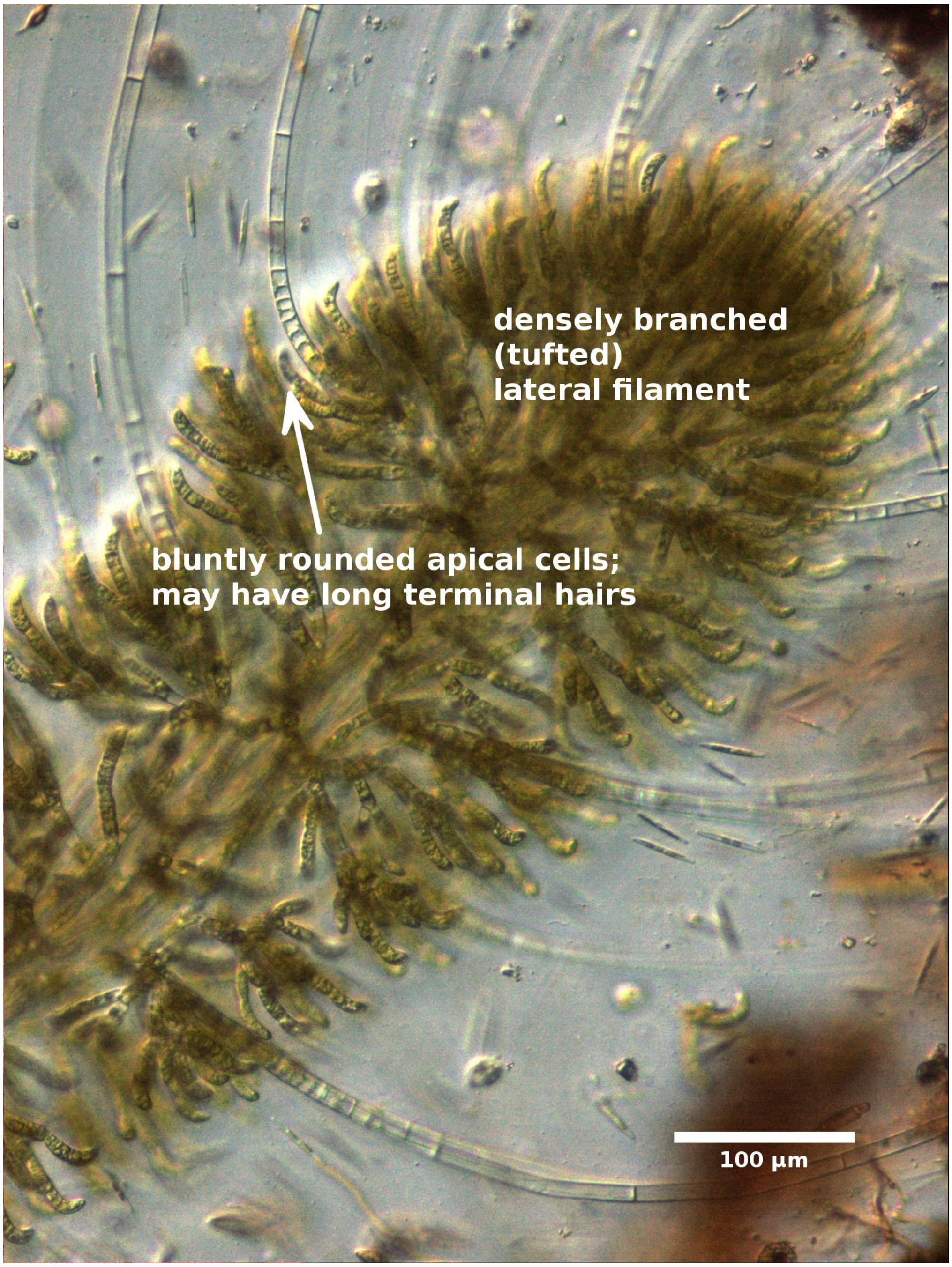

Figure 4.29: *Chaetophora incrassata* (100x DIC), small freshwater pond on Lummi Island, Whatcom County, April 14, 2011.

4.5 *Chaetosphaeridium* Klebahn

Local taxon
Chaetosphaeridium globosum (Nordstedt) Klebahn

Abundance
Infrequently collected.

Local measurements		Width	Length	Biovolume†
Chaetosphaeridium globosum	min	9.3 μm	–	421 μm^3
cells (sphere)	med	12.8 μm	–	1,100 μm^3
	max	14.7 μm	–	1,660 μm^3

†Calculated using original measurements, not summary values.

Description
Chaetosphaeridium is a type of filamentous algae that is related to *Coleochaete* (Section 4.7, page 583). The cells may be solitary or may form a loosely connected chain of cells enclosed in a mucilaginous tube. *Chaetosphaeridium globosa* cells are spherical, with 1–2 parietal chloroplasts and one long, hair-like bristle with a basal sheath (Figures 4.30–4.33). This genus is usually epiphytic, but the sample in Figure 4.32 was collected in a near-shore plankton tow from Silver Lake.

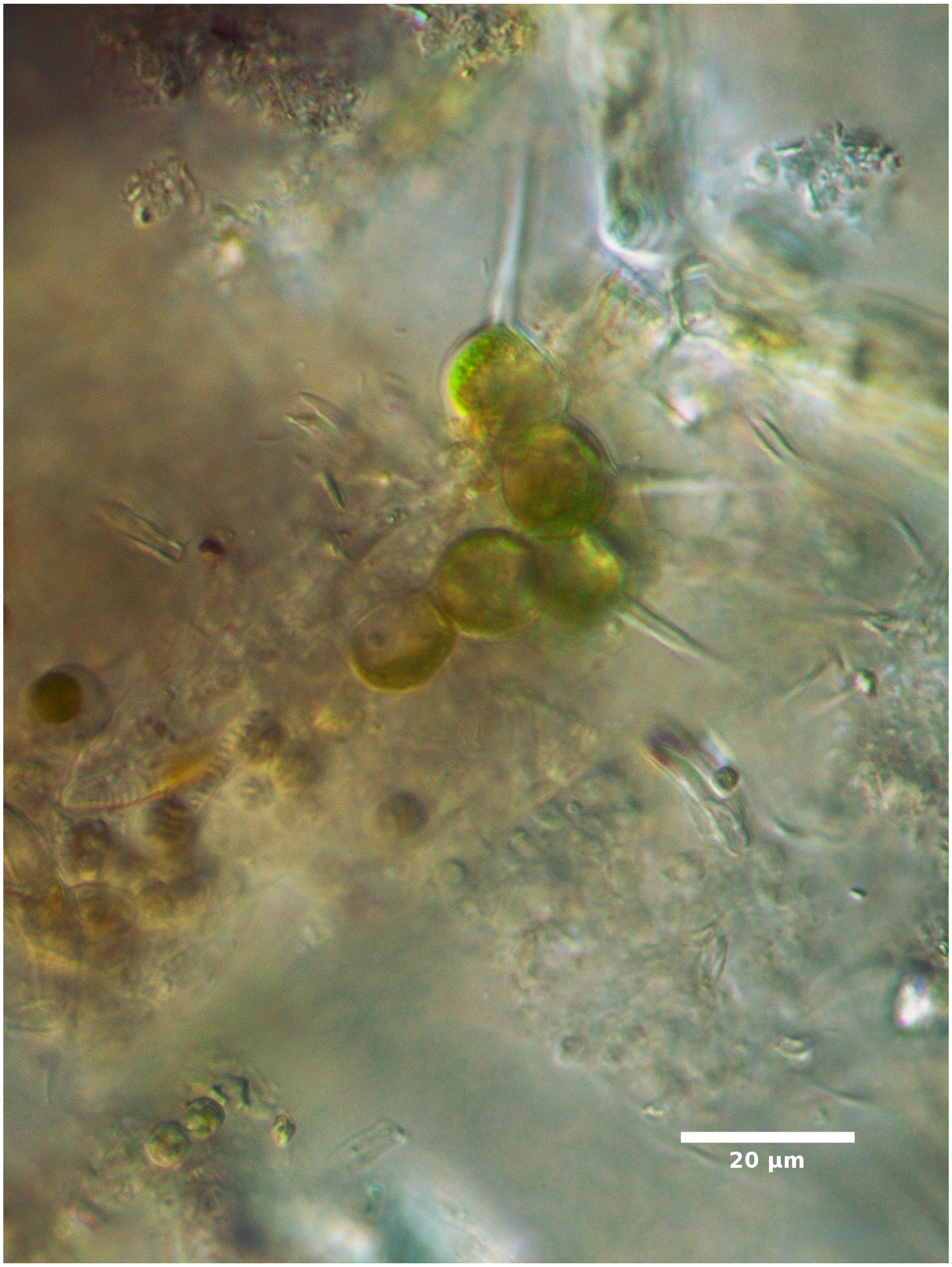

Figure 4.30: *Chaetosphaeridium globosum* (600x DIC), Coal Lake, IWS water quality sampling site, Snohomish County, August 24, 2014.

Figure 4.31: *Chaetosphaeridium globosum* (400x DIC), Bear Lake, Alpine Lakes Wilderness Area, July 12, 2013.

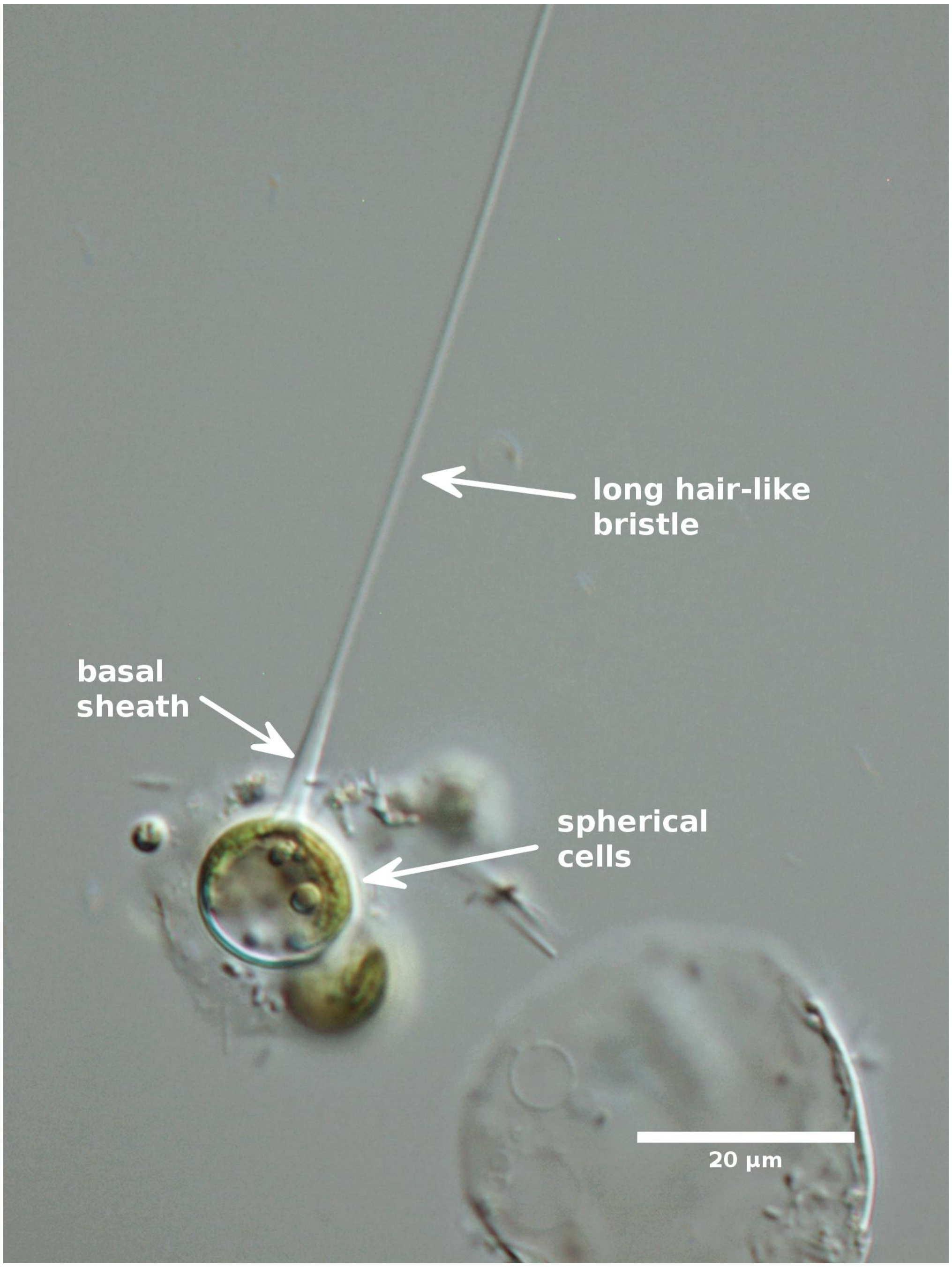

Figure 4.32: *Chaetosphaeridium globosum* solitary cell (600x DIC), Silver Lake, IWS water quality sampling site, Whatcom County, August 28, 2012.

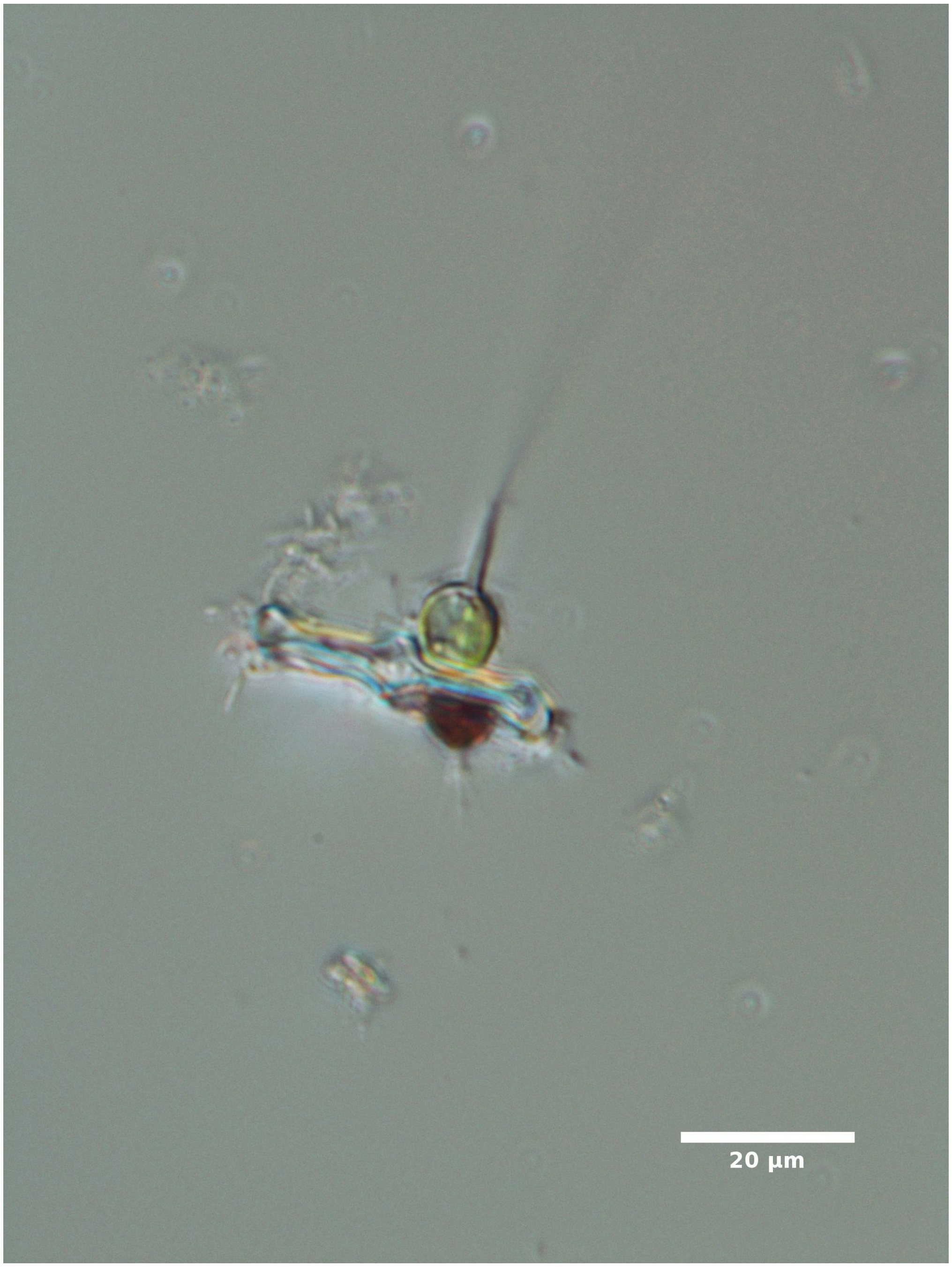

Figure 4.33: *Chaetosphaeridium globosum* solitary cell (600x DIC), Goat Lake, Mt. Loop Hwy, August 24, 2014.

4.6 *Cladophora* Kützing

Local taxon

Cladophora glomerata (Linnaeus) Kützing

Abundance

Infrequently collected in plankton samples; moderately common in flowing water and along shoreline; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Cladophora glomerata	min	33.0 μm	231.2 μm	240,000 μm^3
cells (cylinder)	med	38.8 μm	298.1 μm	343,000 μm^3
	max	42.0 μm	487.9 μm	527,000 μm^3

†Calculated using original measurements, not summary values.

Description

Cladophora filaments are occasionally planktonic, but much more likely to be collected from flowing water or shorelines. *Cladophora glomerata* filaments are branched, but the branching may be sparse (Figures 4.34–4.40). The individual cells are very large, cylindrical, and often asymmetric. The chloroplast is dense and net-like (reticulated). The specimens from Lake Whatcom and Wiser Lake were collected along the shoreline and were encrusted with epiphytic diatoms (Figures 4.37–4.38).

Cladophora produces motile asexual reproductive cells (zoospores) with four equal flagella that resemble *Carteria* (Section 2.1, page 19), and motile sexual reproductive cells (gametes) with two equal flagella that resemble *Chlamydomonas* (Section 2.3, page 35). The motile cells in Figure 4.40 appear to have only two flagella, which would make them gametes; however, the image resolution is not sufficient to confirm this observation.

Figure 4.34: *Cladophora glomerata* (40x brightfield), Lake Whatcom shoreline, IWS water quality sampling site, Whatcom County, April 12, 2011.

Figure 4.35: *Cladophora glomerata* (100x DIC), Lake Whatcom shoreline, IWS water quality sampling site, Whatcom County, April 12, 2011.

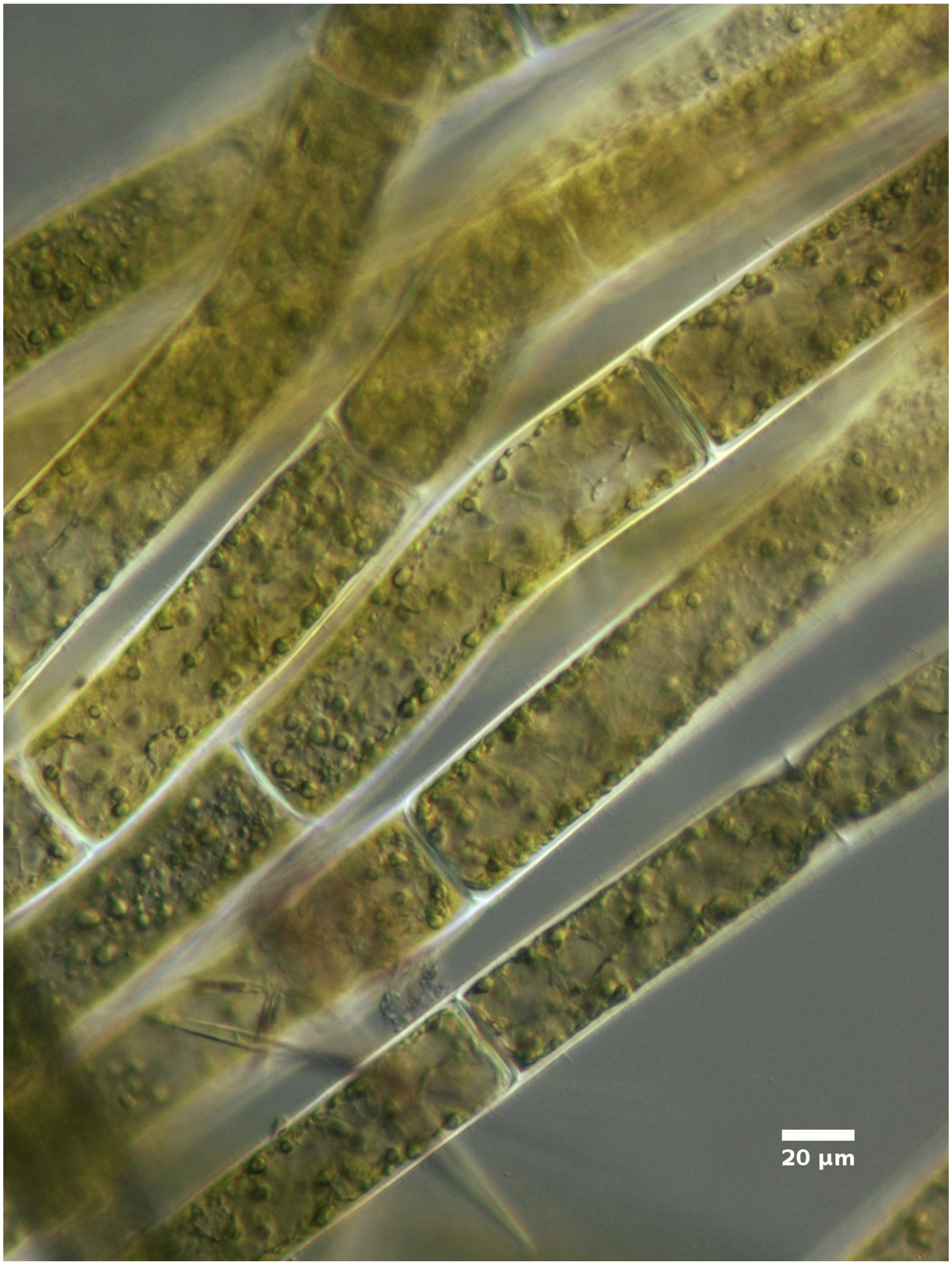

Figure 4.36: *Cladophora glomerata* (200x DIC), Heart Lake, IWS water quality sampling site, Skagit County, October 8, 2013.

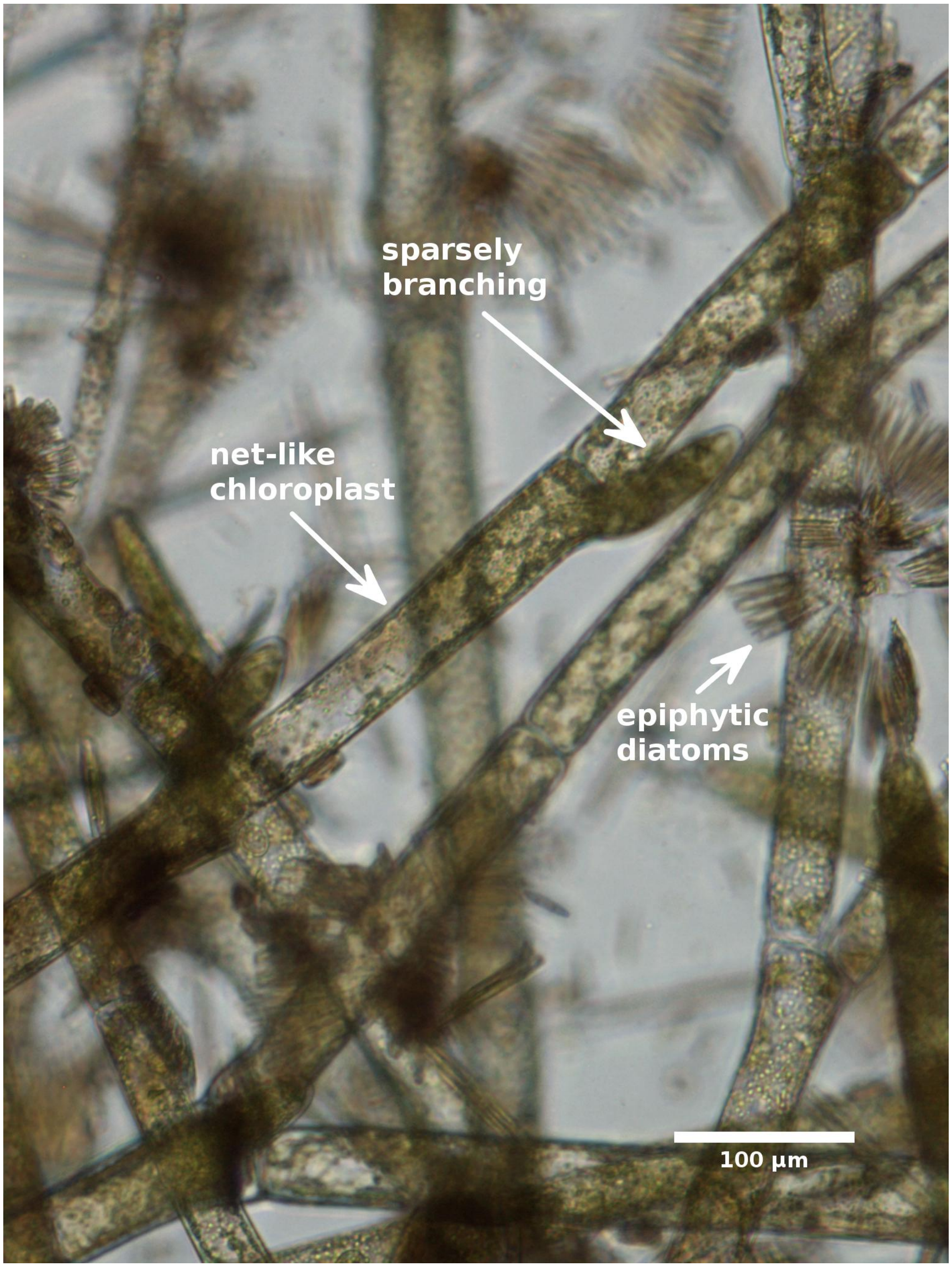

Figure 4.37: *Cladophora glomerata* (100x brightfield), Wiser Lake, IWS water quality sampling site, Whatcom County, April 4, 2013.

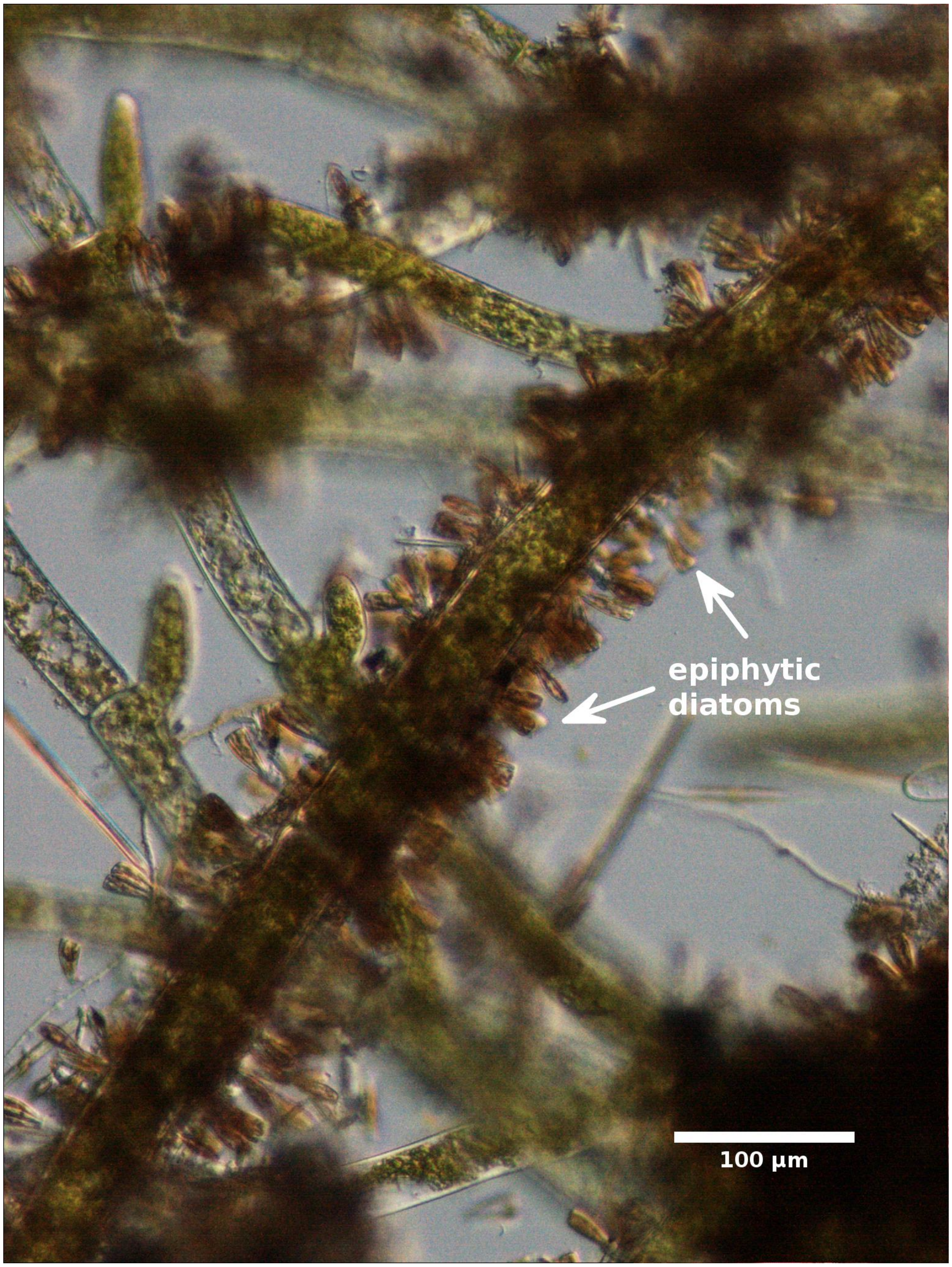

Figure 4.38: *Cladophora glomerata* epiphytes (100x DIC), Lake Whatcom shoreline, IWS water quality sampling site, Whatcom County, April 12, 2011.

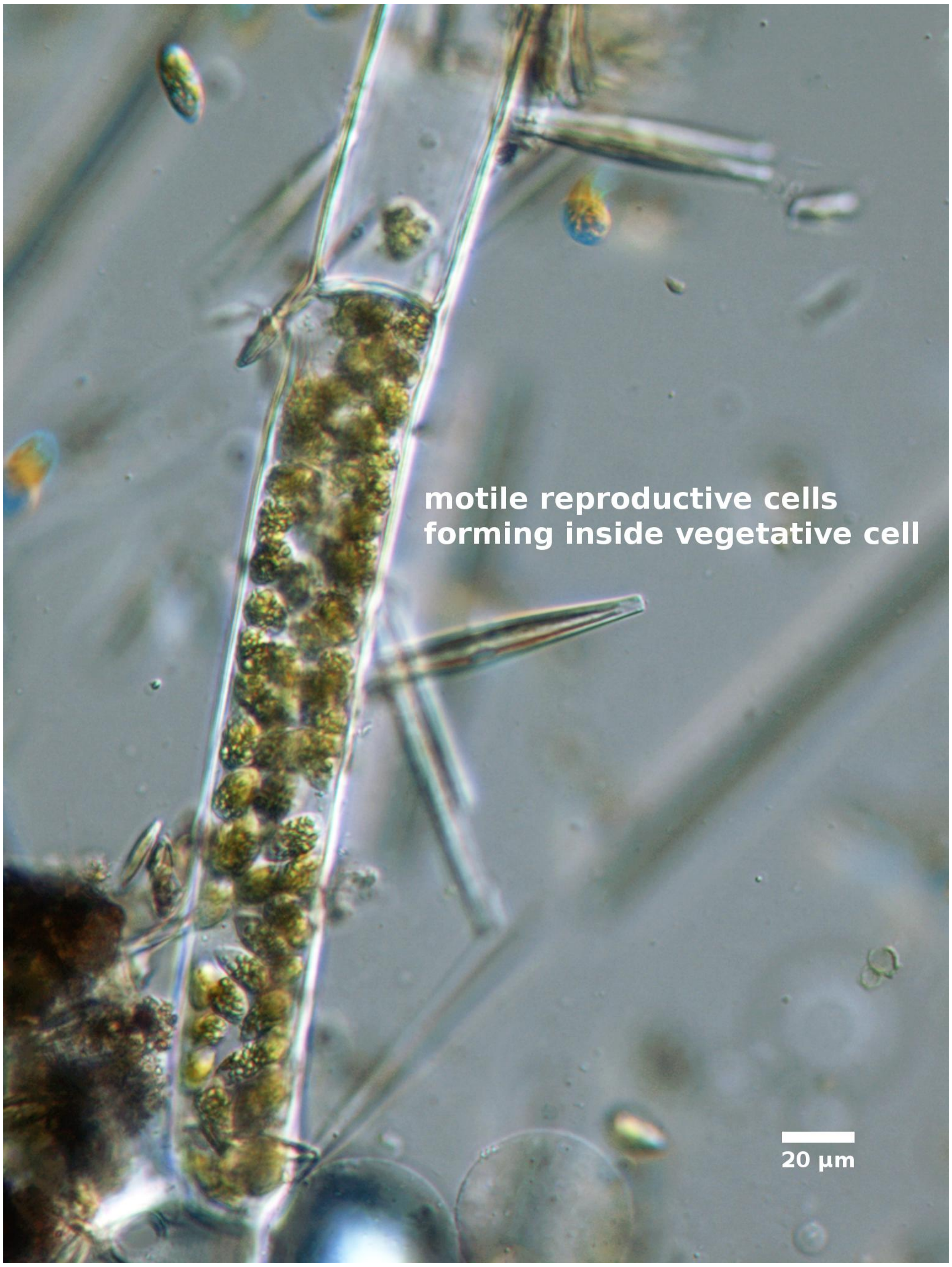

Figure 4.39: *Cladophora glomerata* reproductive cells (200x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, April 4, 2013.

Figure 4.40: *Cladophora glomerata* reproductive cells (600x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, April 4, 2013.

4.7 *Coleochaete* Brébisson

Local taxa
Coleochaete obicularis Pringsheim?;
Coleochaete scutata Brébisson

Abundance
Infrequently collected; moderately common epiphyte on moss.

Local measurements		Width	Length	Biovolume[†]
Coleochaete obicularis?	min	5.1 μm	6.1 μm	80.5 μm^3
cells (rectangular box)	med	5.9 μm	8.0 μm	157 μm^3
	max	7.4 μm	9.6 μm	235 μm^3
Coleochaete scutata	min	13.0 μm	17.0 μm	1,650 μm^3
cells (rectangular box)	med	16.3 μm	22.0 μm	3,230 μm^3
	max	22.6 μm	27.1 μm	4,760 μm^3

[†]Calculated using original measurements, not summary values. Cell biovolume estimates used an estimated cell depth = cell length ÷ 2.5 based on measured length/depth ratios (1.9–2.7).

Description
Coleochaete is classified as a type of filamentous algae because the cells divide to form branching, end-to-end chains of cells. The filaments are irregular and stick together to form a single-layer mass of cells (pseudoparenchyma) that may look like a disk-shaped colony rather than a typical filament (Figures 4.41–4.45). The individual cells are rectangular, with one parietal chloroplast and one or more pyrenoids. The cells may also have long bristles or hairs.

Coleochaete obicularis cells are rectangular, 1–2 times longer than wide, and often contain bristles . The filaments form radiating strands in a flat, disk-shaped colony that is usually epiphytic. *Coleochaete obicularis* resembles *Coleochaete scutata*, but has much smaller cells. The specimens in Figures 4.41–4.42 were tentatively identified as *Coleochaete obicularis* based on their small cell size.

Coleochaete scutata can be distinguished by its large, rectangular cells and flat, disk-shaped colonies that are attached to aquatic plants (Figures 4.43–4.45).

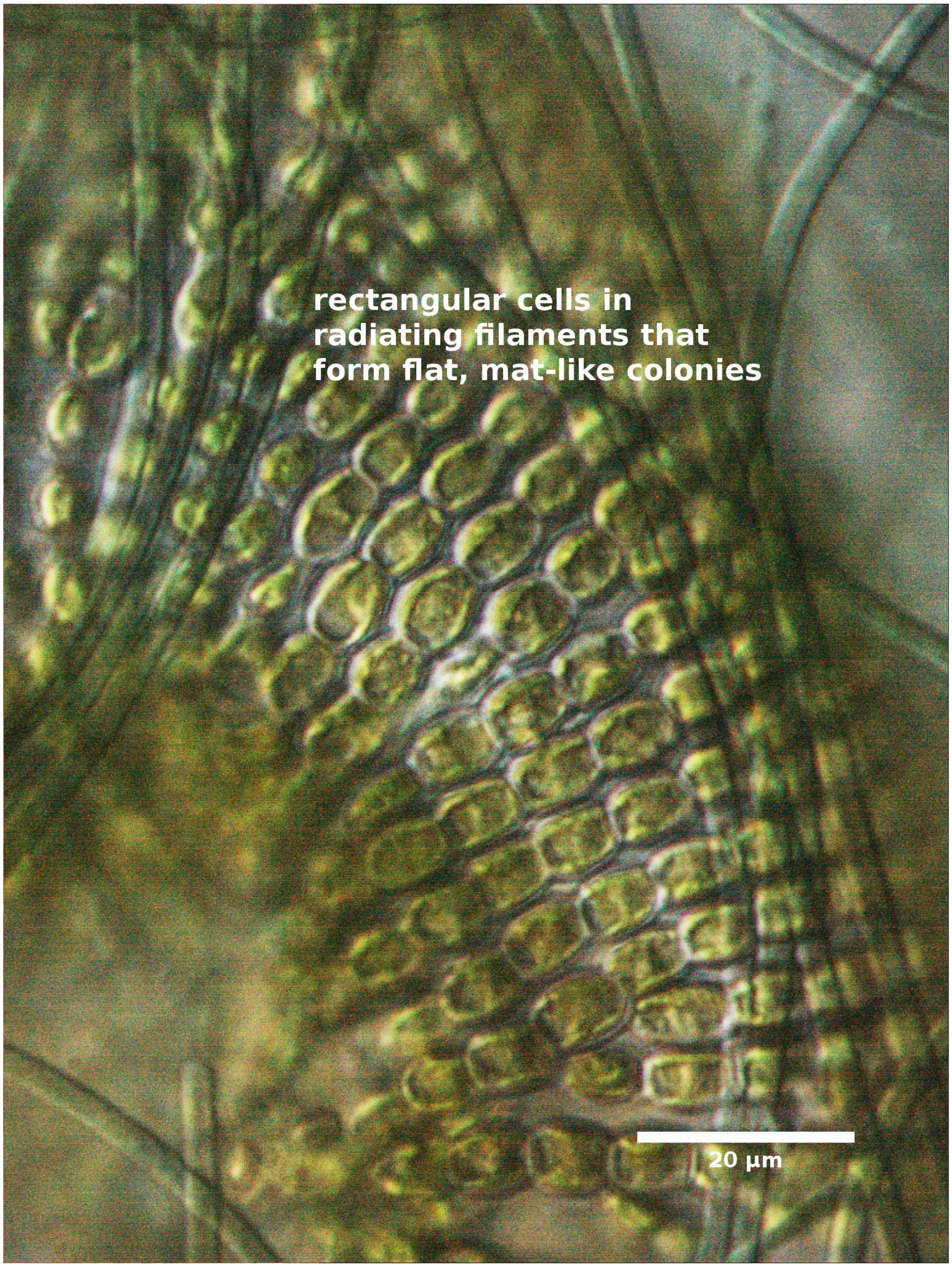

Figure 4.41: *Coleochaete obicularis*? (600x DIC), freshwater aquarium, April 1, 2011.

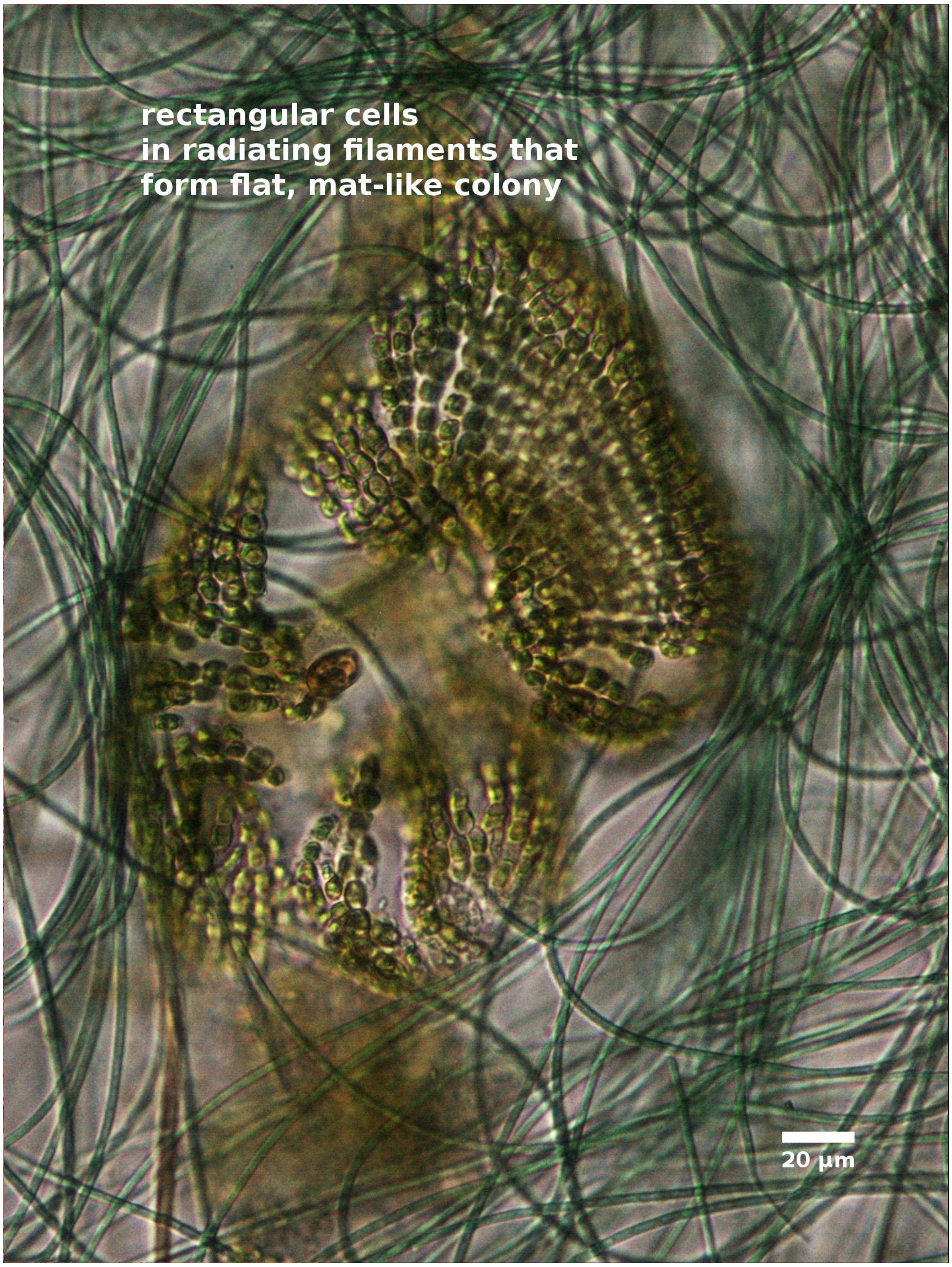

Figure 4.42: *Coleochaete obicularis*? (200x DIC), freshwater aquarium, April 1, 2011.

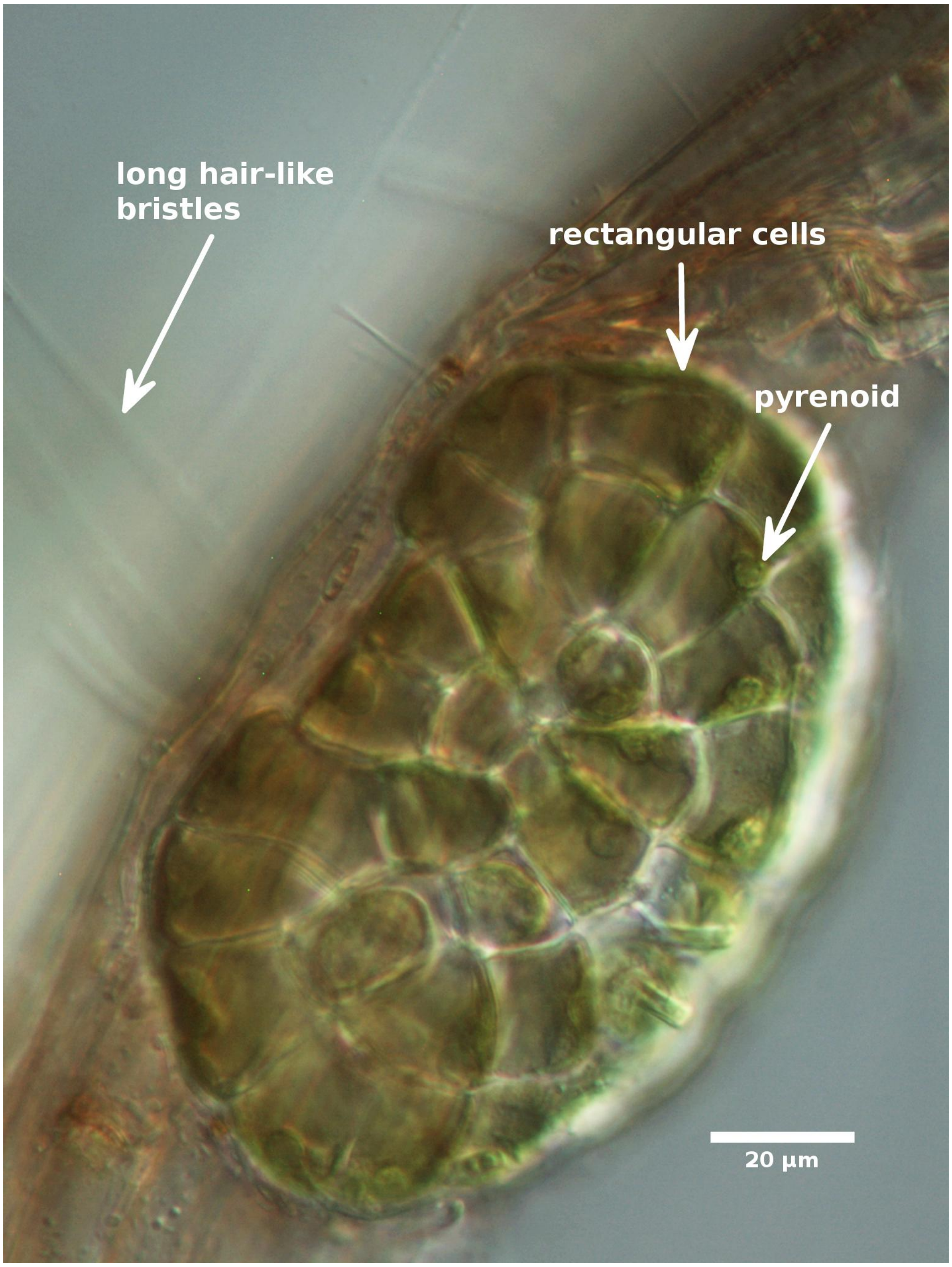

Figure 4.43: *Coleochaete scutata* (400x DIC), Myrtle Lake, IWS water quality sampling site, Snohomish County, August 20, 2013.

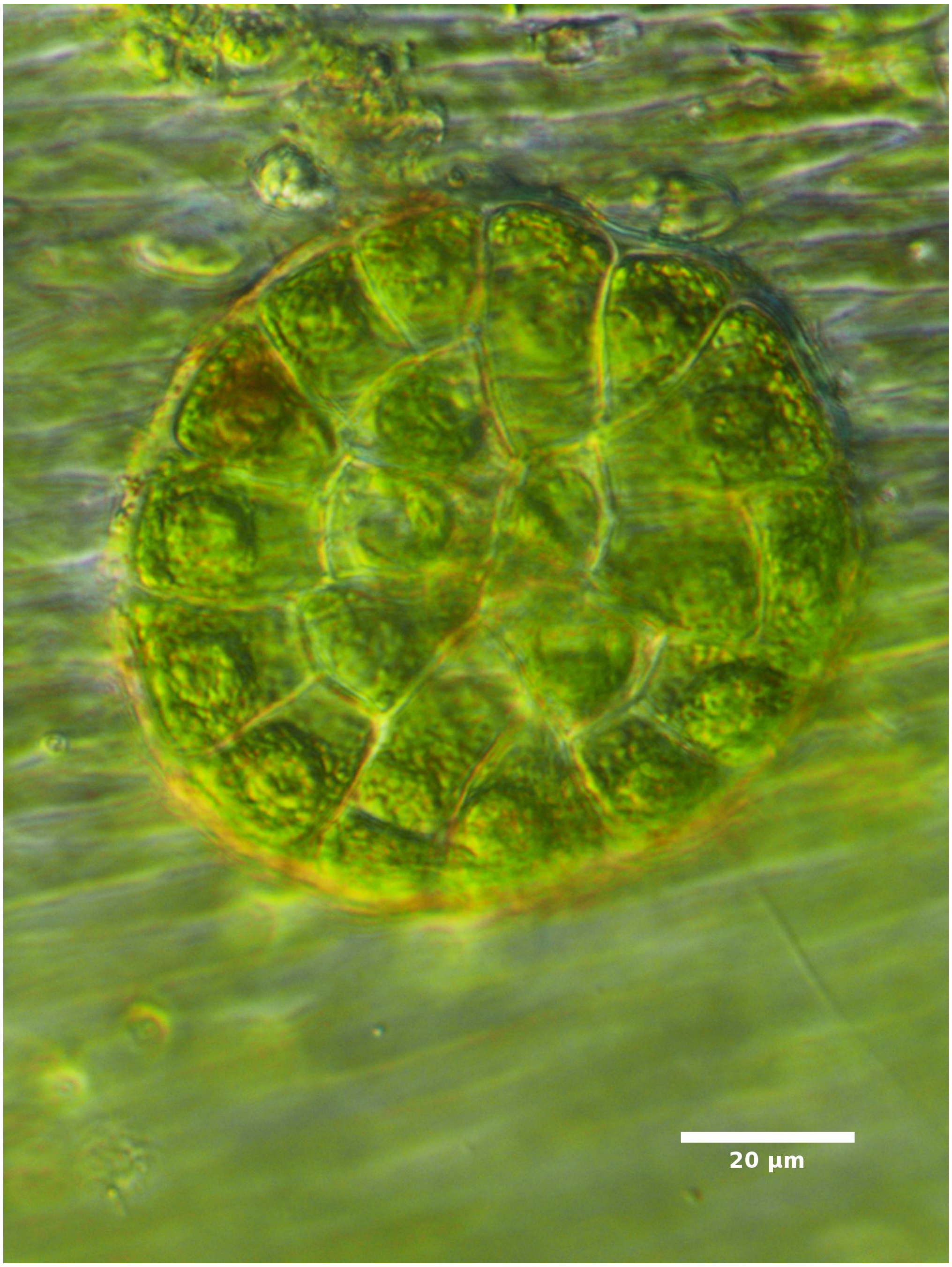

Figure 4.44: *Coleochaete scutata* (600x DIC), small pond near Fairhaven College, Whatcom County, April 24, 2015.

Figure 4.45: *Coleochaete scutata* stained with methylene blue (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 9, 2013.

4.8 *Draparnaldia* Bory

Local taxon

Draparnaldia glomerata (Vaucher) C. Agardh

Abundance

Infrequently collected in plankton samples; moderately common in flowing water and along shoreline; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Draparnaldia glomerata	min	19.2 μm	20.2 μm	5,850 μm^3
axial cells (cylinder)	med	33.9 μm	52.5 μm	49,100 μm^3
	max	50.4 μm	193.8 μm	387,000 μm^3
Draparnaldia glomerata	min	6.3 μm	11.7 μm	751 μm^3
branch cells (cylinder)	med	10.7 μm	20.9 μm	1,580 μm^3
	max	14.7 μm	32.5 μm	4,900 μm^3

†Calculated using original measurements, not summary values.

Description

Draparnaldia glomerata filaments can be identified by the large, barrel-shaped primary (axial) cells and tufted, plume-like secondary (branch) cells (Figures 4.46–4.49). The axial cells have a narrow, band-shaped chloroplast that completely circles the cell. The cells in the branch filaments are much smaller, and taper into blunt points. Some of the branch cells may extend into long, multicellular hairs. The formation of these extensions is often triggered by phosphorus limitation (John, et al., 2011).

Draparnaldia filaments are highly variable under different environmental conditions, and often resemble *Stigeoclonium* (Section 4.20, page 722; see discussion by van Beem & Simons, 1988). Although *Stigeoclonium* filaments may be slightly differentiated into axial and branch filaments, the axial filament will not consist of large, barrel-shaped axial cells, and the plant doesn't look tufted. Small filaments of *Draparnaldia* may also resemble *Chaetophora* (Section 4.4, page 560), especially if the *Draparnaldia* axial cells are not much larger than the branch cells.

Draparnaldia often produced motile reproductive cells (Figures 4.50–4.53). The motile cells are approximately spherical when they first emerge (Figure 4.50), but quickly start to elongate, forming holdfasts while still retaining the eyespot of the original motile cells (Figures 4.50 and 4.52). By the time the filaments contain 2–4 cells, the filamentous structure is apparent (Figures 4.54–4.55).

Figure 4.46: *Draparnaldia glomerata* (40x brightfield), freshwater pond near Graham, Pierce County, May 10, 2011.

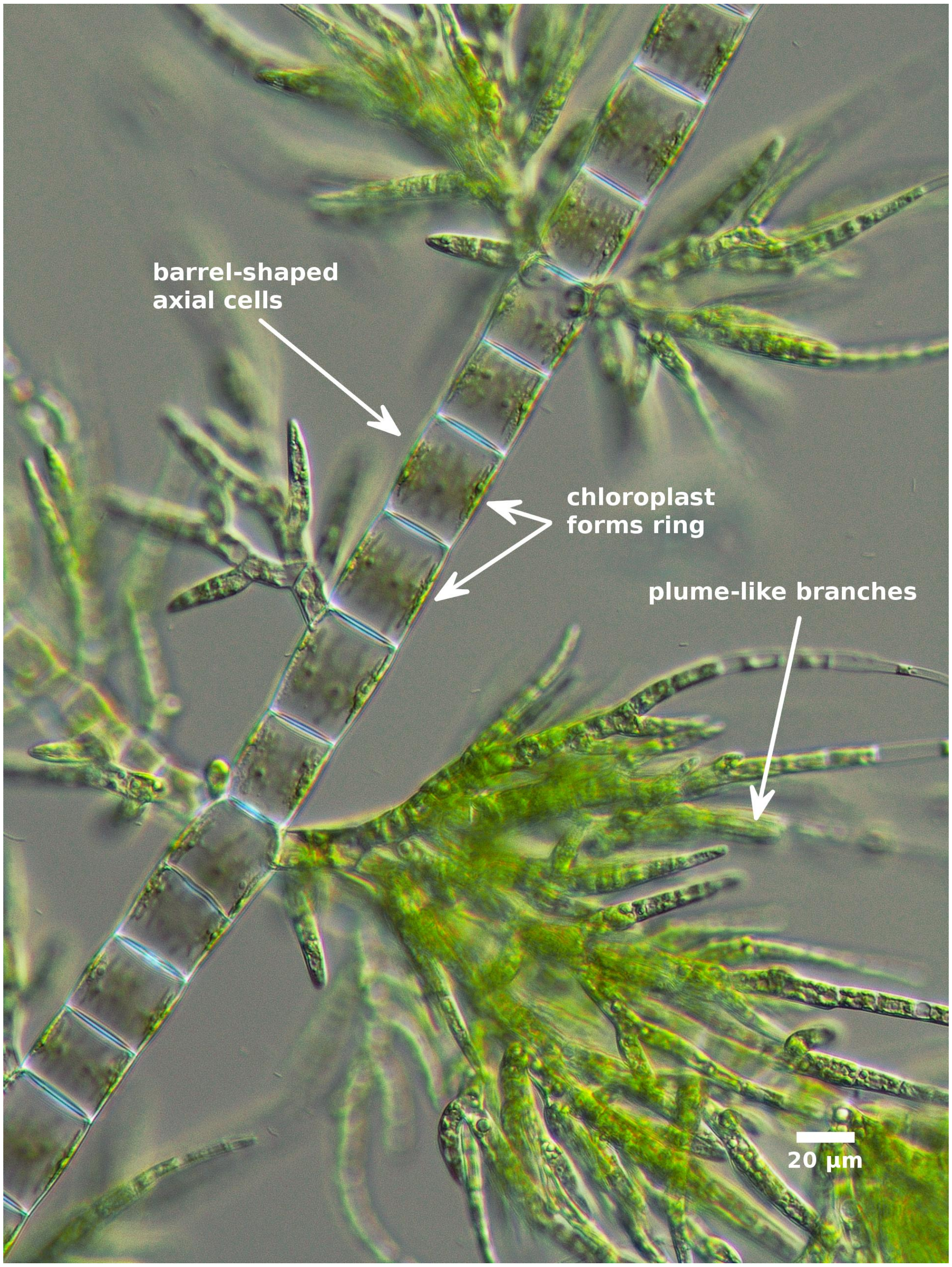

Figure 4.47: *Draparnaldia glomerata* (200x DIC), Independence Lake, Mt. Loop Hwy, June 2, 2014.

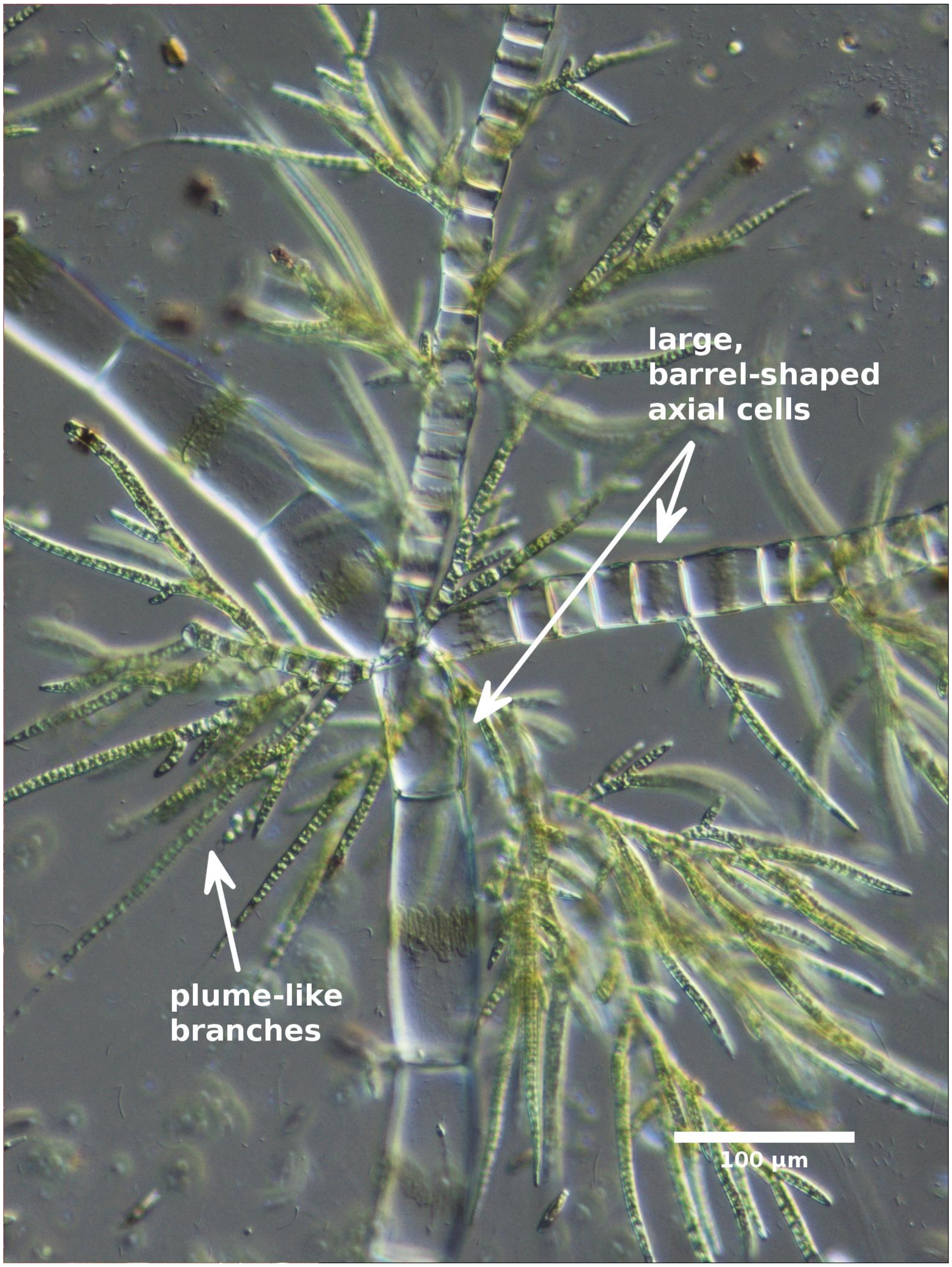

Figure 4.48: *Draparnaldia glomerata* (100x DIC), freshwater pond near Graham, Pierce County, May 10, 2011.

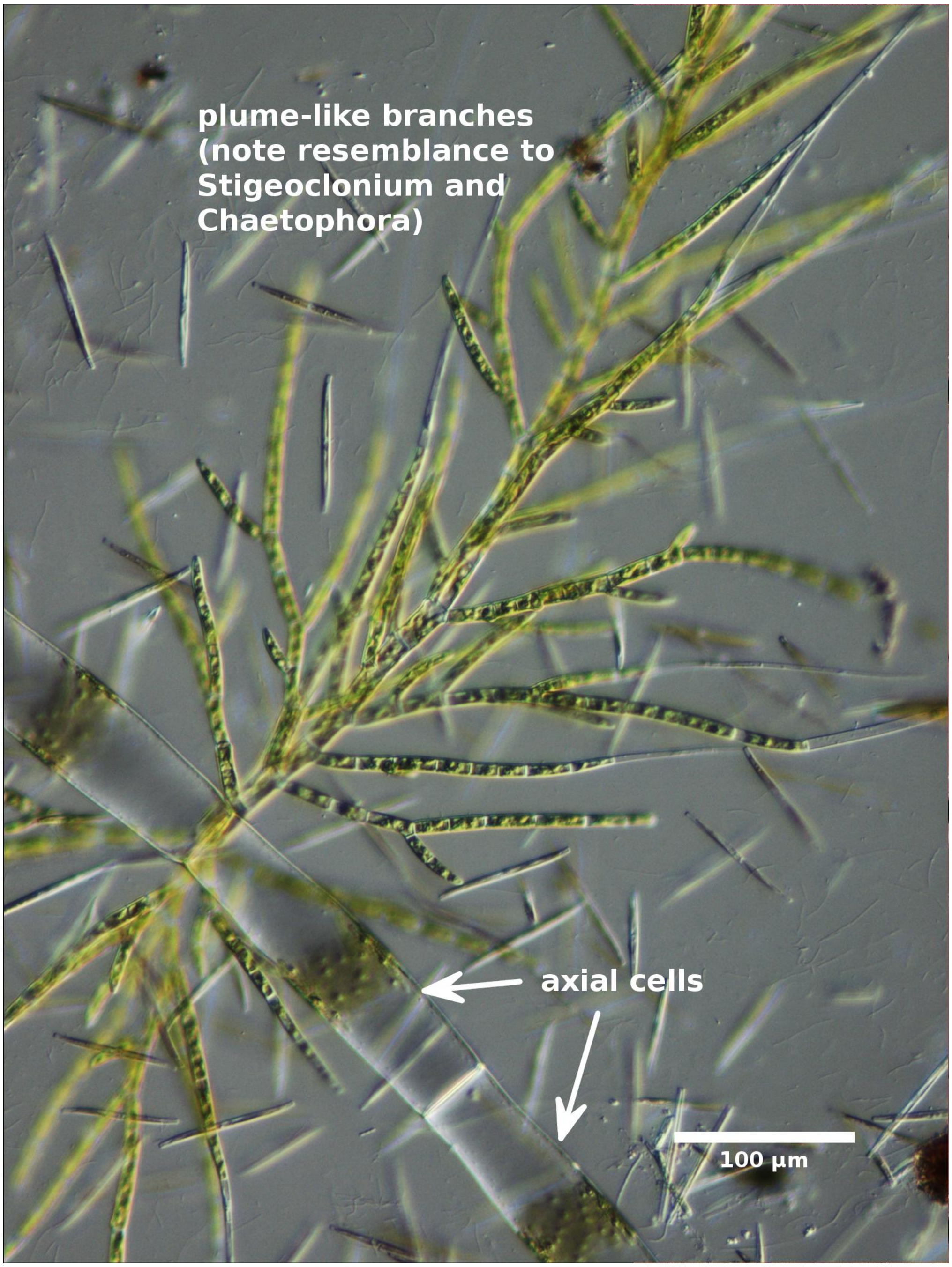

Figure 4.49: *Draparnaldia glomerata* (100x DIC), Cedar Lake, IWS water quality sampling site, Whatcom County, April 9, 2012.

Figure 4.50: *Draparnaldia glomerata* reproductive cells (600x DIC), Cedar Lake, IWS water quality sampling site, Whatcom County, April 9, 2012.

Figure 4.51: *Draparnaldia glomerata* reproductive cells (200x DIC), Cedar Lake, IWS water quality sampling site, Whatcom County, April 9, 2012.

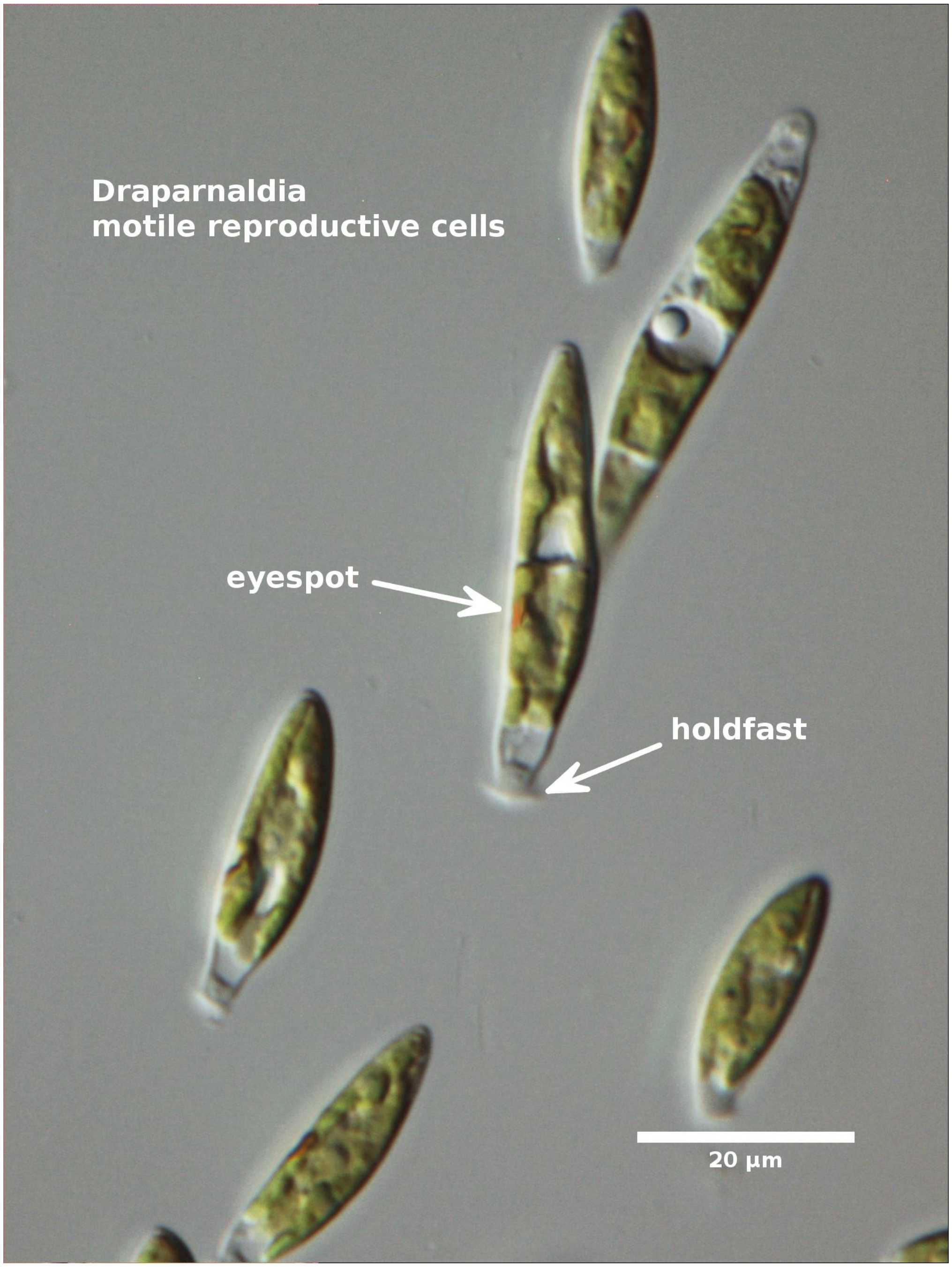

Figure 4.52: *Draparnaldia glomerata* reproductive cells (600x DIC), Cedar Lake, IWS water quality sampling site, Whatcom County, April 9, 2012.

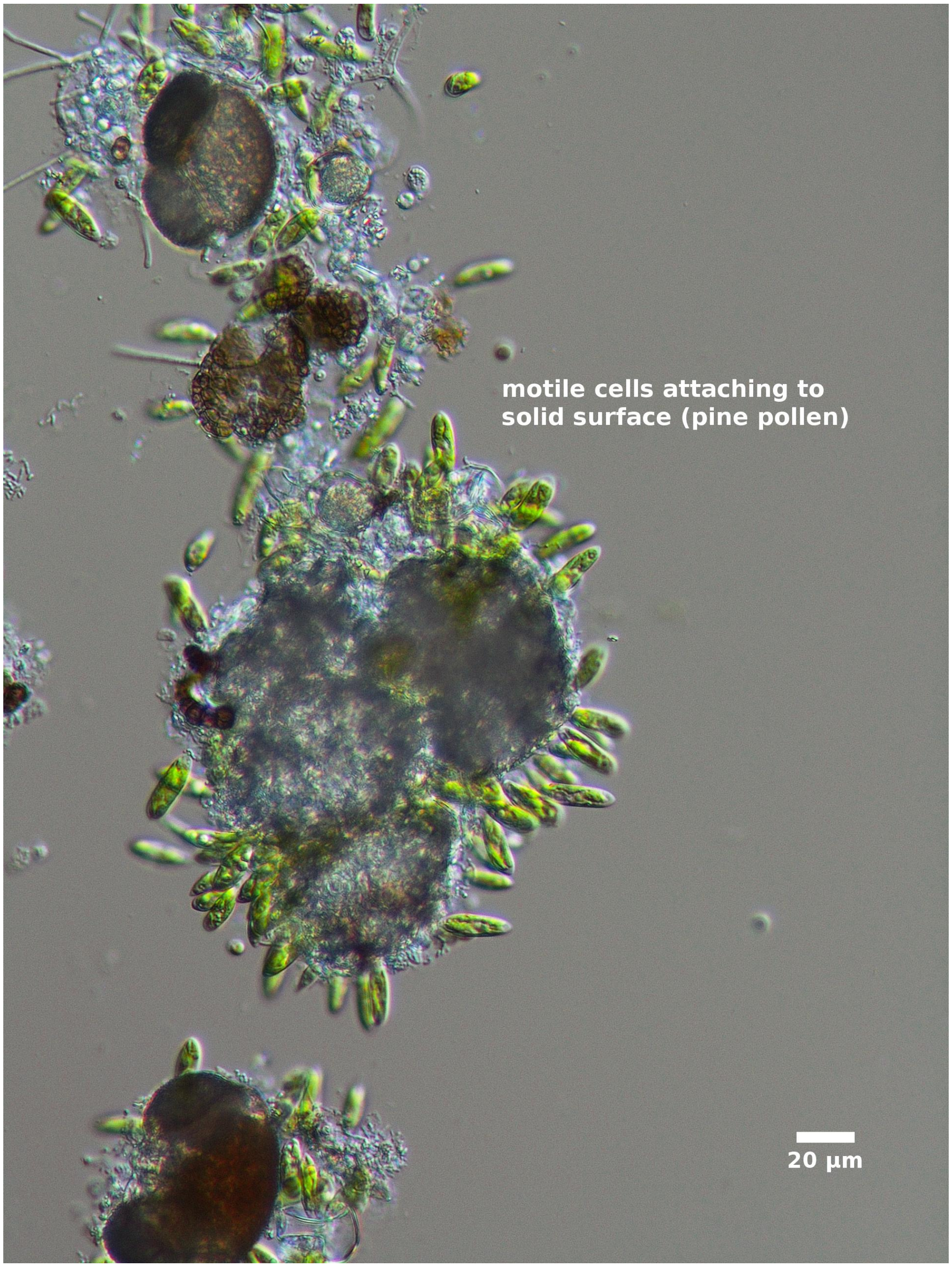

Figure 4.53: *Draparnaldia glomerata* reproductive cells (200x DIC), Independence Lake, Mt. Loop Hwy, June 2, 2014.

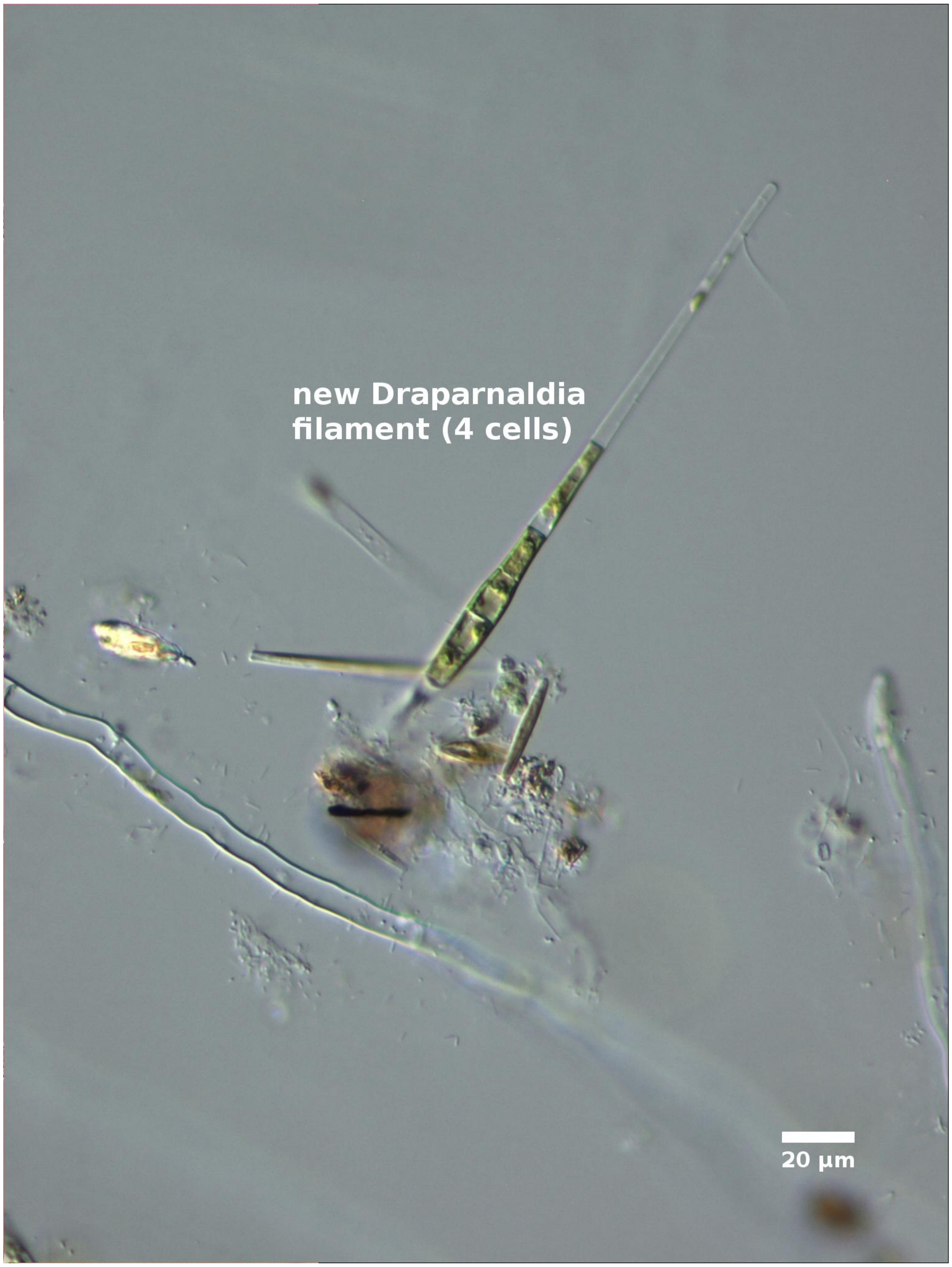

Figure 4.54: *Draparnaldia glomerata* new filament (200x DIC), Cedar Lake, IWS water quality sampling site, Whatcom County, April 9, 2012.

Figure 4.55: *Draparnaldia glomerata* new filaments (200x DIC), Diablo Lake, Ross Lake National Recreation Area, September 20, 2012.

4.9 *Geminella* Turpin

Local taxa

Geminella elipsoidea (Prescott) G. M. Smith;
Geminella interrupta Turpin;
Geminella minor (Nägeli) Heering; *Geminella mutabilis* (Brébisson) Wille

Abundance

Infrequently collected, but may be planktonic; may form blooms when present.

Local measurements		Width	Length	Biovolume†
Geminella elipsoidea	min	8.9 μm	6.8 μm	288 μm^3
cells (spheroid)	med	11.3 μm	9.4 μm	672 μm^3
	max	13.4 μm	14.8 μm	1,270 μm^3
Geminella interrupta	min	5.9 μm	8.6 μm	171 μm^3
cells (spheroid)	med	6.8 μm	10.6 μm	272 μm^3
	max	7.7 μm	13.8 μm	348 μm^3
Geminella minor	min	5.8 μm	11.4 μm	342 μm^3
cells (cylinder)	med	6.2 μm	14.2 μm	468 μm^3
	max	7.0 μm	17.3 μm	557 μm^3
Geminella minor, var.1	min	10.3 μm	18.8 μm	1,810 μm^3
cells (cylinder)	med	11.0 μm	25.1 μm	2,560 μm^3
	max	11.4 μm	36.0 μm	3,330 μm^3
Geminella mutabilis	min	9.6 μm	6.3 μm	304 μm^3
cells (spheroid)	med	13.7 μm	17.6 μm	1,790 μm^3
	max	15.2 μm	30.1 μm	3,360 μm^3

†Calculated using original measurements, not summary values.

Description

Geminella filaments are unbranched and enclosed in a distinct mucilaginous sheath (Figures 4.56–4.70). The cells are oval, elliptical, or cylindrical, and often are arranged in pairs. Some species have cells or cell pairs that are separated from adjacent cells, forming pseudofilaments. The cells contain a single, centrally-located, parietal chloroplast that usually contains at least one visible pyrenoid.

Geminella resembles *Gloeotila* (Section 4.10, page 619), which can be distinguished by the absence of visible pyrenoids,[21] and tendency to form very short filaments. *Geminella* also resembles *Radiofilum* (Section 4.18, page 680), which has spherical or bead-like cells enclosed in a wide mucilage layer. *Geminella* and *Radiofilum* are often associated with soft, boggy or acidic water (John, et al., 2011), and most of the local specimens were collected in boggy mountain lakes or shallow, low elevation wetlands. Another interesting feature shared by *Geminella* and *Radiofilum* is the occasional tendency for some cells to divide parallel to the filament, resulting in cell clumps or multiseriate filaments (multiple rows) enclosed in the common mucilage layer (e.g., Figure 4.59 and Figures 4.127 in Section 4.18).

Geminella elipsoidea cells are broadly rounded, cubical or rectangular, and usually slightly wider than long. The cells form pairs that are attached along most of the end wall within the pair, but may be attached or unattached between pairs, forming a pseudofilament (Figures 4.56–4.59). The chloroplast is large, filling most of the cell, and becomes net-like (reticulated) in older cells. The filament is surrounded by wide, distinct, mucilage layer that may look slightly stratified.

Geminella interrupta cells are small, oval, and usually paired (Figures 4.60–4.63). Each cell pair is widely separated from adjacent pairs in the filament, forming a pseudofilament. The chloroplast forms a central band circling the cell and contains a visible pyrenoid. The mucilage surrounding the filament is wide and indistinct.

Geminella minor cells are long and cylindrical, often with slightly rounded end walls (Figures 4.64–4.65). The cells form a continuous chain, lacking the pair groups that characterize other species in this genus. The plate-like chloroplast is located in the center of the cell, and usually contains at least one pyrenoid. The filament is surrounded by diffuse mucilage that is difficult to see without staining.

[21] The absence of pyrenoids is not a particularly good taxonomic feature. Recent improvements in microscopy have revealed the presence of pyrenoids in species that were initially described as lacking this feature.

Geminella minor var.1 resembles *Geminella minor*, but the cells are much larger and are not rounded on the ends (Figures 4.66–4.67). Many other features are similar to *Geminella minor*, including the wide, diffuse mucilage layer surrounding the filament, so these larger cells seem to be a variety of *Geminella minor*.

Geminella mutabilis cells are long, cylindrical, and broadly rounded (Figures 4.68–4.70). The chloroplast forms a central band and usually contains a distinct pyrenoid. In this species, most of the cells are joined continuously within the filament, but occasionally the cells or cell pairs are separated from adjacent cells (pseudofilament). The filament is surrounded by a wide, distinct mucilage layer.

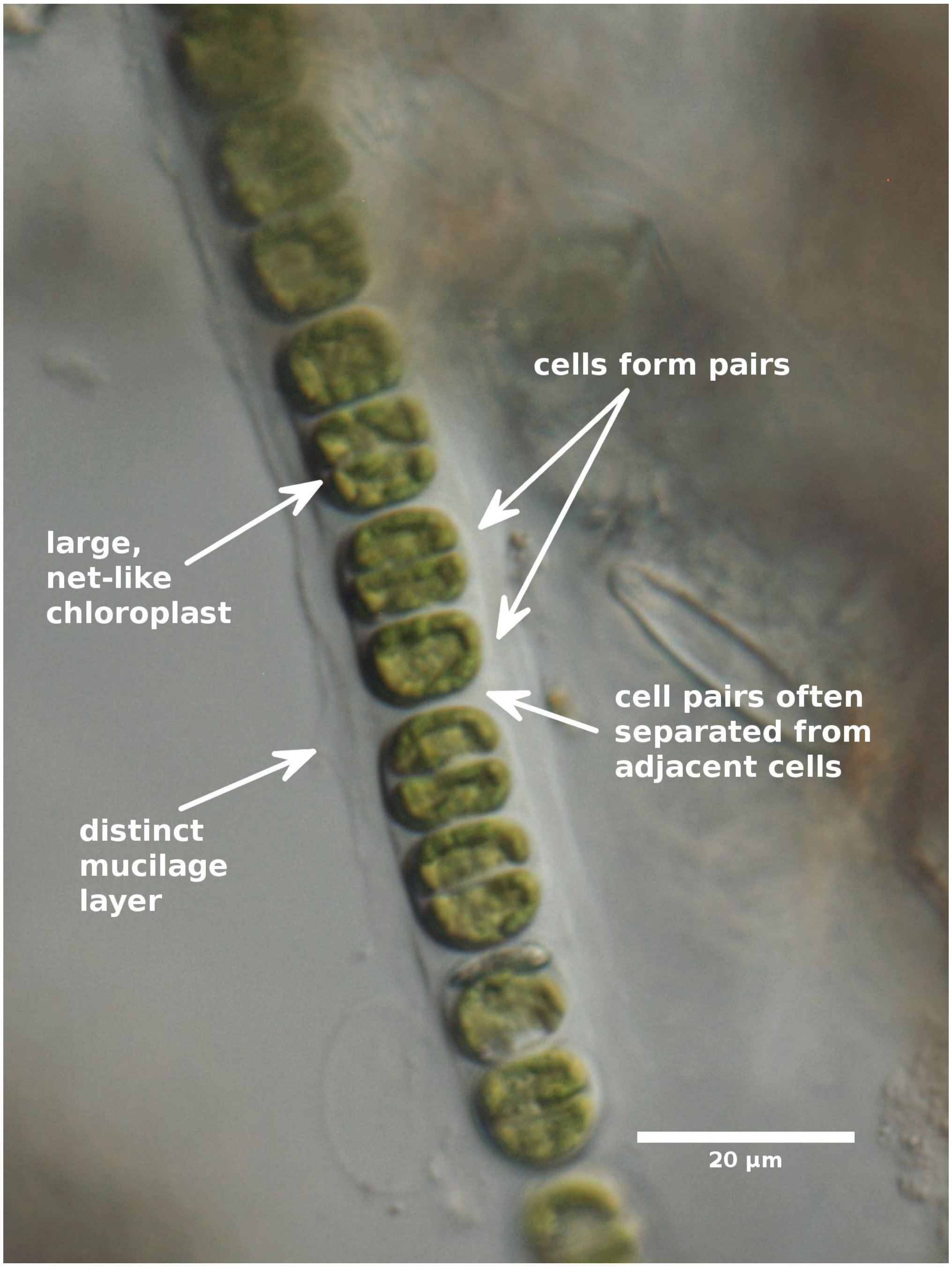

Figure 4.56: *Geminella elipsoidea* (600x DIC), Lake Evan, IWS water quality sampling site, Snohomish County, August 15, 2011.

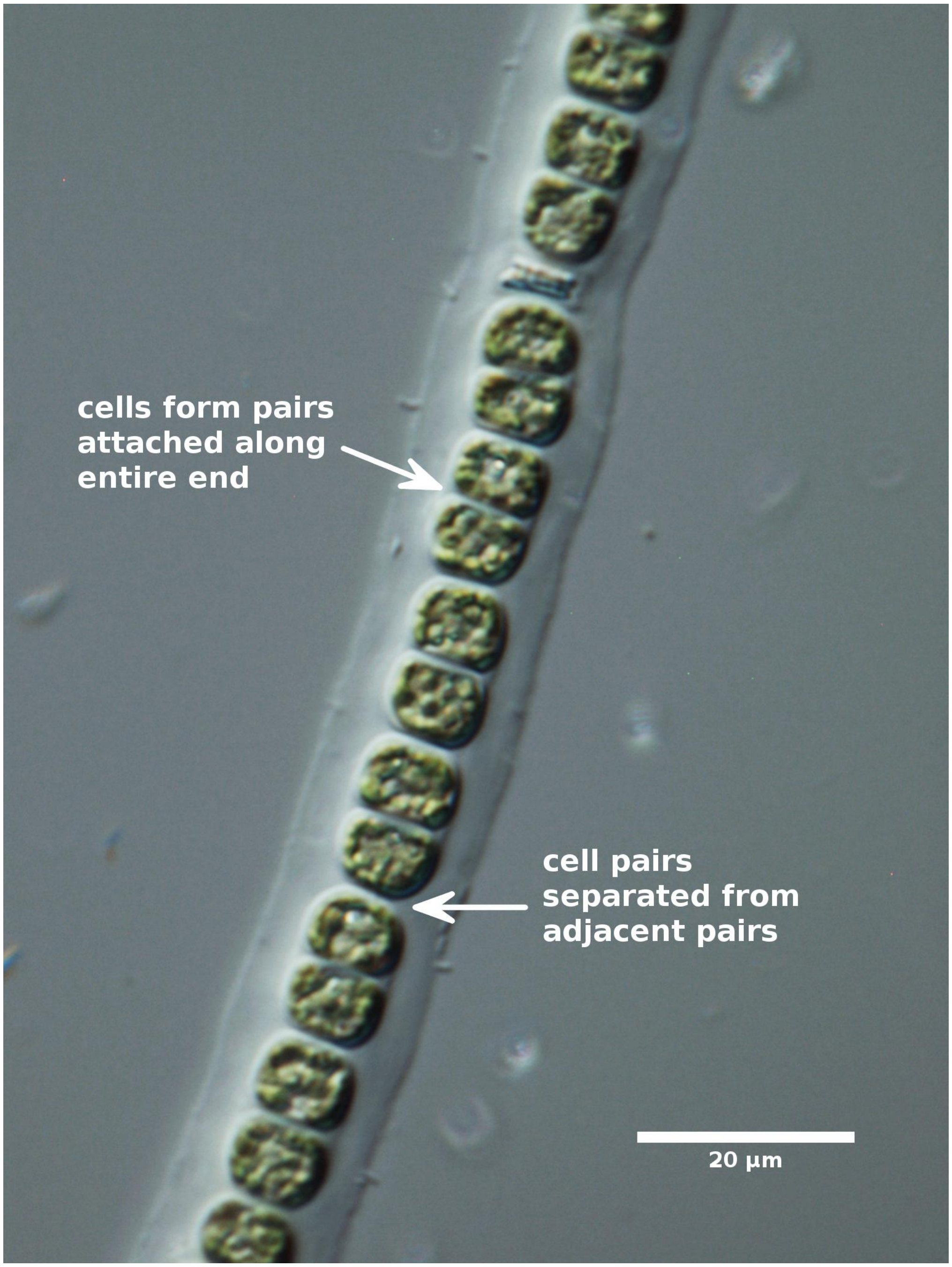

Figure 4.57: *Geminella elipsoidea* (600x DIC), Barclay Lake, North Cascades along Hwy 2, July 22, 2013.

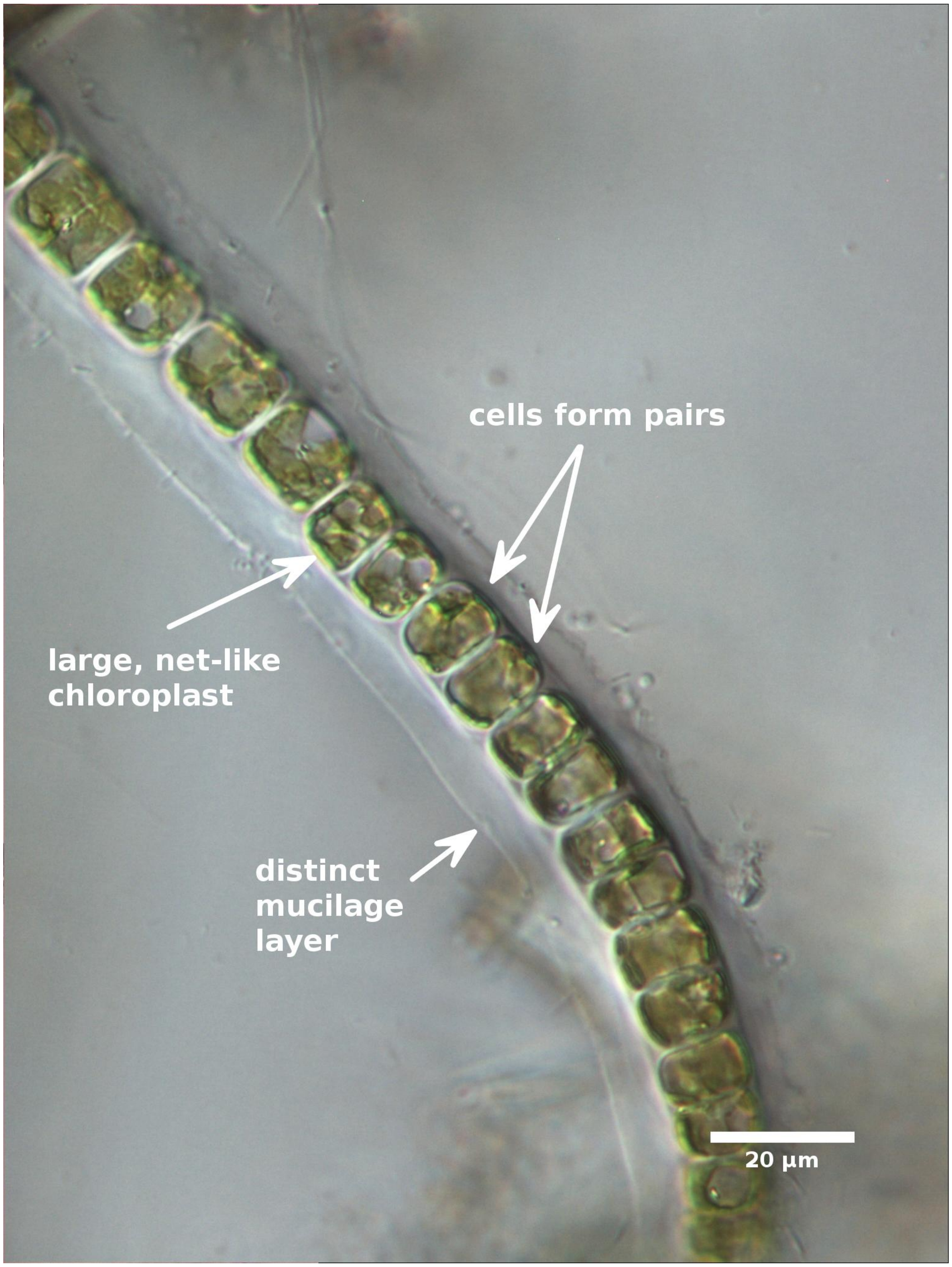

Figure 4.58: *Geminella elipsoidea* (400x DIC), Bridal Veil Falls on trail to Lake Serene, Mt. Loop Hwy, August 15, 2011.

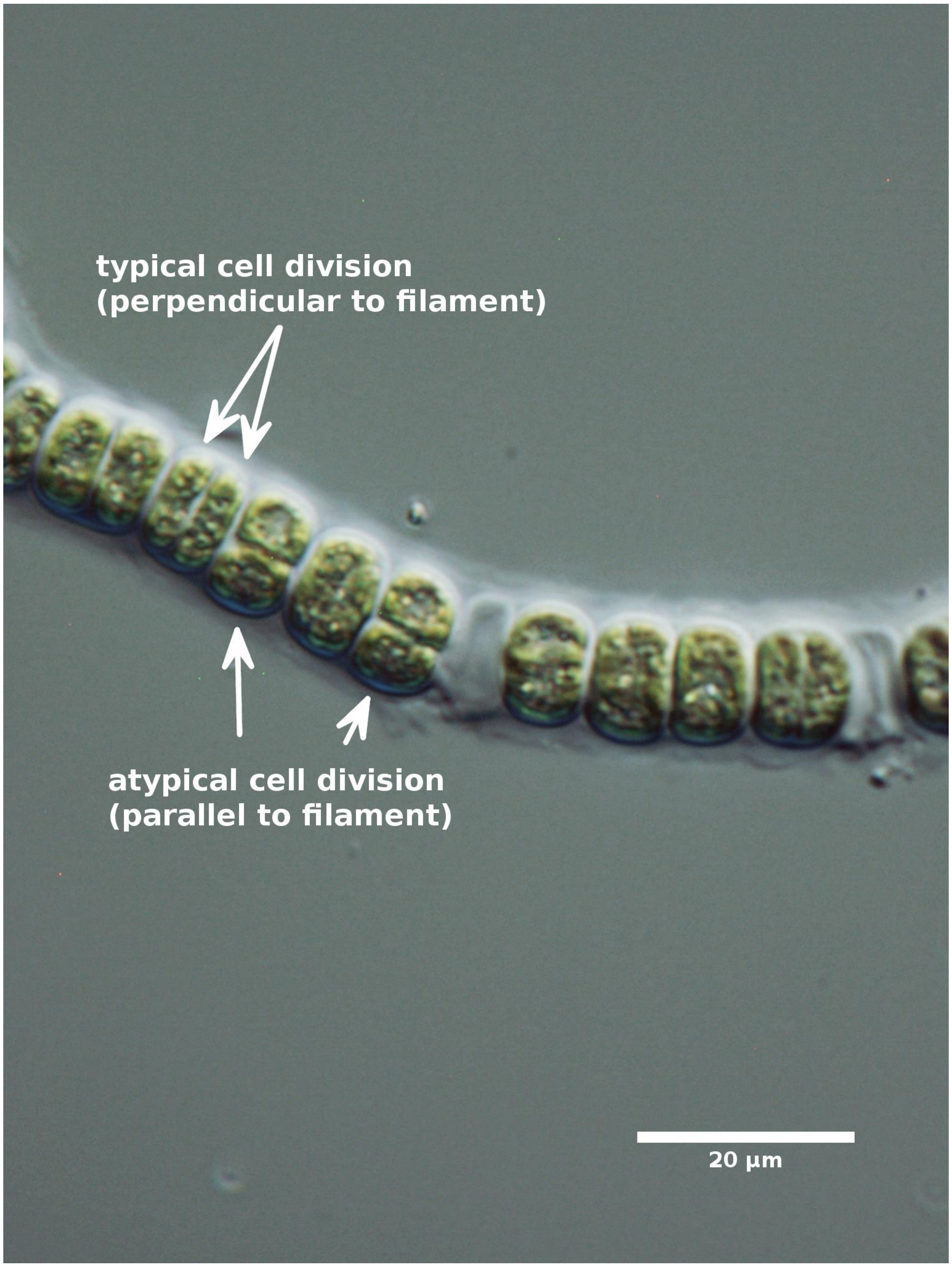

Figure 4.59: *Geminella elipsoidea* (600x DIC) showing atypical cell division, Barclay Lake, North Cascades along Hwy 2, July 22, 2013.

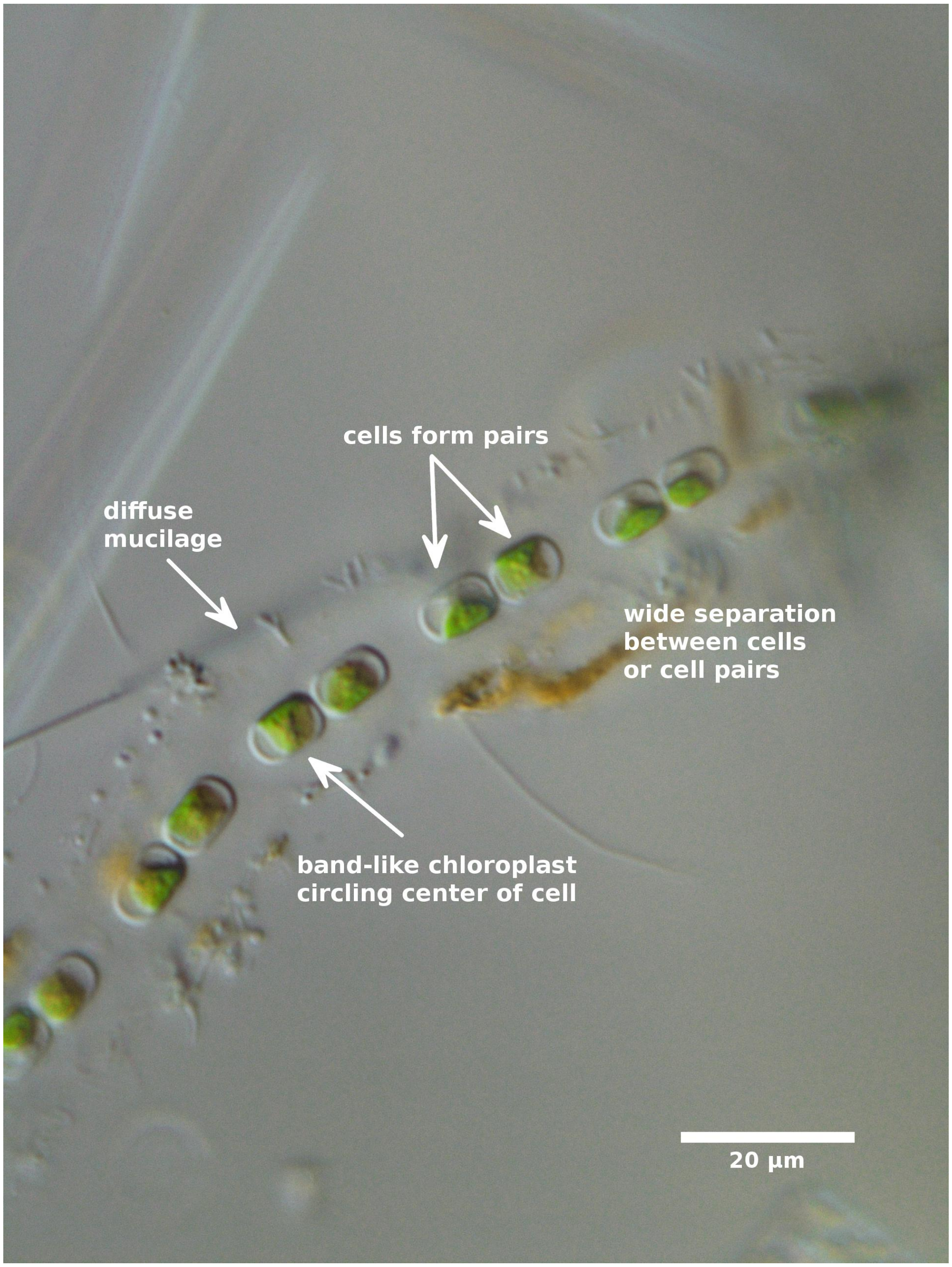

Figure 4.60: *Geminella interrupta* (600x DIC), storm water treatment pond, Whatcom County, February 12, 2016.

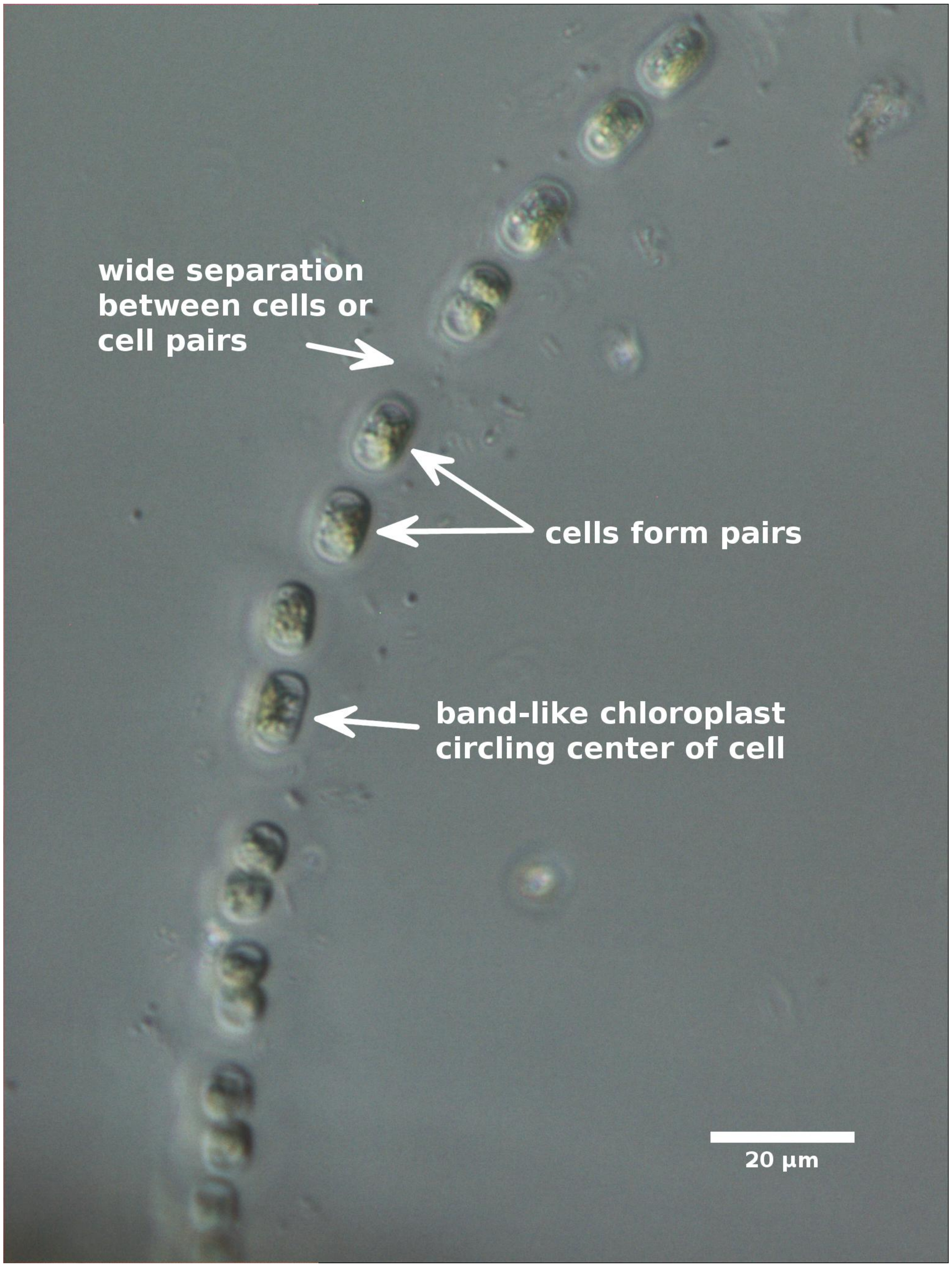

Figure 4.61: *Geminella interrupta* (400x DIC), Ross Lake, Ross Lake National Recreation Area, September 23, 2010.

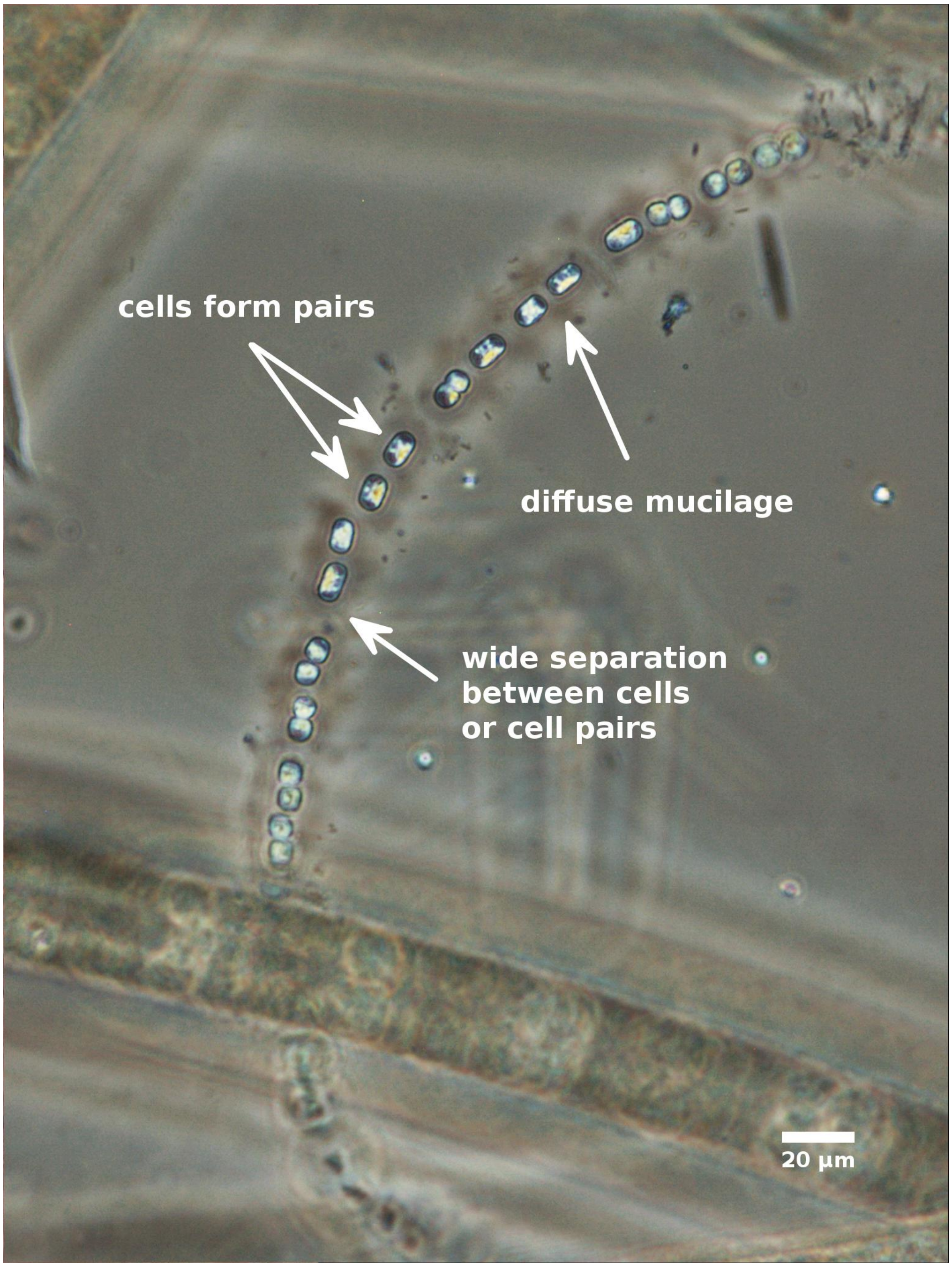

Figure 4.62: *Geminella interrupta* (200x phase contrast), Ross Lake, Ross Lake National Recreation Area, September 23, 2010.

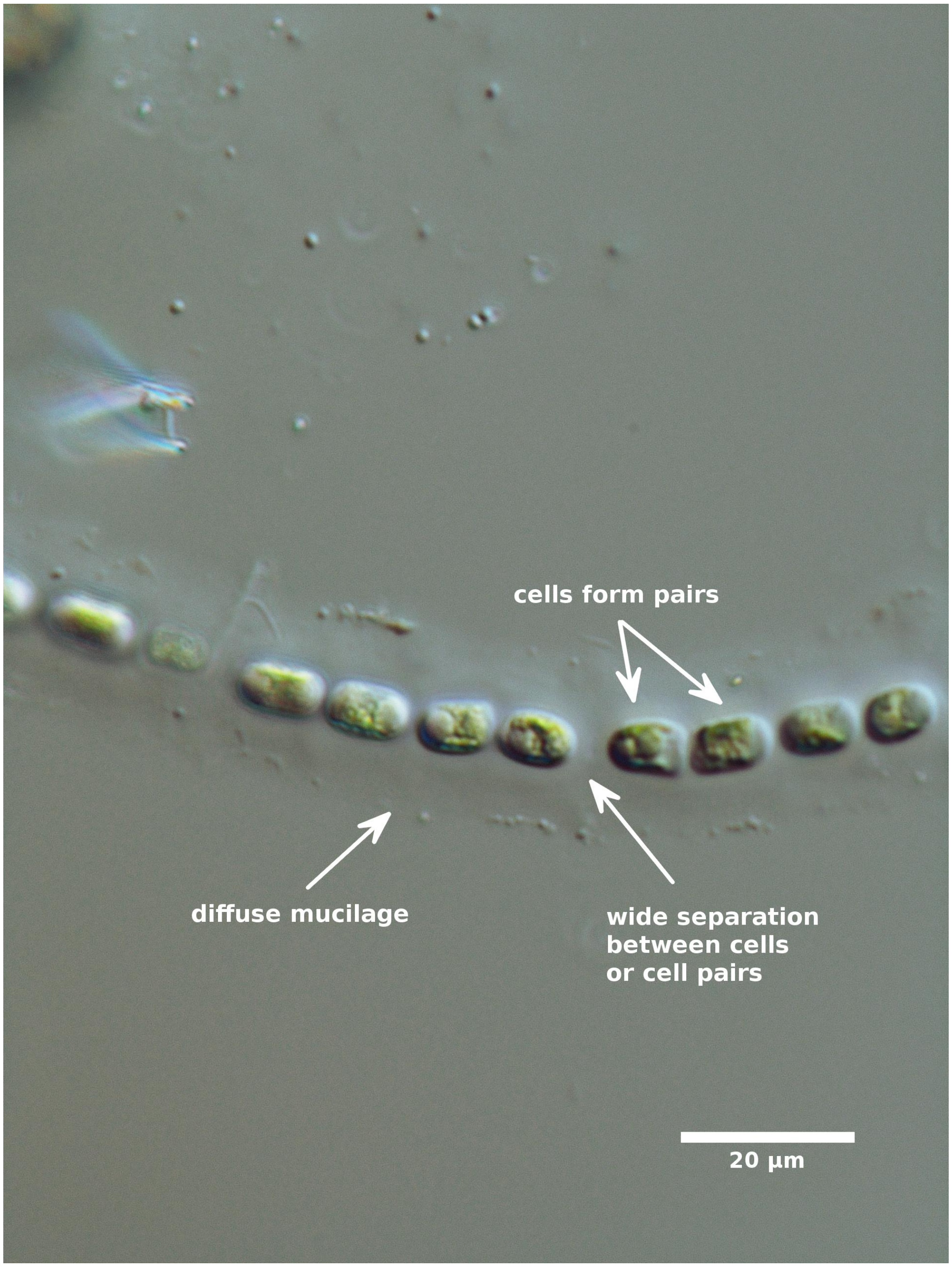

Figure 4.63: *Geminella interrupta* (600x DIC), Little Twin Lake (Winthrop area), eastern Washington, June 18, 2014.

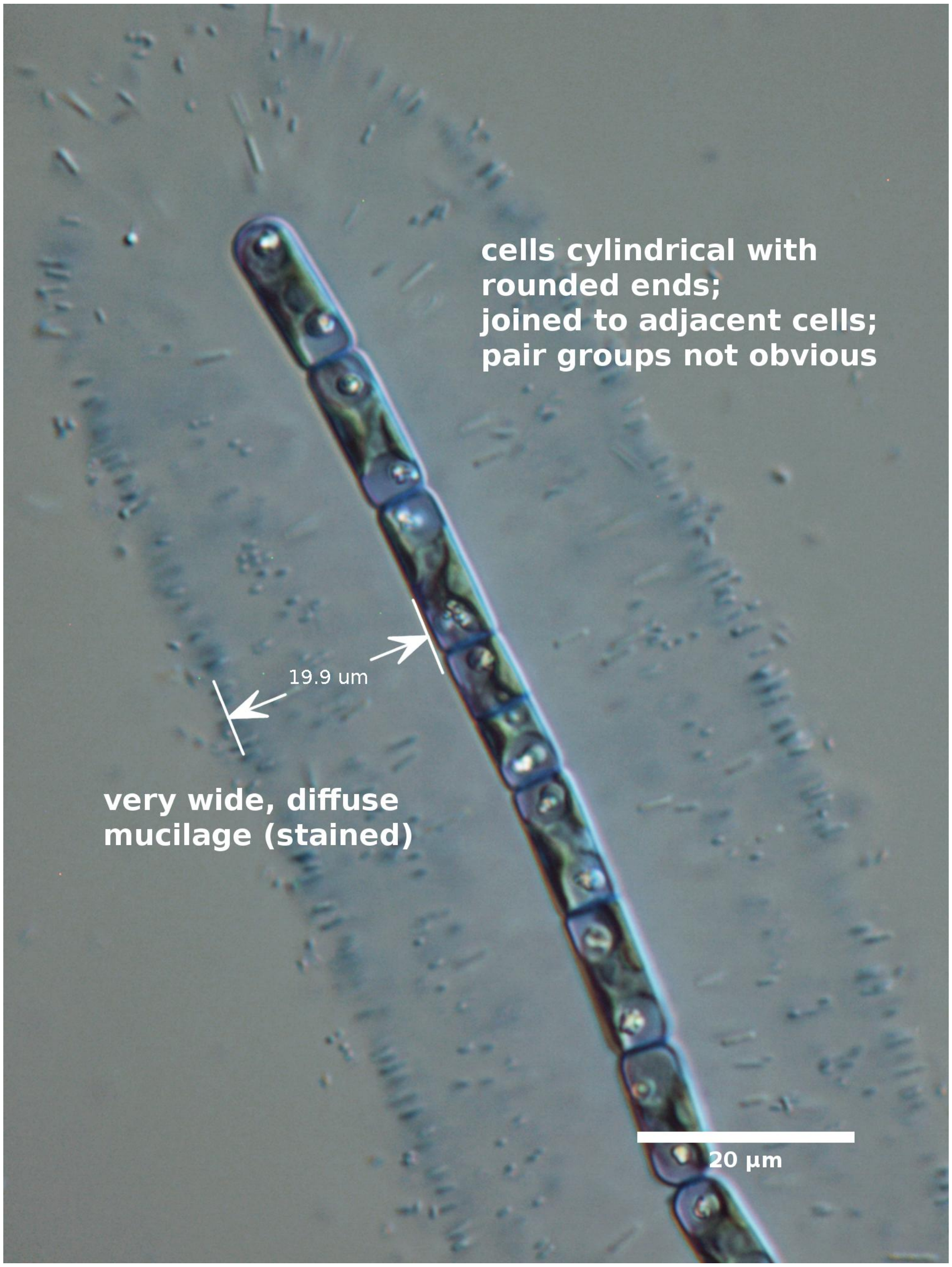

Figure 4.64: *Geminella minor* stained with methylene blue (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 30, 2013.

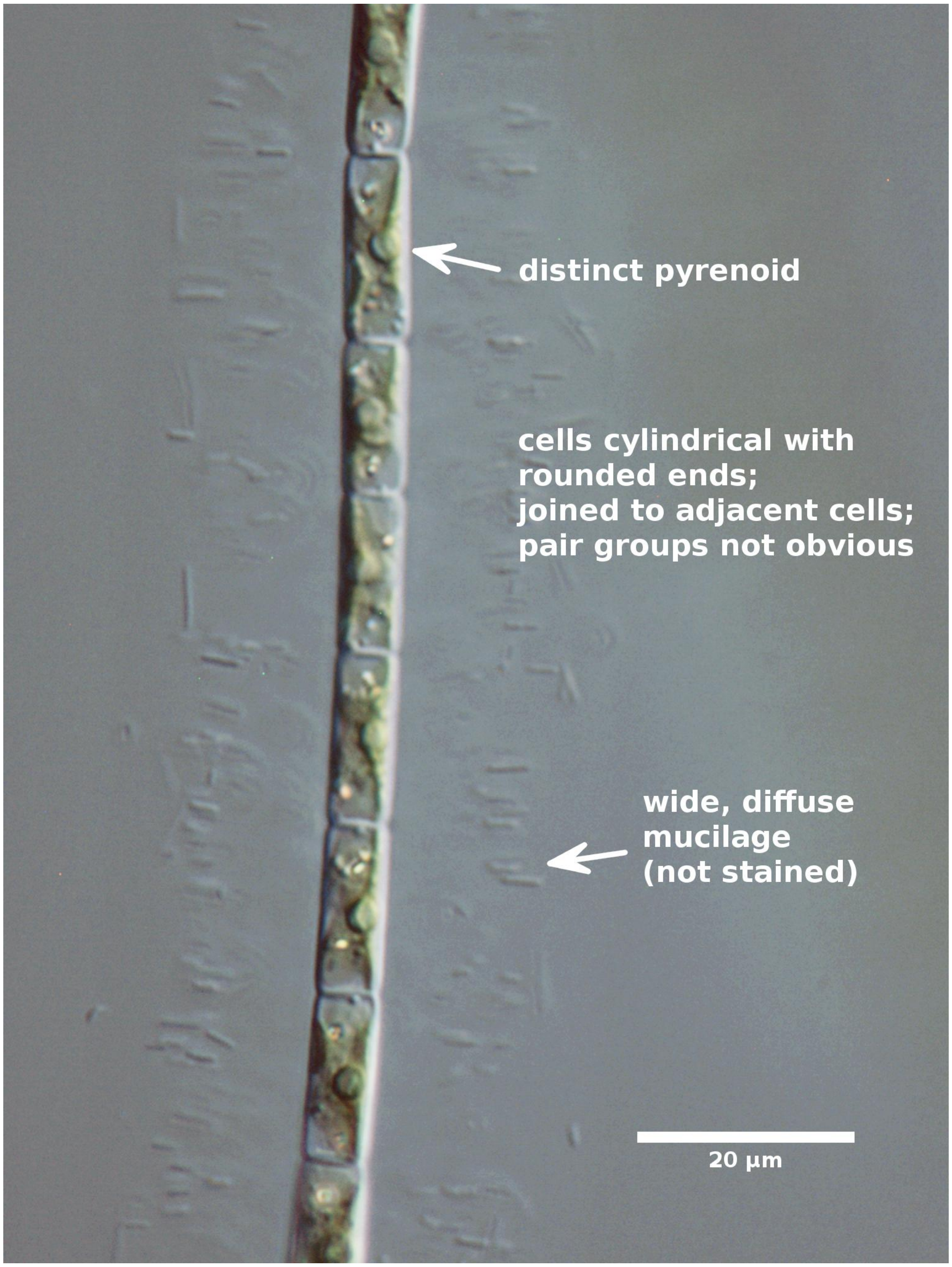

Figure 4.65: *Geminella minor* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 30, 2013.

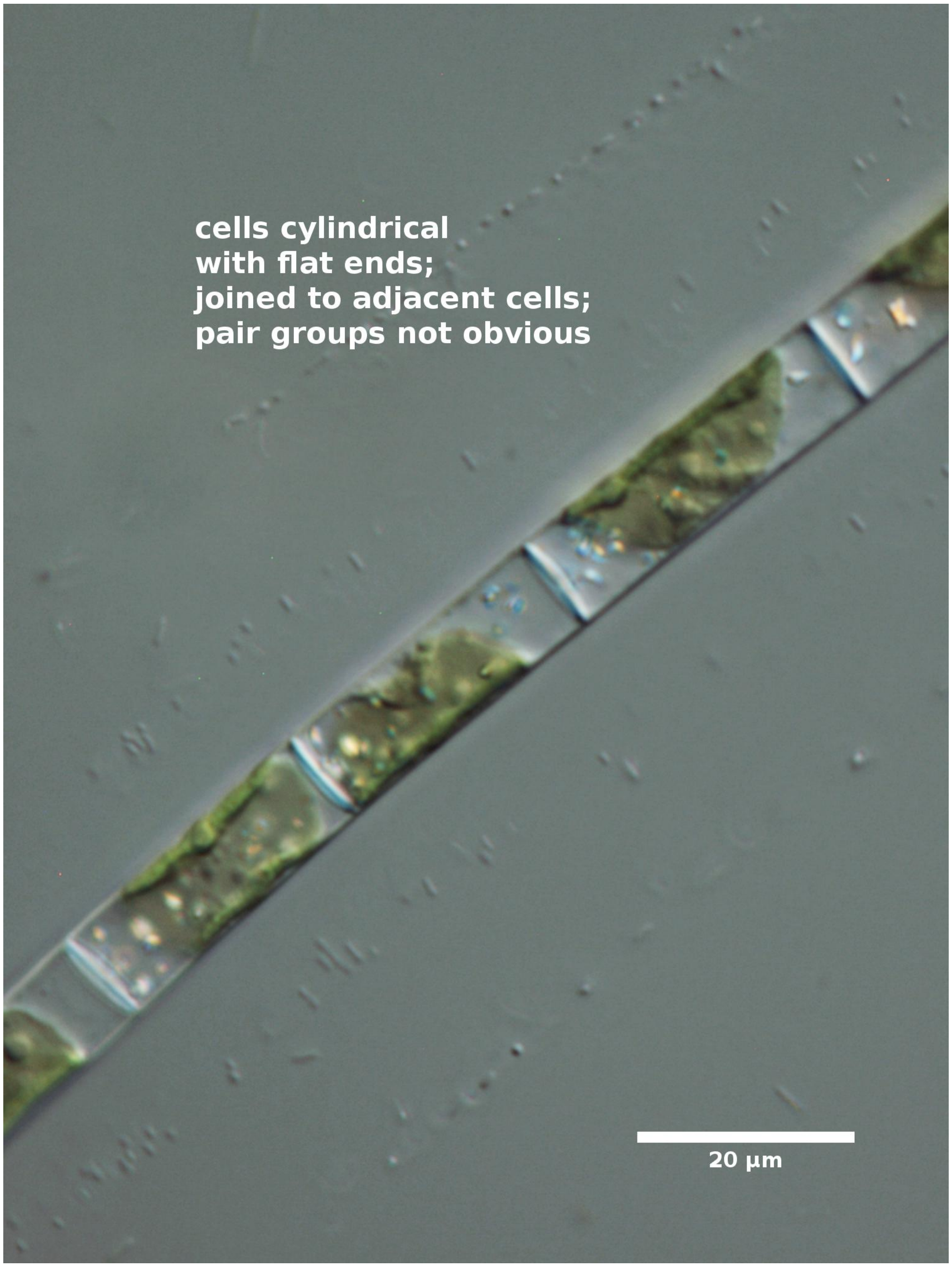

Figure 4.66: *Geminella minor* var.1 (600x DIC), Sunday Lake, IWS water quality sampling site, Snohomish County, July 16, 2013.

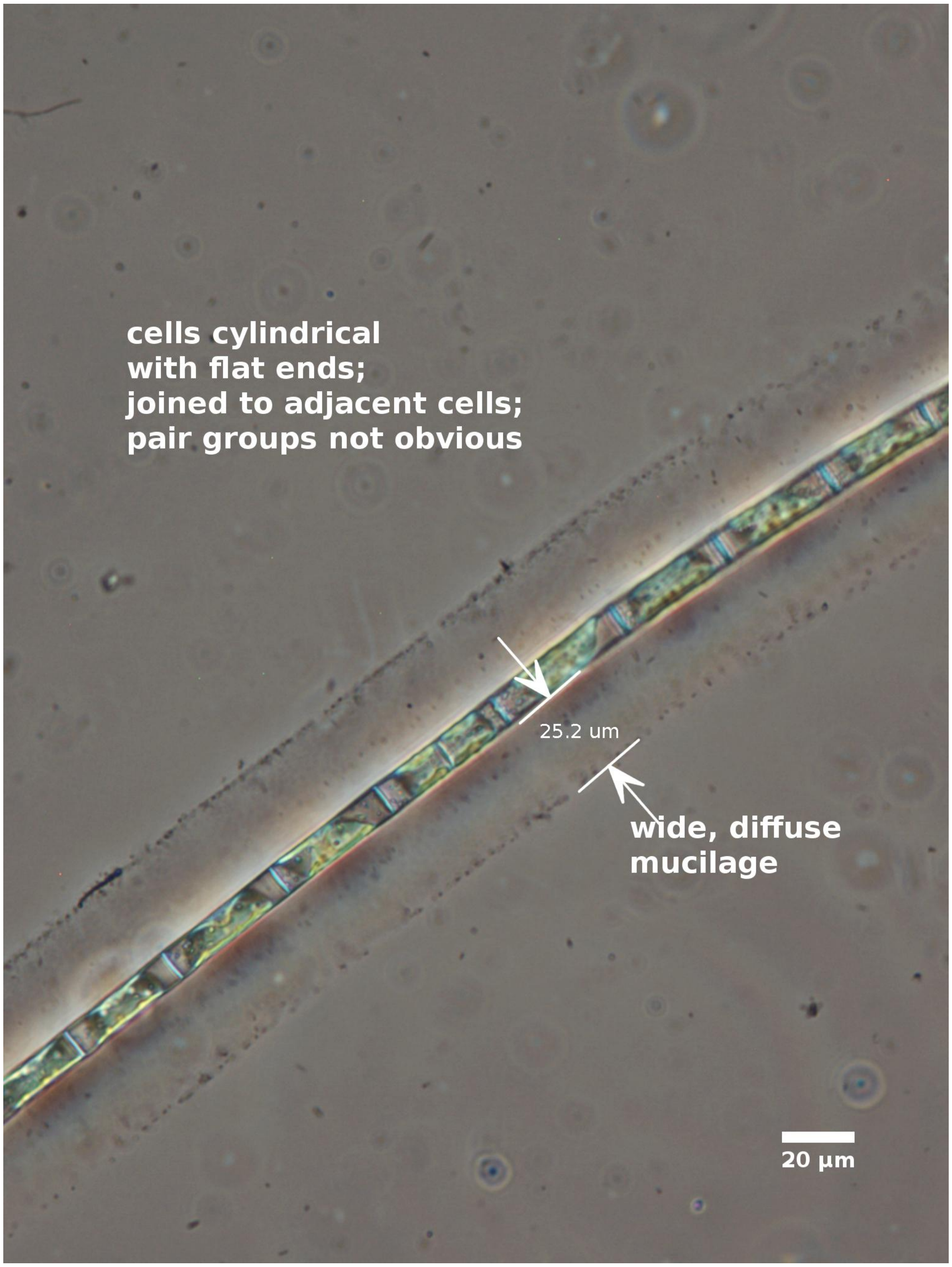

Figure 4.67: *Geminella* var.1 (200x phase contrast), Sunday Lake, IWS water quality sampling site, Snohomish County, July 16, 2013.

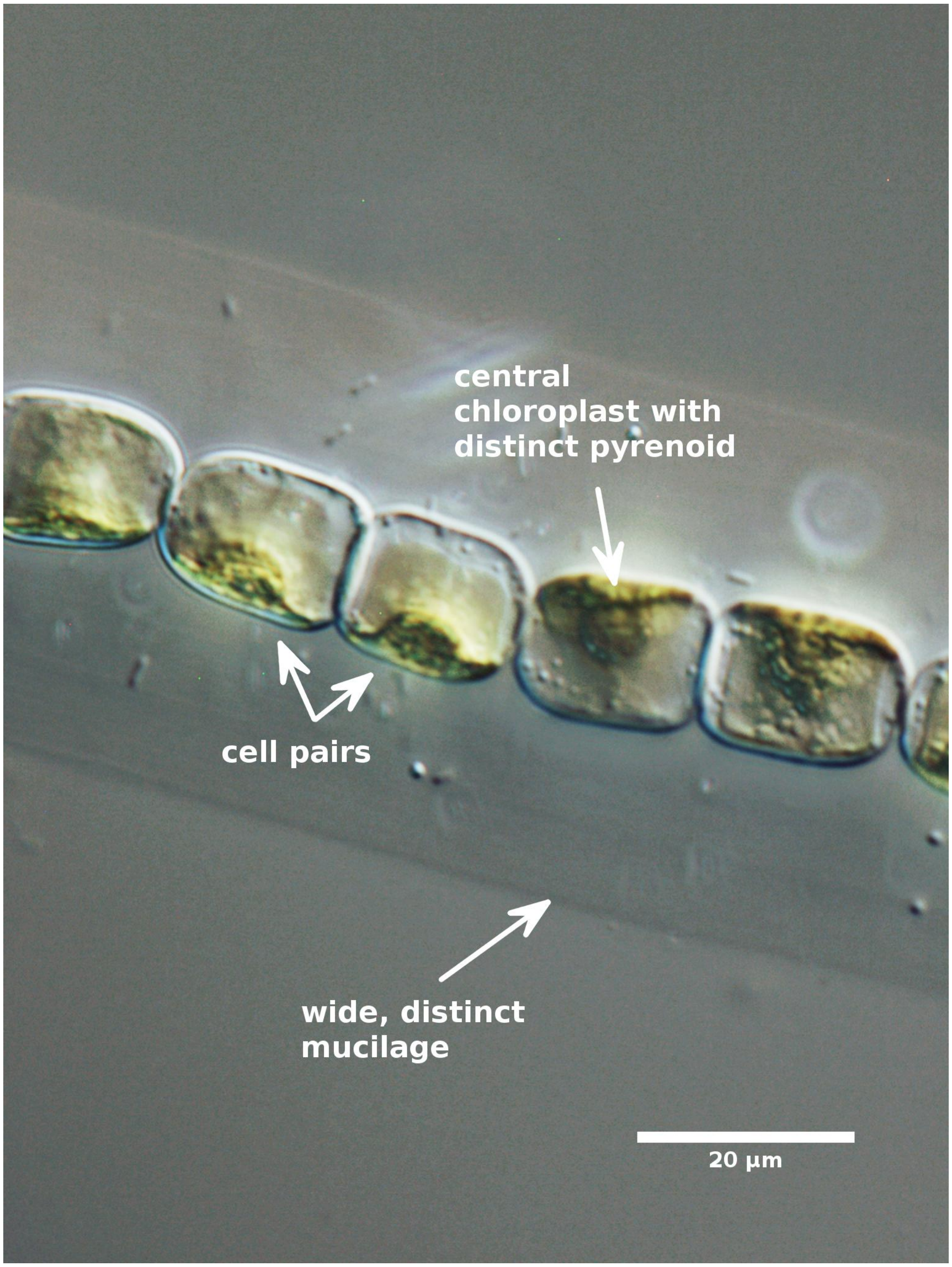

Figure 4.68: *Geminella mutabilis* (600x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, July 31, 2012.

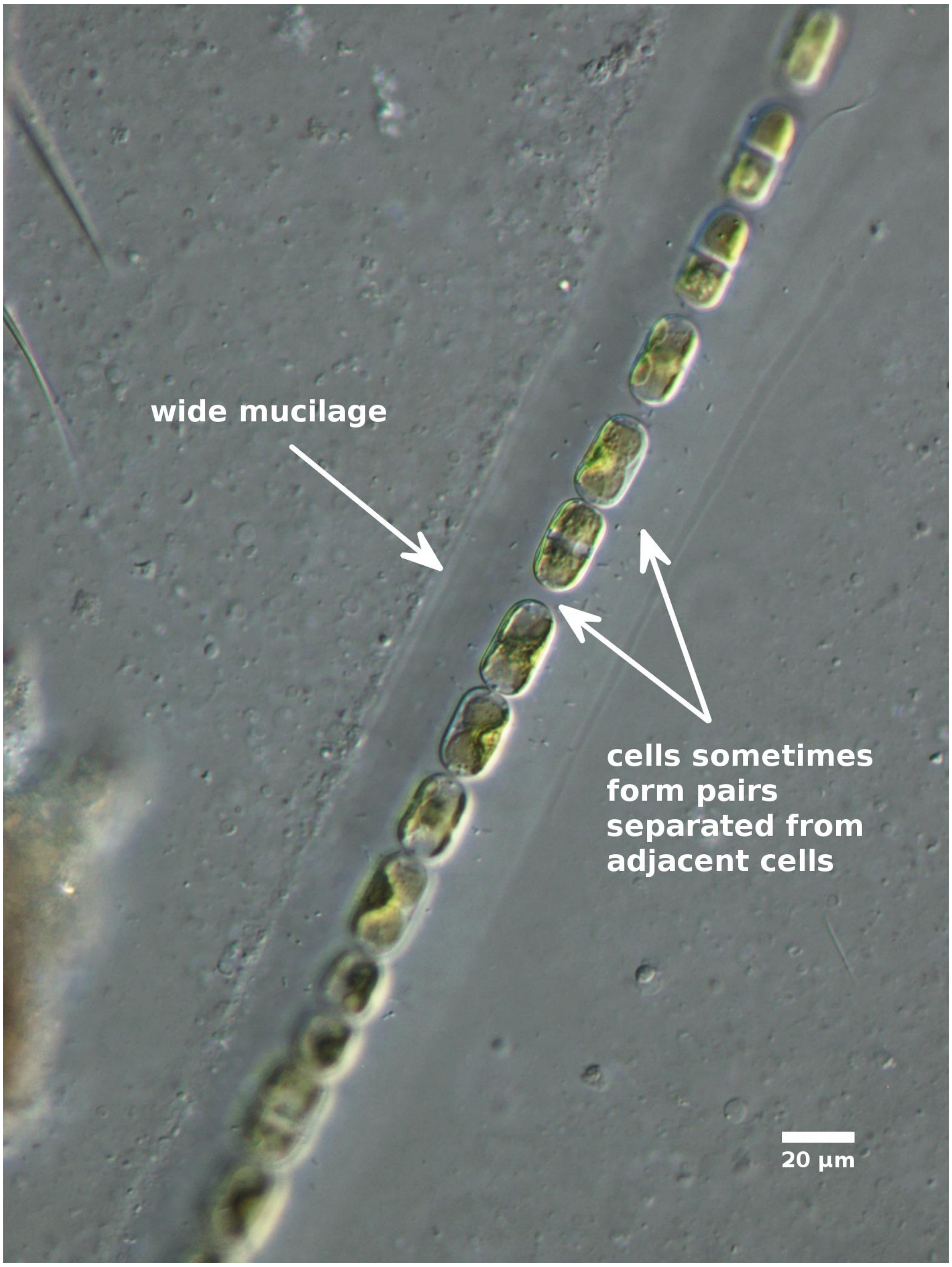

Figure 4.69: *Geminella mutabilis* (200x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, July 31, 2012.

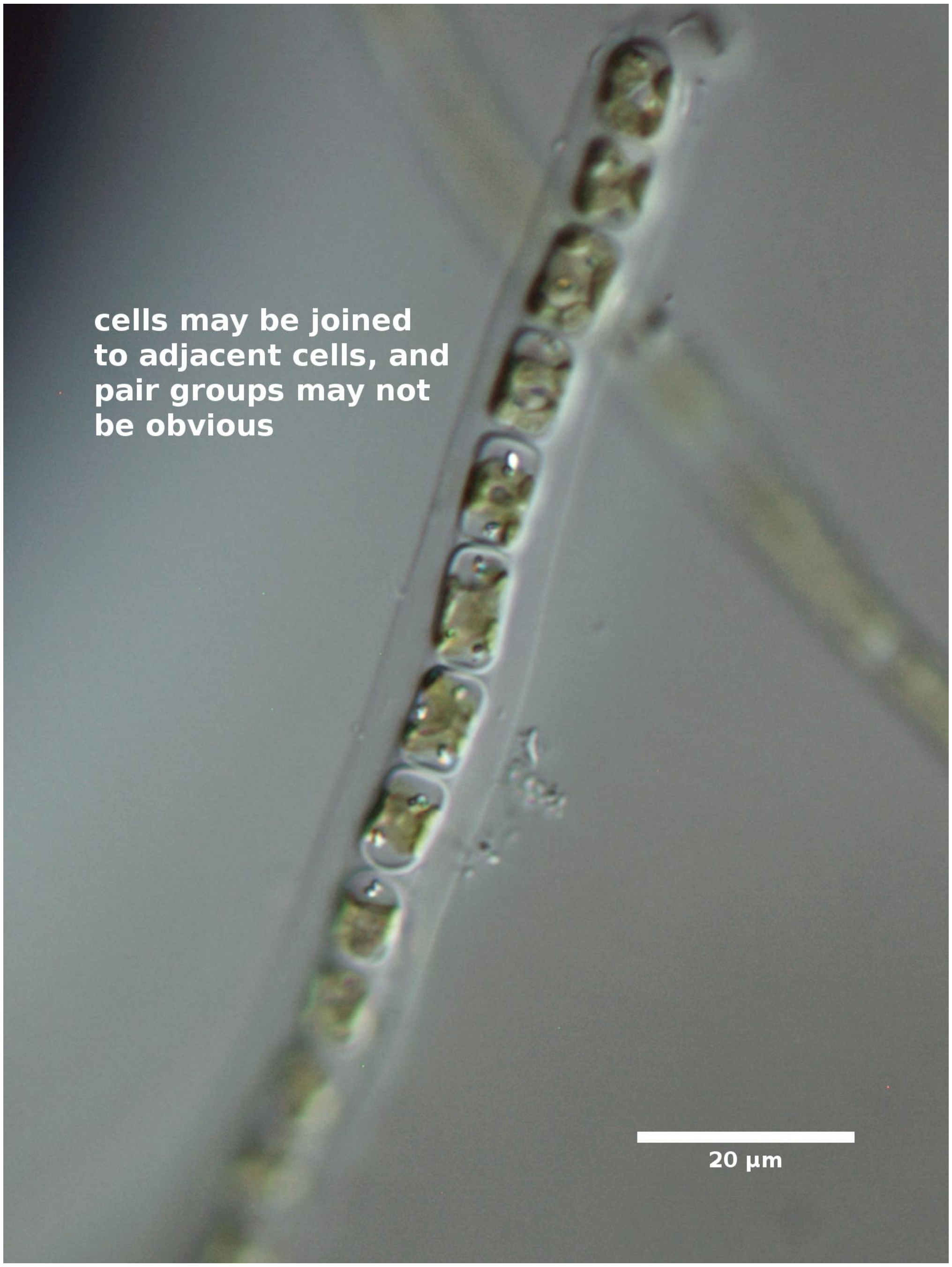

Figure 4.70: *Geminella mutabilis* (600x DIC), Bear Lake, Alpine Lakes Wilderness Area, July 12, 2013.

4.10 *Gloeotila* Kützing

Local taxon
Gloeotila monospora (Lund) Hindák

Abundance
Infrequently collected, but may be planktonic; may form blooms when present.

Local measurements		Width	Length	Biovolume†
Gloeotila monospora‡	min	3.5 μm	16.5 μm	200 μm^3
cells (cyl + two $\frac{1}{2}$ spheres)	med	4.5 μm	27.0 μm	239 μm^3
	max	5.3 μm	42.4 μm	516 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume based on cylinder length ($<$ cell length).

Description
Most species of *Gloeotila* form short filaments that may have gaps between cells (pseudofilaments). The filaments are surrounded by a diffuse mucilage that may be difficult to see unless stained with methylene blue or viewed using phase contrast illumination. The individual cells are long and cylindrical, with broadly rounded ends. The cells contain a centrally located, plate-like, parietal chloroplast that lacks visible pyrenoids[22] (Figures 4.71–4.74). *Gloeotila* closely resembles *Geminella* (Section 4.9, page 601). The major distinguishing features for *Gloeotila* are the short, easily fragmented filaments, and the absence of visible pyrenoids in the chloroplasts (Wehr, et al., 2015).

Gloeotila monospora forms short pseudofilaments with small gaps between the cells (Figures 4.71–4.74). The filaments are enclosed in a very wide, diffuse mucilaginous sheath that is difficult to see unless stained or viewed using phase contrast illumination (Figure 4.72). The individual cells are long, narrow, rounded cylinders. The chloroplast is plate-like, confined to one side of the cell, and appears to lack pyrenoids. The cells in Figure 4.74 are much shorter than the other specimens, but this type of size variation is typical for this species.

[22]The absence of pyrenoids is not a particularly good taxonomic feature. Recent improvements in microscopy have revealed the presence of pyrenoids in species that that were initially described as lacking this feature.

Figure 4.71: *Gloeotila monospora* (600x DIC), Deer Lake, IWS water quality sampling site, Island County, October 30, 2009.

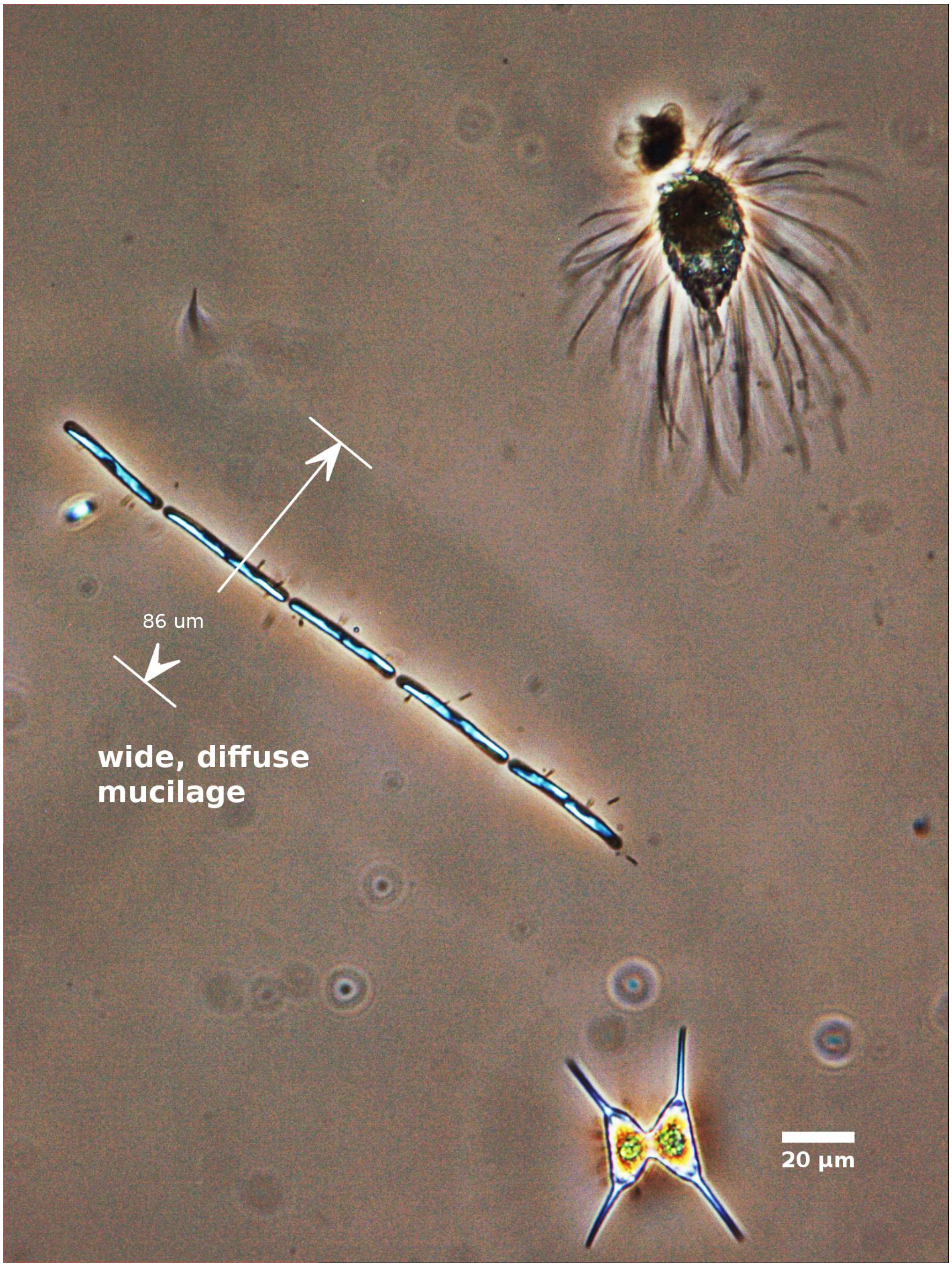

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Figure 4.72: *Gloeotila monospora* (200x phase contrast), Deer Lake, IWS water quality sampling site, Island County, October 30, 2009.

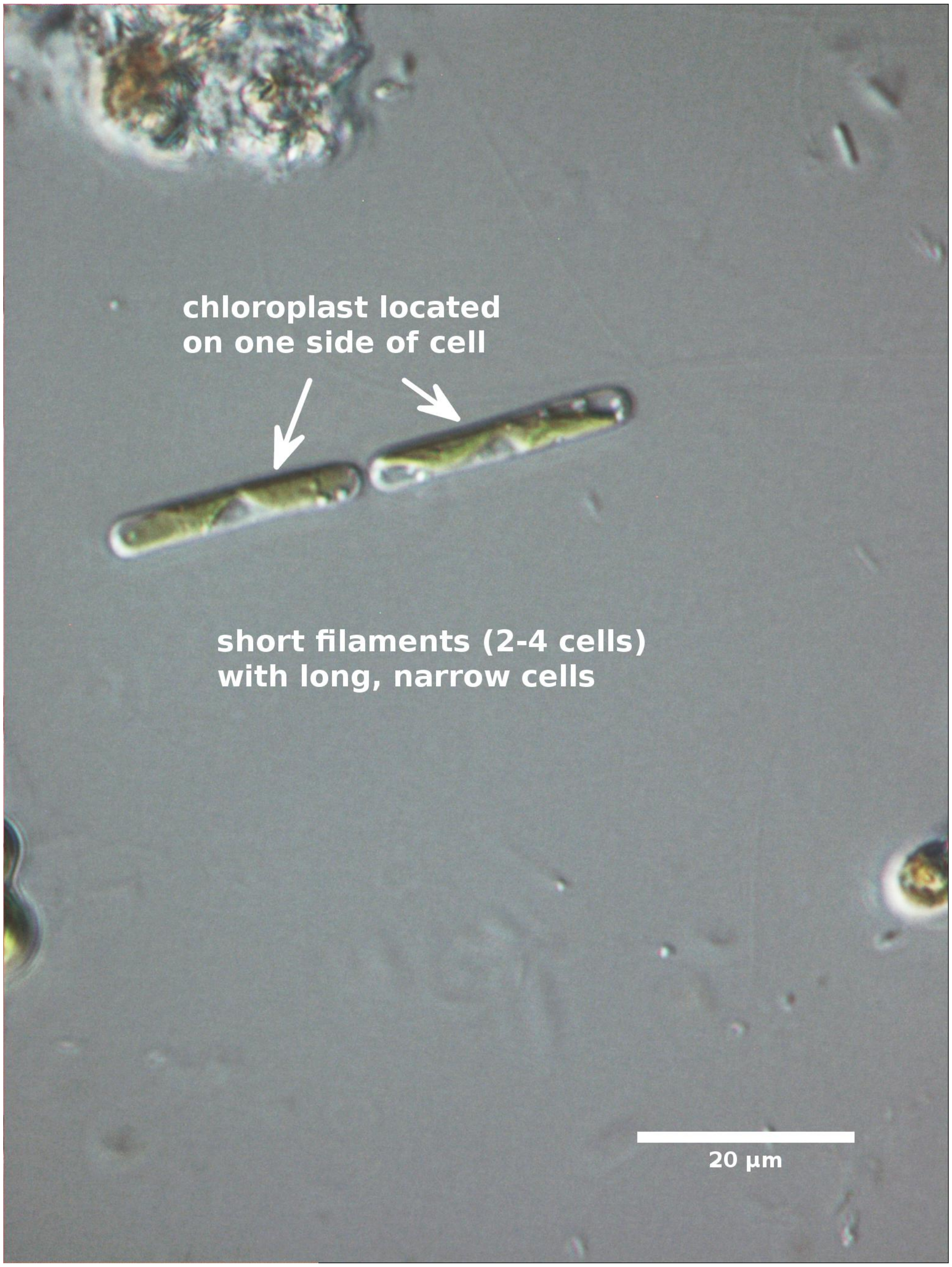

Figure 4.73: *Gloeotila monospora* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 12, 2010.

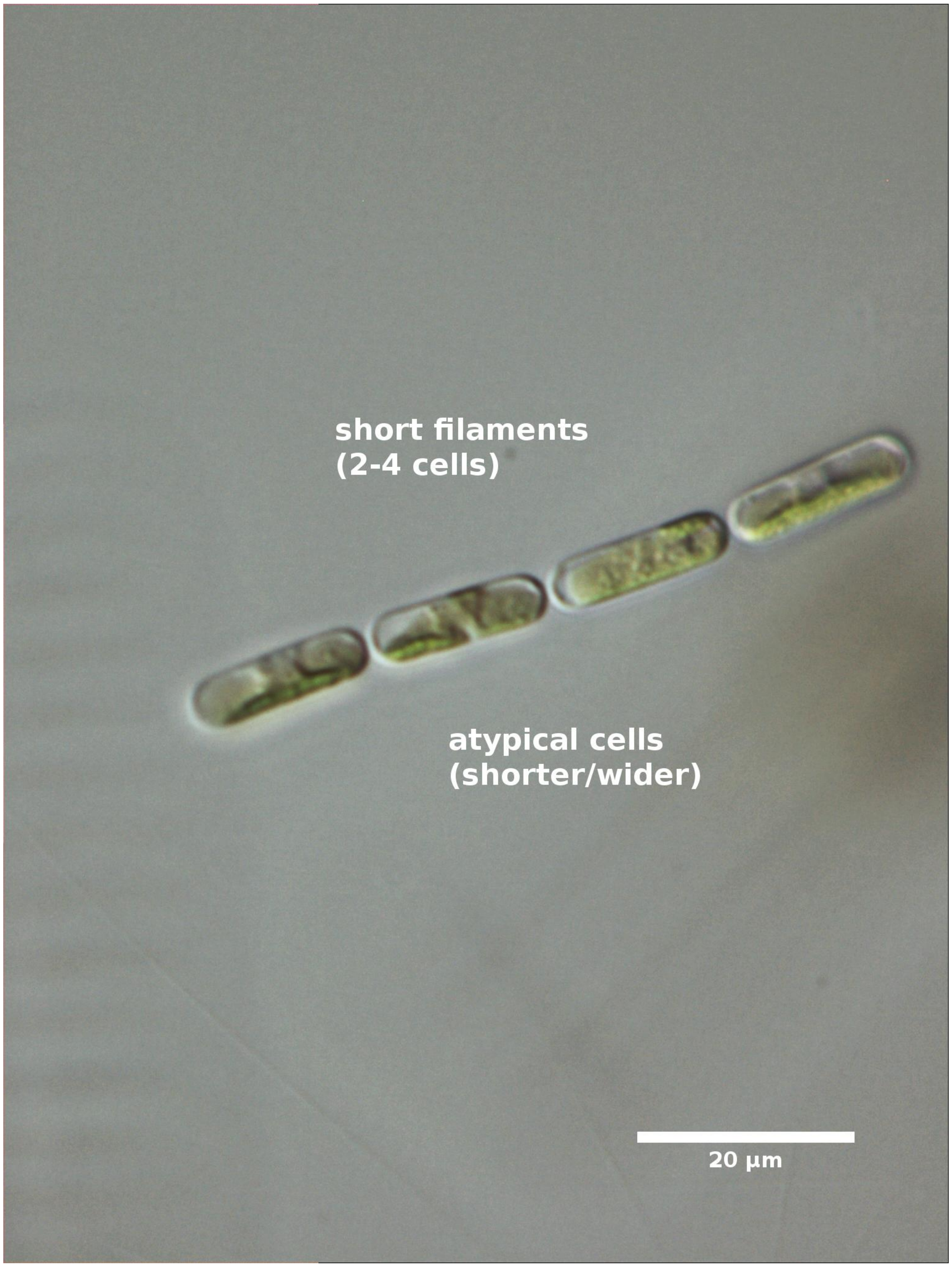

Figure 4.74: *Gloeotila monospora* (600x DIC), Lake Whatcom, IWS water quality sampling site, Whatcom County, October 5, 2011.

4.11 *Hydrodictyon* Roth

Local taxon

Hydrodictyon reticulatum (Linnaeus) Bory

Abundance

Infrequently collected.

Local measurements		Width	Length	Biovolume†
Hydrodictyon reticulatum	min	15.7 μm	56.8 μm	11,800 μm^3
cells (cylinder)	med	33.1 μm	268.9 μm	262,000 μm^3
	max	72.7 μm	655.7 μm	2,200,000 μm^3

†Calculated using original measurements, not summary values.

Description

Hydrodictyon reticulatum ("water net") forms net-like colonies containing cells joined end wise in pentagonal (5-cell) or hexagonal (6-cell) subgroups (Figures 4.75–4.79). The individual cells are cylindrical, with a parietal chloroplast that contains many small pyrenoids. The cells vary tremendously in size, forming small, medium, and large nets within the same sample. This species was collected along the shoreline in Wiser Lake (Figures 4.76–4.77) and was observed, but not photographed, in a storm water treatment pond in the Lake Whatcom watershed. *Hydrodictyon* is uncommon in plankton samples, but may be moderately common in slow moving ponds and ditches.

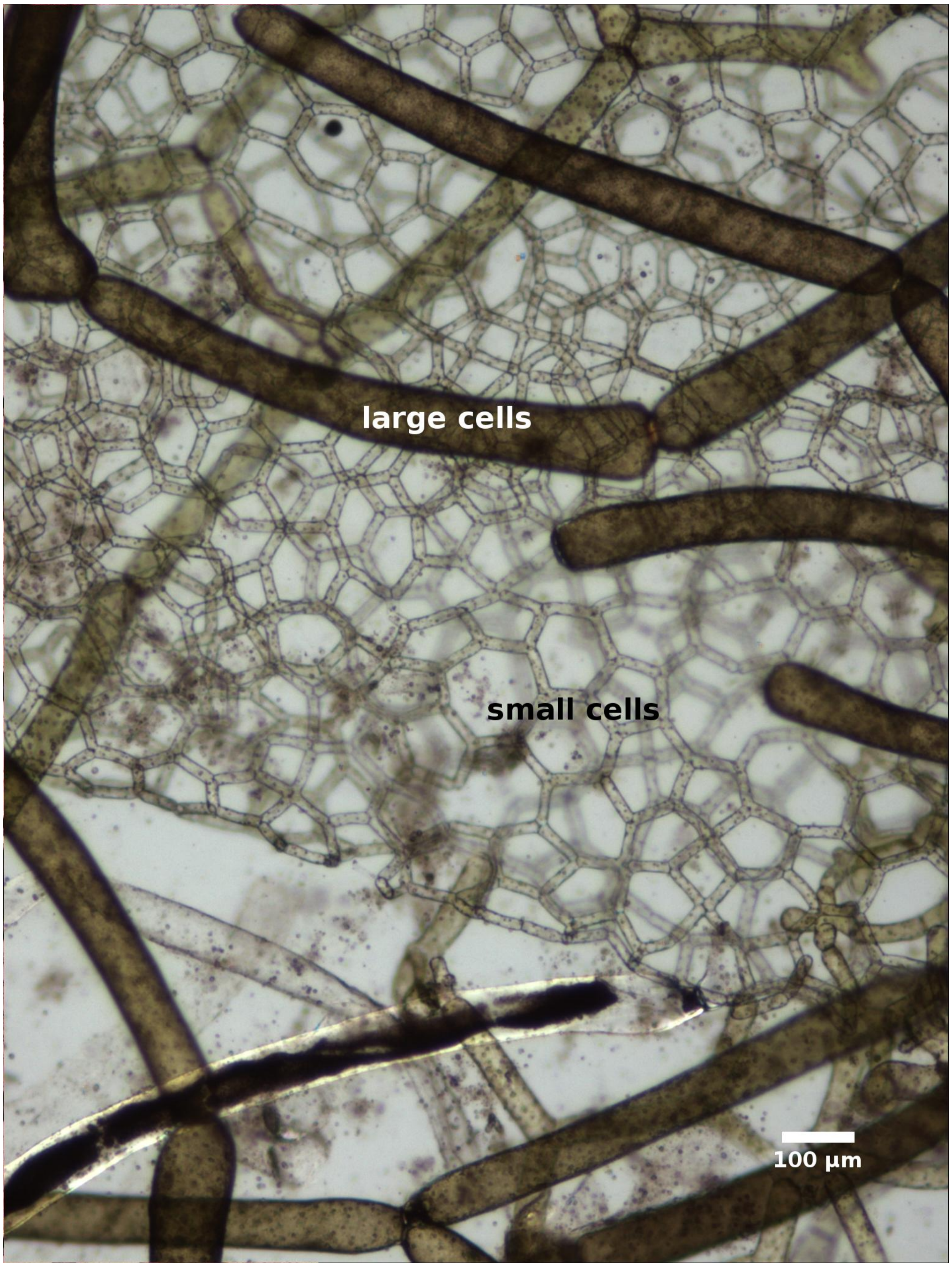

Figure 4.75: *Hydrodictyon reticulatum* (40x brightfield), Wards Biological Supply Co., April 9, 2012.

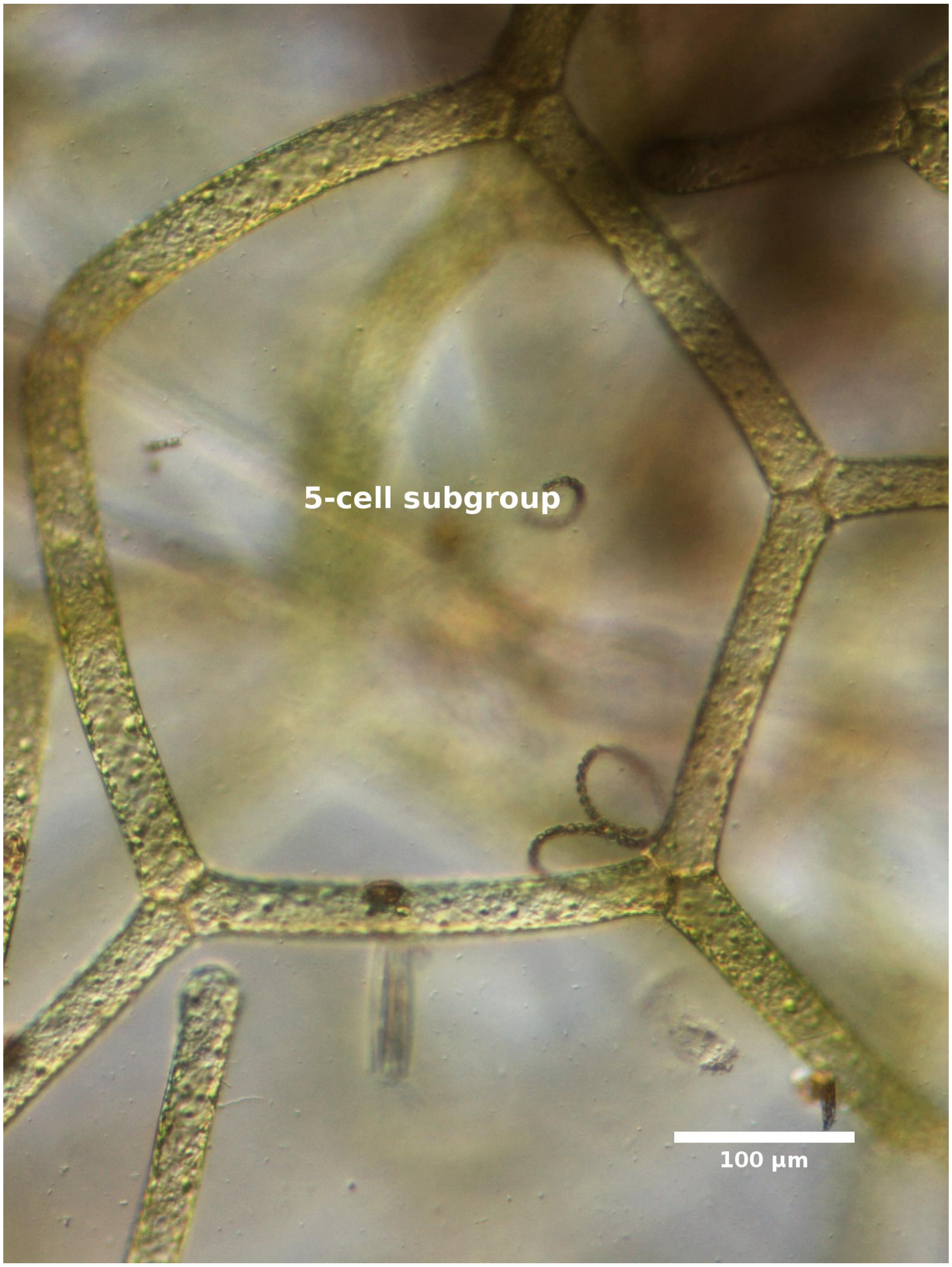

Figure 4.76: *Hydrodictyon reticulatum* (100x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, May 31, 2013.

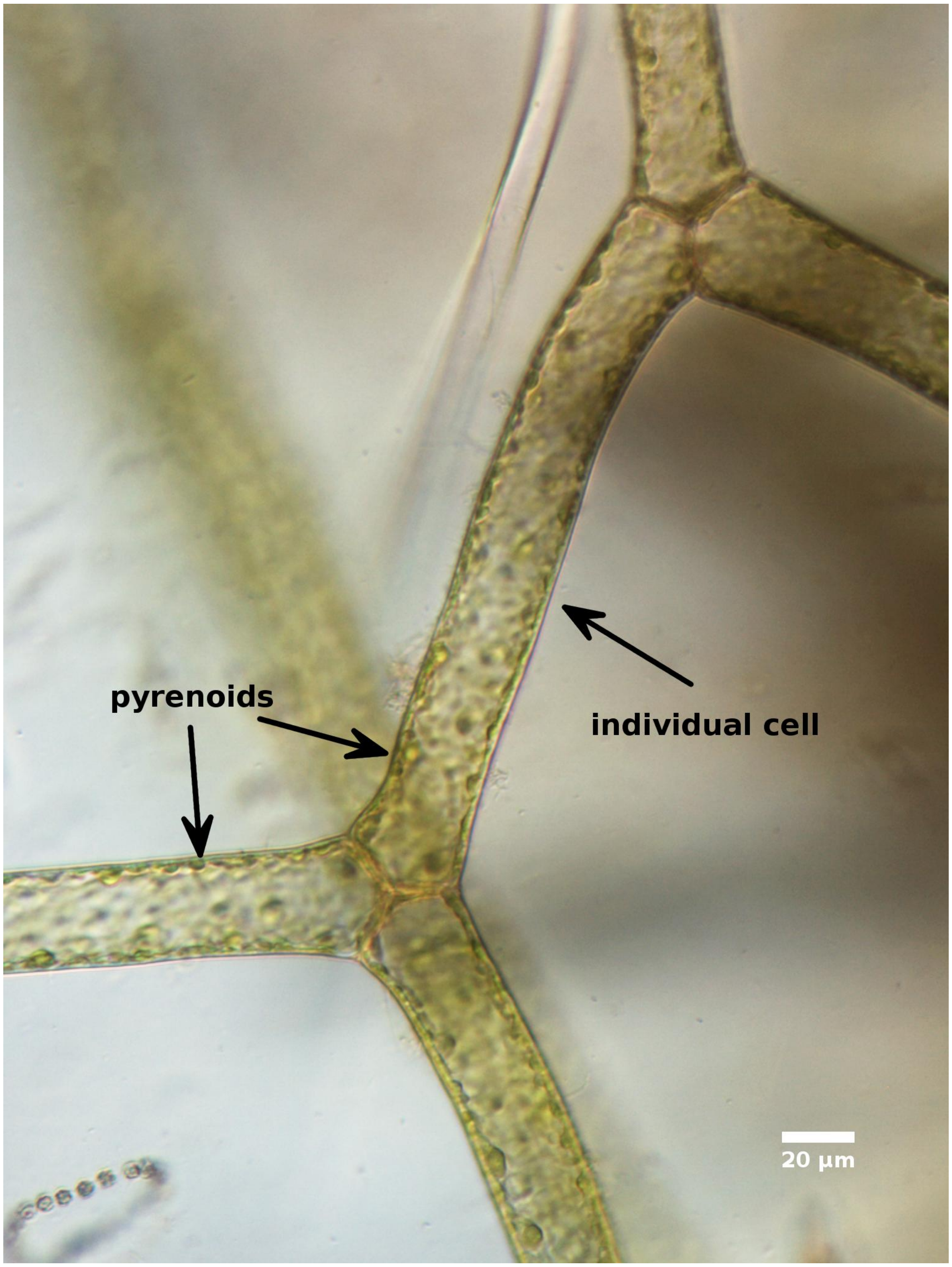

Figure 4.77: *Hydrodictyon reticulatum* (200x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, May 31, 2013.

Figure 4.78: *Hydrodictyon reticulatum* (40x brightfield), Wards Biological Supply Co., April 9, 2012.

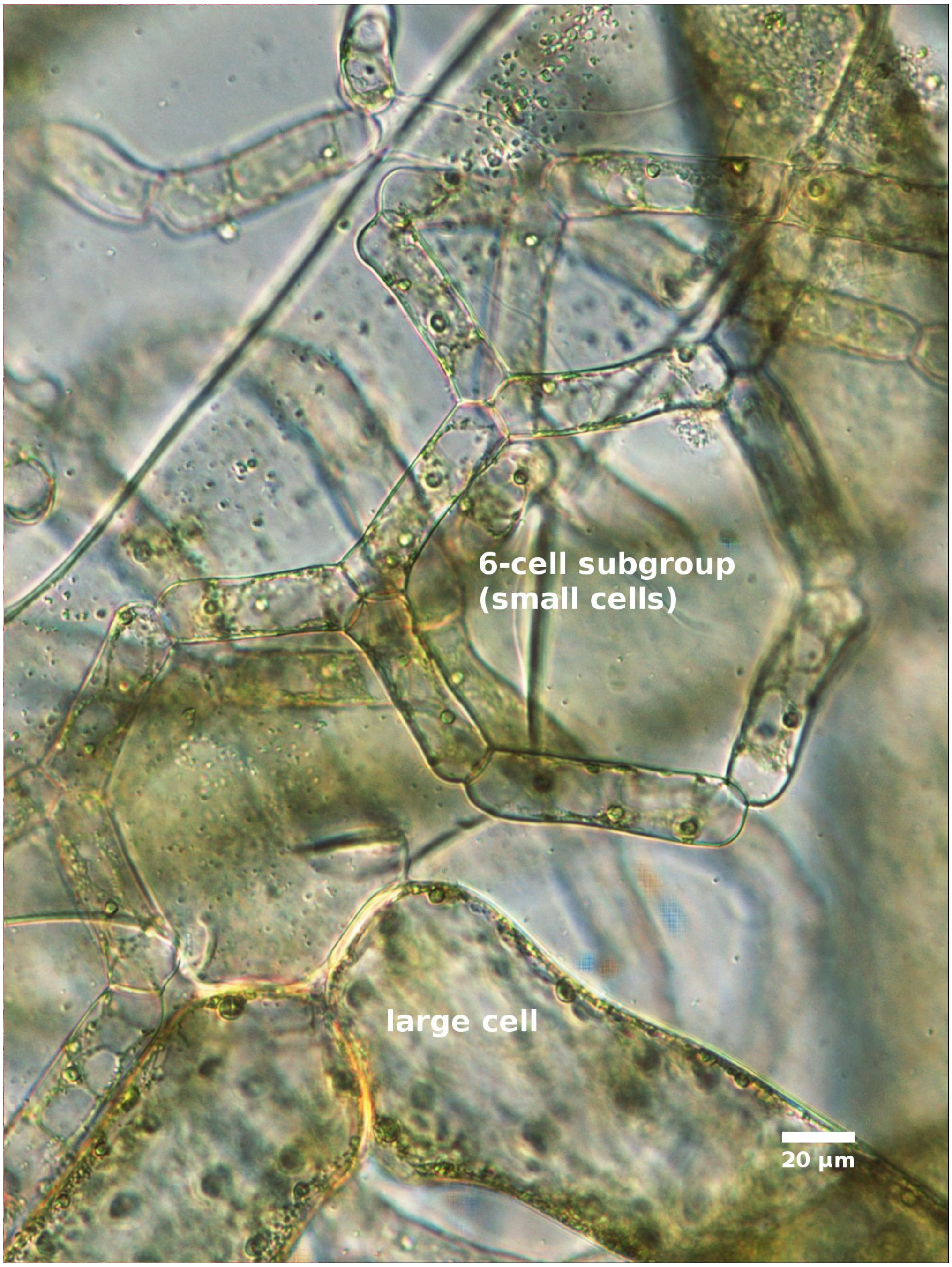

Figure 4.79: *Hydrodictyon reticulatum* (200x DIC), Wards Biological Supply Co., April 5, 2012.

4.12 *Klebsormidium* P. C. Silva, K. Mattos & W. Blackwell

Local taxon

Klebsormidium flaccidum (Kützing) P. C. Silva, K. R. Mattox & W. H. Blackwell

Abundance

Infrequently collected in plankton samples; moderately common in flowing water and along shoreline; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume[†]
Klebsormidium flaccidum	min	5.0 μm	3.0 μm	94.2 μm^3
cells (cylinder)	med	8.4 μm	8.0 μm	383 μm^3
	max	20.4 μm	38.7 μm	12,300 μm^3

[†]Calculated using original measurements, not summary values.

Description

Klebsormidium filaments are long, unbranched, straight or gently curved, and lack any obvious mucilaginous sheath (Figures 4.80–4.84). The individual cells are cylindrical, and the chloroplast forms a parietal band that circles up to 70–80% the cell. The cells may have H-shaped end wall segments, but this feature is not always apparent. Environmental factors can change the appearance of *Klebsormidium*, making identification difficult (John, et al., 2011).

Klebsormidium can be difficult to distinguish from *Ulothrix* (Section 4.22, page 737), but the most common local species, *Ulothrix zonata*, can be identified by its large cells ($\gg$15 μm wide) and ring-shaped chloroplast. *Klebsormidium* also resembles some *Geminella* (Section 4.9, page 601), which has a thick mucilaginous sheath; and *Microspora* (Section 4.13, page 636), which has a net-like (reticulated) chloroplast rather than an incomplete parietal band.

Klebsormidium flaccidum is characterized by cylindrical cells containing a wide, saddle-shaped chloroplast that covers 50% or more of the cell wall (Figures 4.80–4.84). The filaments are long and do not fragment easily. The H-shaped segmentation is not easy to see, but careful examination of several filament ends will usually reveal the short H-shaped segments (Figure 4.84)

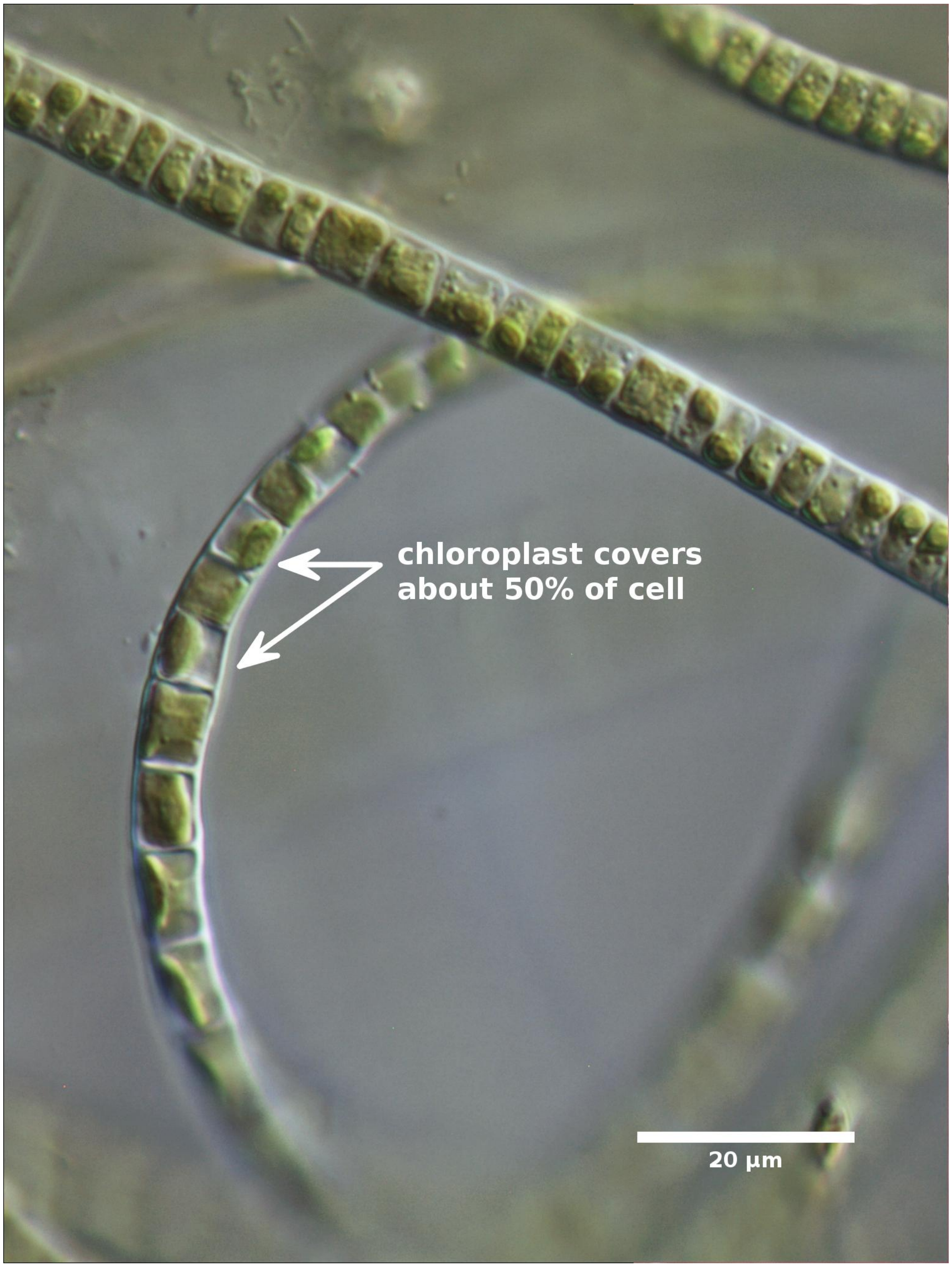

Figure 4.80: *Klebsormidium flaccidum* (600x DIC), Bertrand Estates pond, Whatcom County, April 6, 2012.

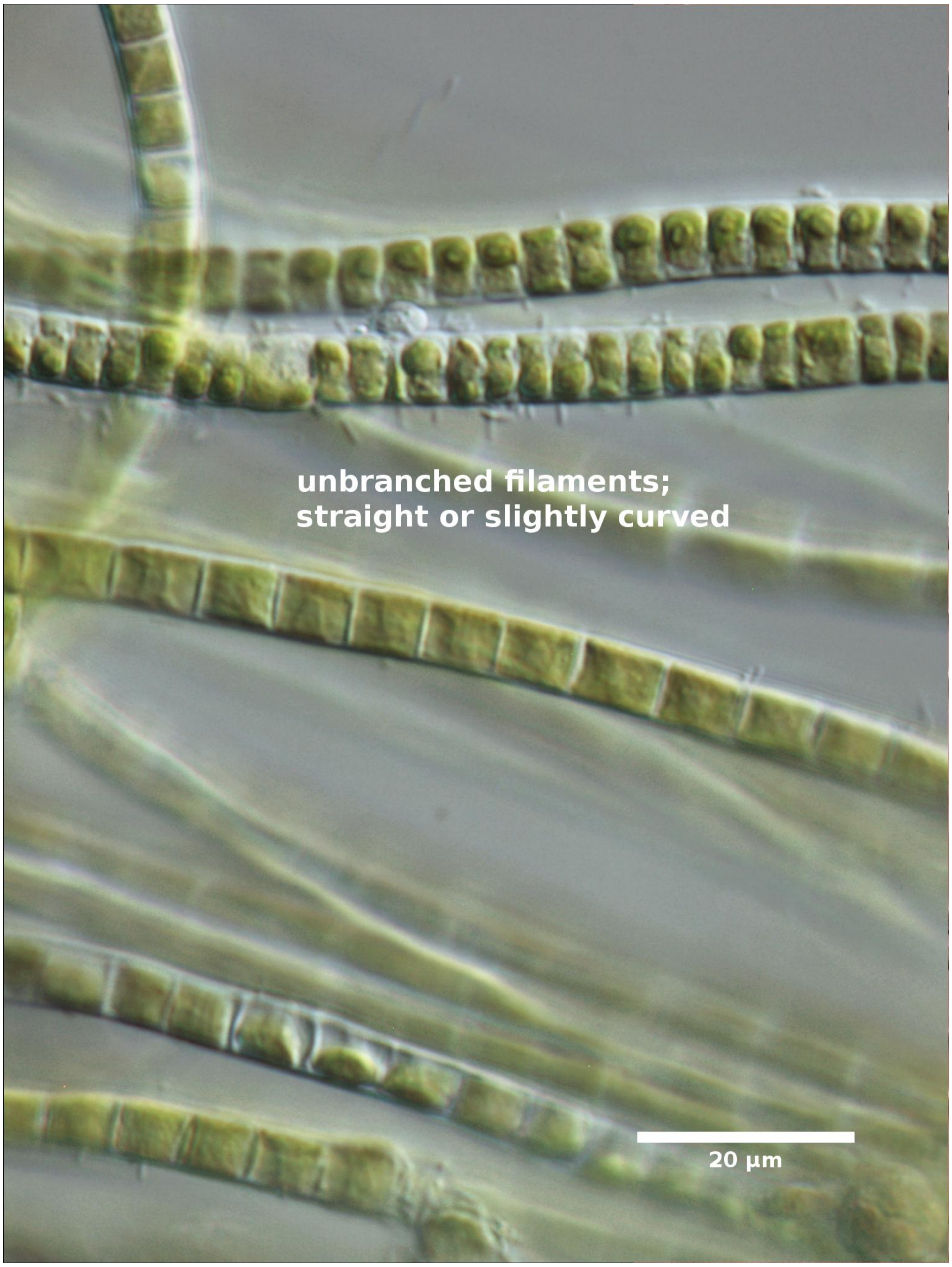

Figure 4.81: *Klebsormidium flaccidum* bloom (600x DIC), Bertrand Estates pond, Whatcom County, April 6, 2012.

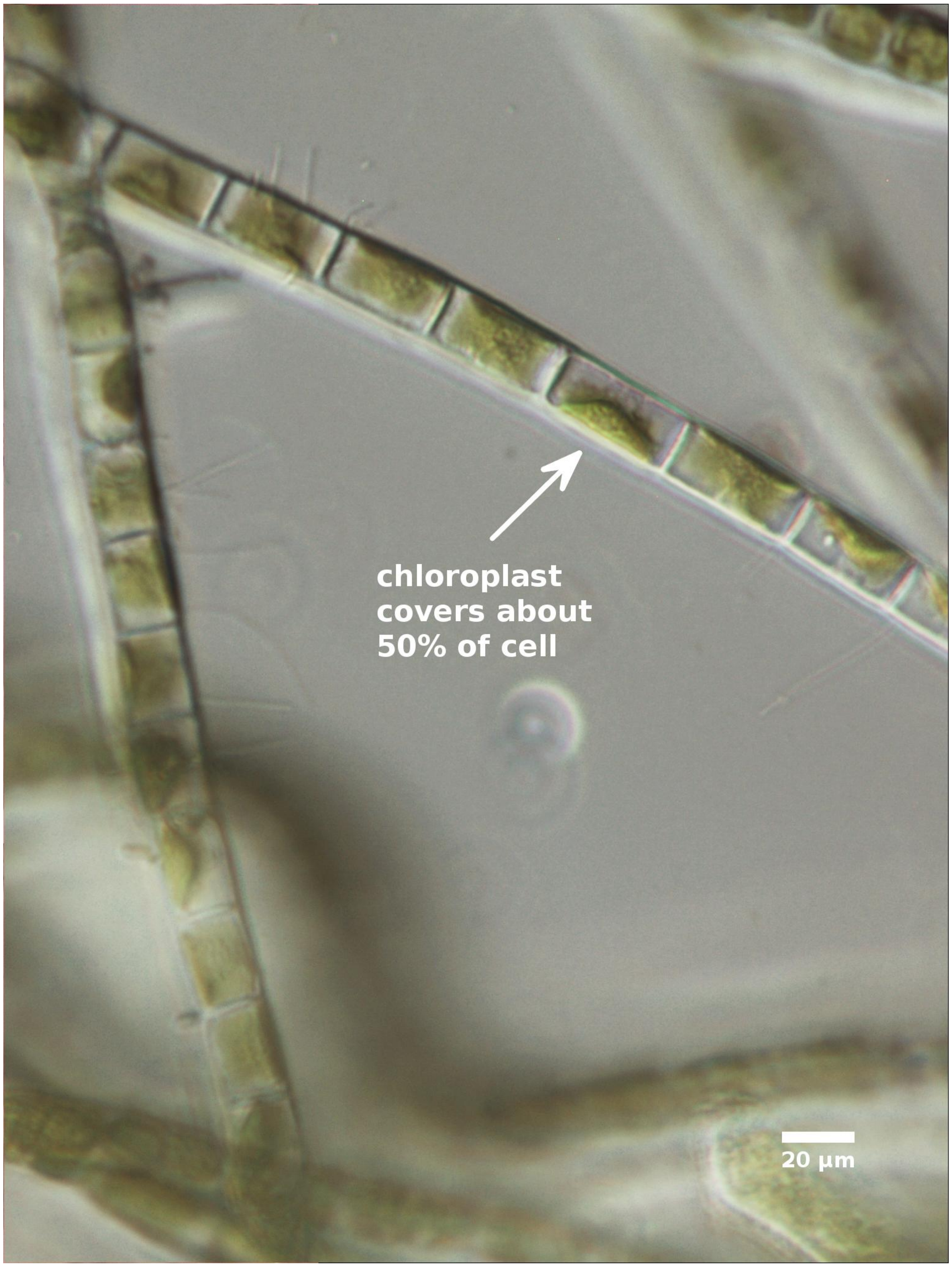

Figure 4.82: *Klebsormidium flaccidum* (200x DIC), Bridal Veil Falls on trail to Lake Serene, Mt. Loop Hwy, August 15, 2011.

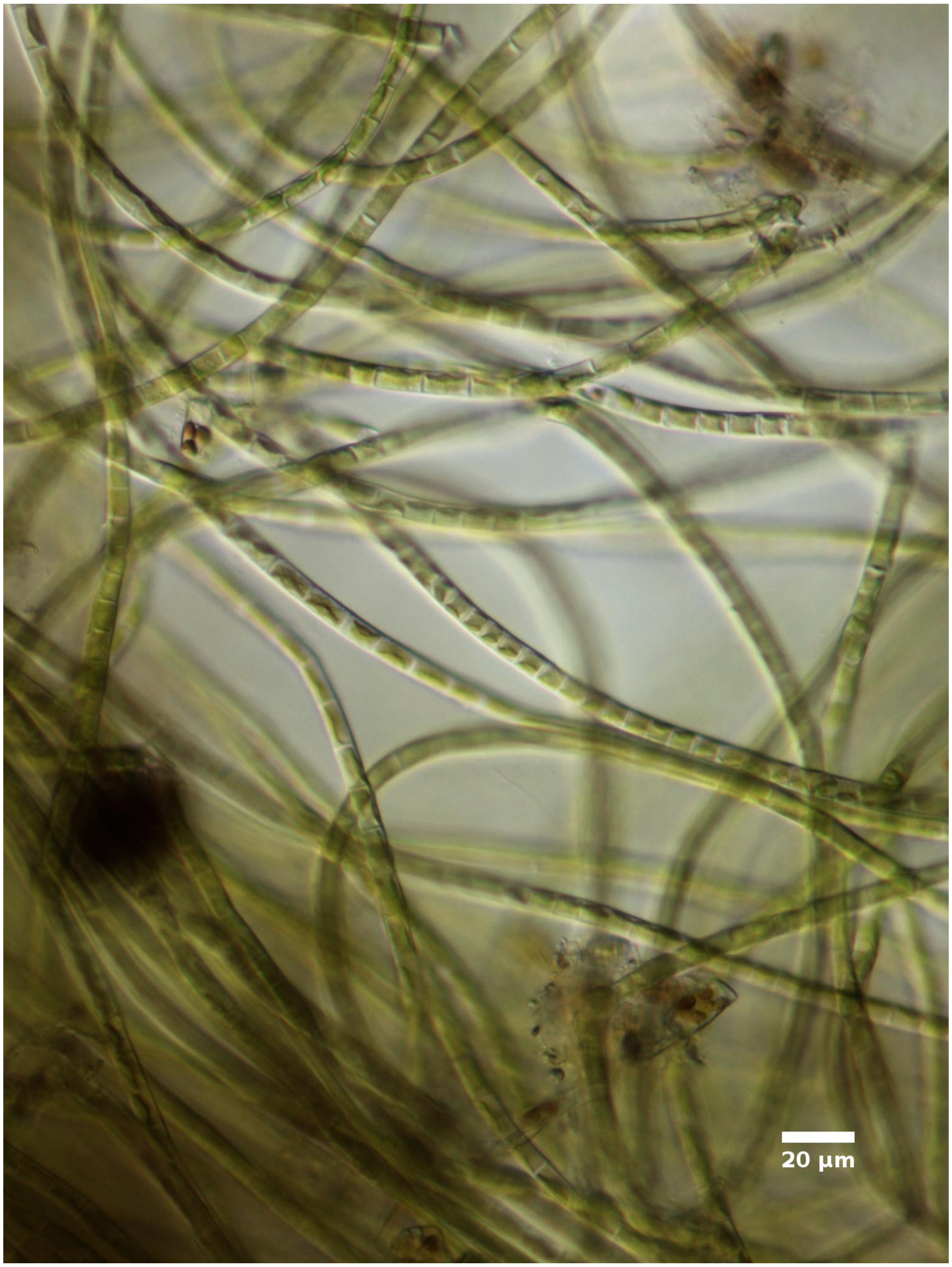

Figure 4.83: *Klebsormidium flaccidum* bloom (200x DIC), standing water along S. Campus Trail, Western Washington University, May 2, 2013.

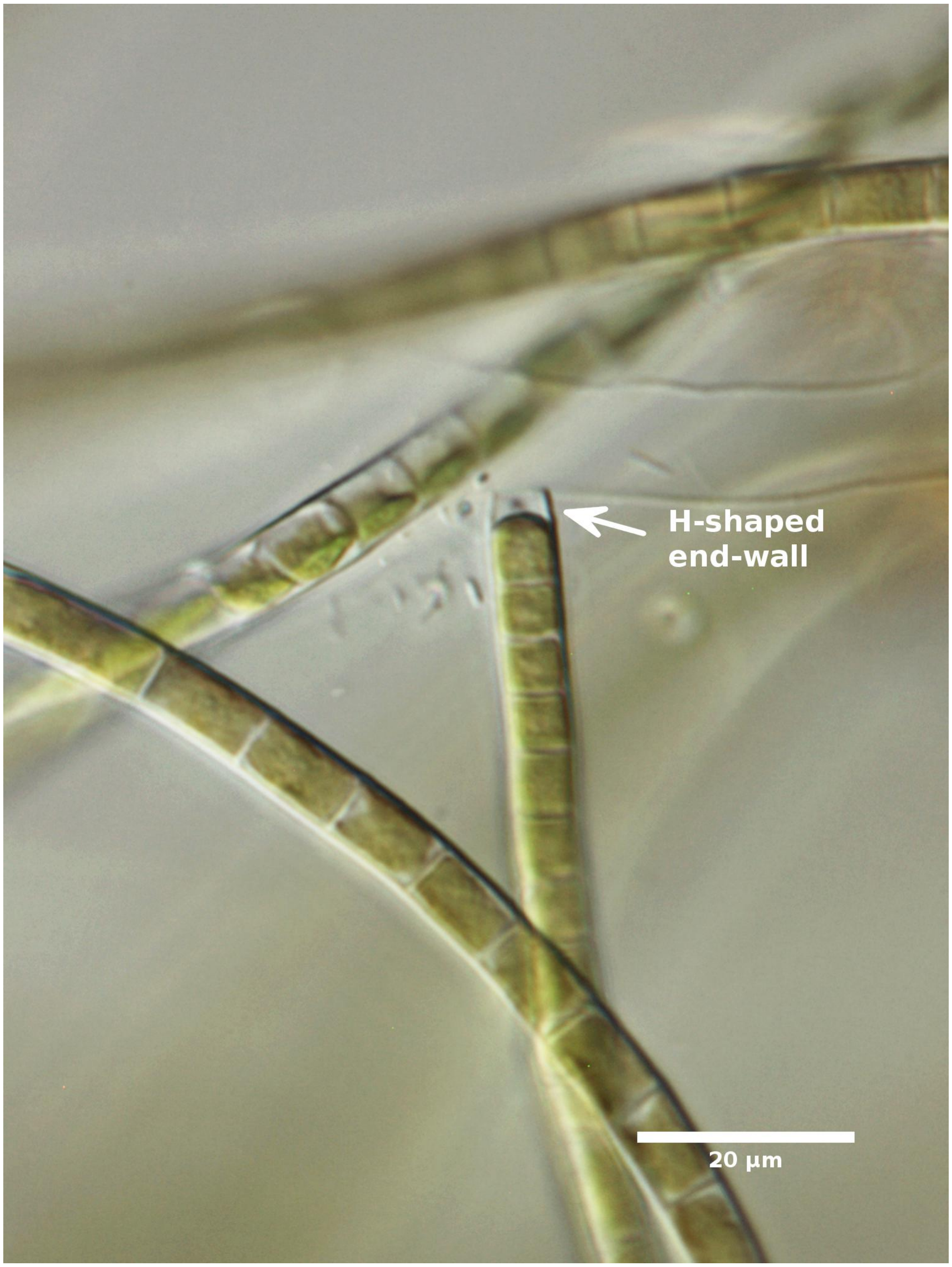

Figure 4.84: *Klebsormidium flaccidum* (600x DIC), standing water along S. Campus Trail, Western Washington University, May 2, 2013.

4.13 *Microspora* Thuret

Local taxa
Microspora amoena (Kützing) Rabenhorst;
Microspora amoena, var.1;
Microspora floccosa (Vaucher) Thuret?;
Microspora pachyderma (Wille) Lagerheim

Abundance
Moderately common in plankton samples, flowing water, and along shoreline; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Microspora amoena	min	21.2 μm	26.8 μm	9,460 μm^3
cells (cylinder)	med	23.0 μm	36.0 μm	15,000 μm^3
	max	25.7 μm	43.3 μm	21,300 μm^3
Microspora amoena var.1	min	18.2 μm	25.6 μm	7.330 μm^3
cells (cylinder)	med	20.1 μm	31.0 μm	9,890 μm^3
	max	21.0 μm	32.7 μm	10,900 μm^3
Microspora floccosa?	min	11.5 μm	10.6 μm	1,240 μm^3
cells (cylinder)	med	12.9 μm	24.9 μm	2,950 μm^3
	max	14.9 μm	44.4 μm	7,740 μm^3
Microspora pachyderma	min	8.0 μm	9.0 μm	516 μm^3
cells (cylinder)	med	9.2 μm	11.1 μm	716 μm^3
	max	10.9 μm	13.4 μm	1,250 μm^3

†Calculated using original measurements, not summary values.

Description
Microspora filaments are simple and unbranched. The individual cells are cylindrical, with a distinctive, H-shaped wall segmentation that is visible on the ends of the filaments and sometimes along the length of the filament (Figures 4.85–4.96). The chloroplast is parietal and net-like (reticulated), often looking beaded at low magnification. Although the cell wall may be thick and stratified,

the filament is not surrounded by a mucilage layer. The H-shaped wall segments are usually sufficient to distinguish *Microspora* from other filamentous algae except for *Klebsormidium* (Section 4.12, page 630) and *Tribonema* Derbes & Solier.[23] *Klebsormidium* chloroplasts form a smooth parietal band; *Tribonema* has yellow-green chloroplasts and does not store starch, so cells won't stain purple or dark brown in Lugol's iodine solution.

Microspora amoena has large cylindrical cells surrounded by a thick (>2 μm) cell wall (Figures 4.85–4.87). The cells are slightly constricted at the cross-walls, and the H-segments are very clearly visible. The chloroplast is dense, bead-like, and fills most of the cell. This species often has orange or brown iron deposits in the cross-walls. It is commonly associated with boggy areas and flowing water (Ramananthan, 1964); the local specimens were collected in a cold, clear stream originating from ice caves.

The specimens identified as *Microspora amoena* var.1 (Figures 4.88–4.89) are very similar to *Microspora amoena*, but have unconstricted, cylindrical cells that are slightly narrower than *Microspora amoena*. *Microspora amoena* var.1 has a thick (>2 μm) cell wall, with clearly visible H-segments, and a dense, bead-like chloroplast that fills most of the cell. This species could also be *Microspora loefgrenii* (Nordstedt) Lagerheim or *Microspora wittrockii* (Wille) Lagerheim, which are all very similar (Ramananthan, 1964).

Microspora floccosa has thin cell walls (<2 μm), so the H=segments are rarely visible except at the end of the filament (Figures 4.90–4.93). The chloroplast is typically pale green, bead-like (reticulated), and often forms bands rather than filling the entire cell. This species is described as occurring in stagnant water (Ramananthan, 1964); the local specimens were collected along the shoreline of moderately productive lakes.

Microspora pachyderma is characterized by small, short, cylindrical cells with thick (>2 μm) walls and a large, plate-like chloroplast that fills most of the cell (Figures 4.94–4.96). The taxonomic literature is mixed on whether the H-segments are visible (Ramananthan, 1964) but John et al. (2011) and Prescott (191962) describe the wall as being striated, with clearly visible segmentation. This species is usually associated with sphagnum swamps and bogs; all of the local specimens were collected in boggy mountain lakes and ponds.

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[23] See **Freshwater Algae in Northwest Washington, Volume IV. Chrysophyceae, Xanthophyceae, and Haptophyta**.

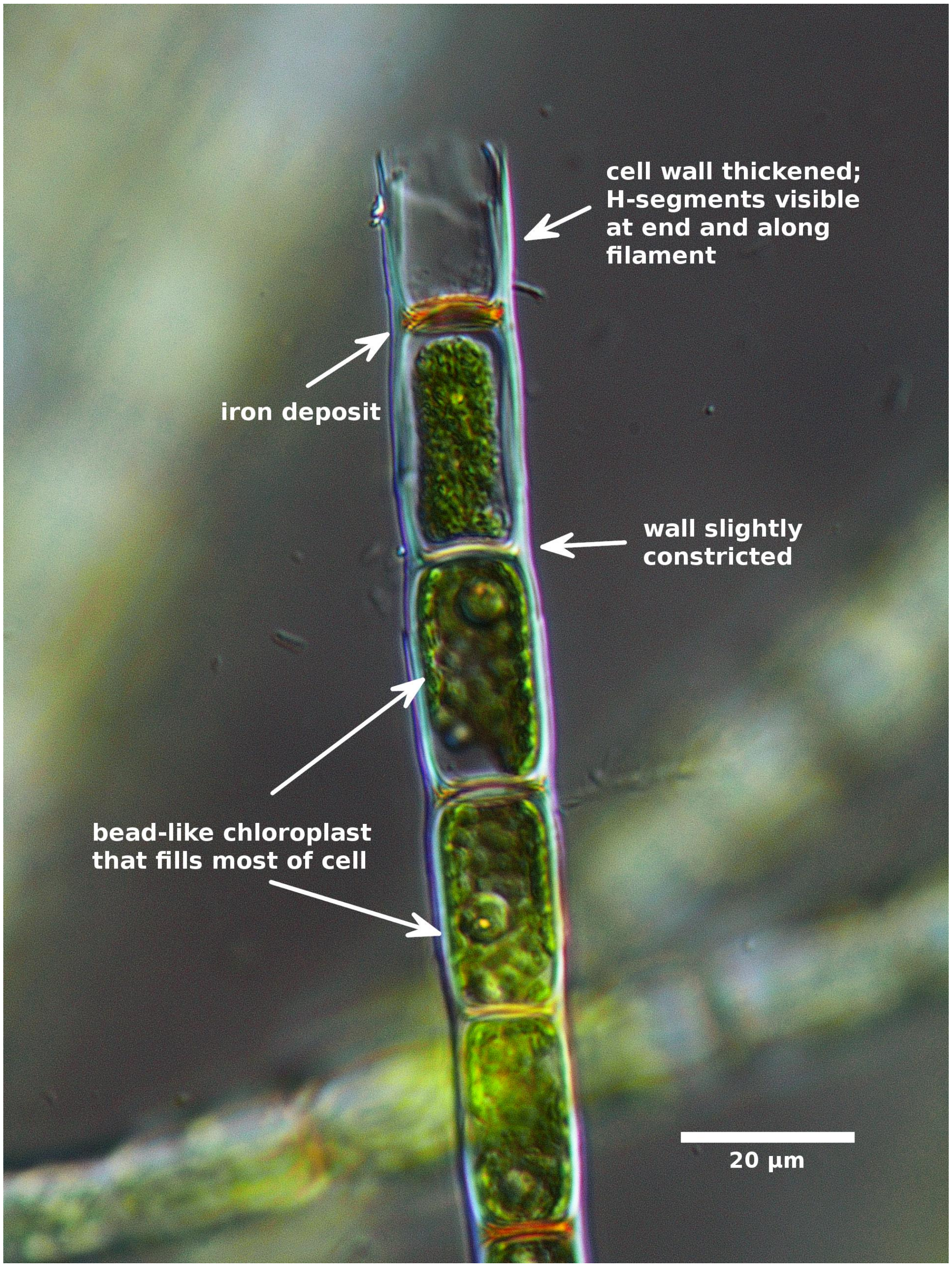


Figure 4.85: *Microspora amoena* (600x DIC), Big Four Ice Caves melt water stream, Mt. Loop Hwy, May 19, 2014.

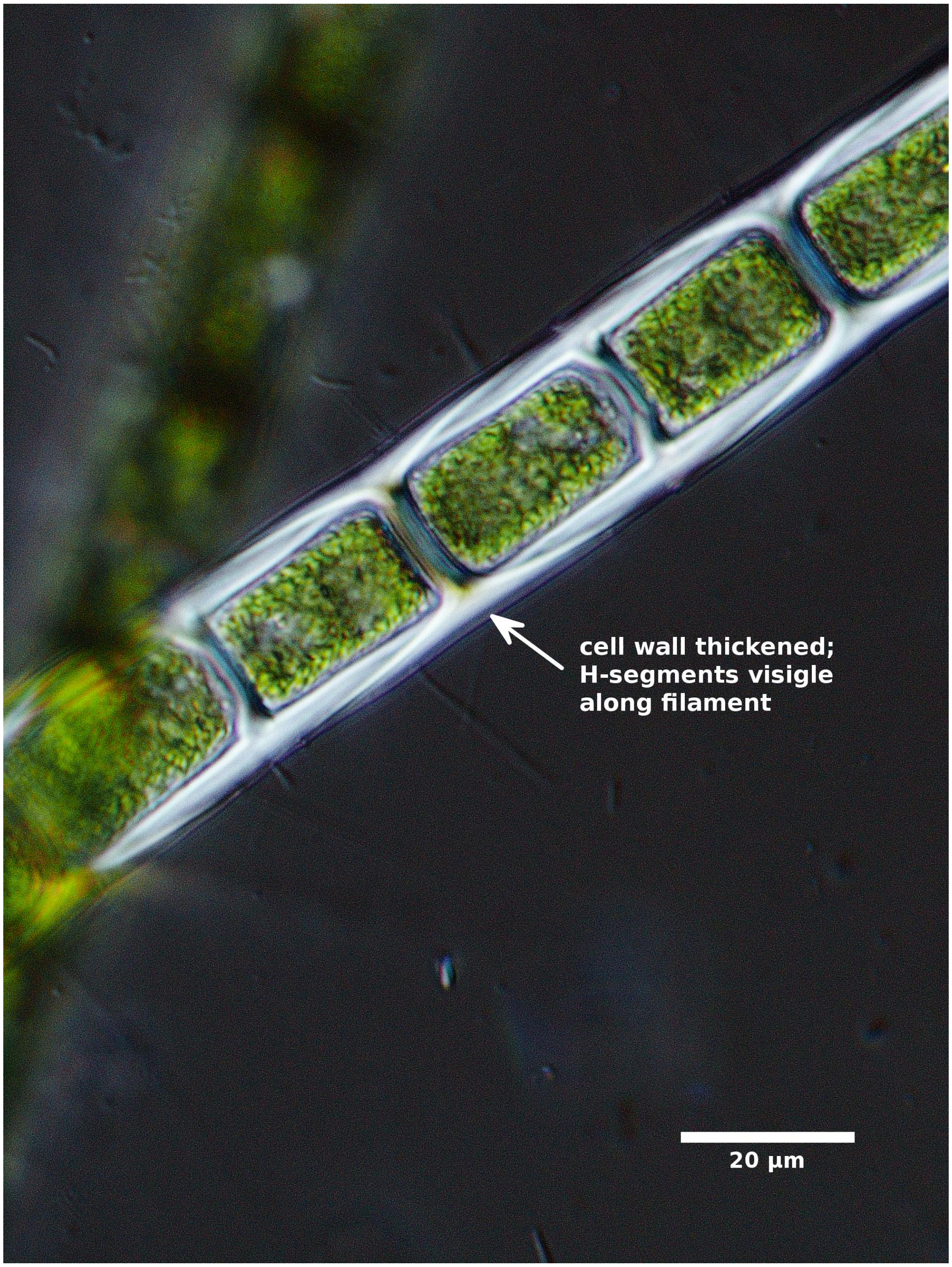


Figure 4.86: *Microspora amoena* (600x DIC), Big Four Ice Caves melt water stream, Mt. Loop Hwy, May 19, 2014.

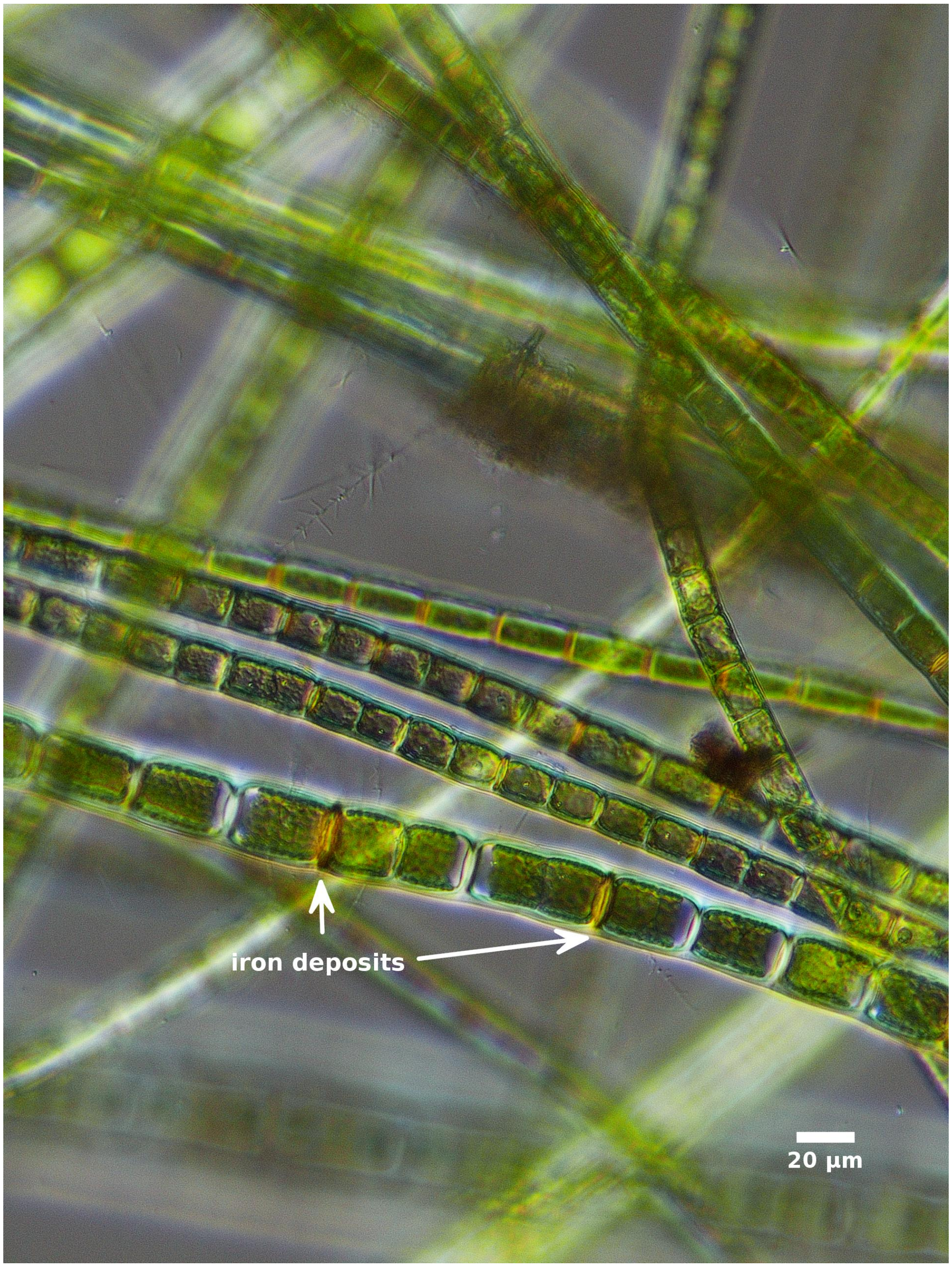


Figure 4.87: *Microspora amoena* (600x DIC), Big Four Ice Caves melt water stream, Mt. Loop Hwy, May 19, 2014.

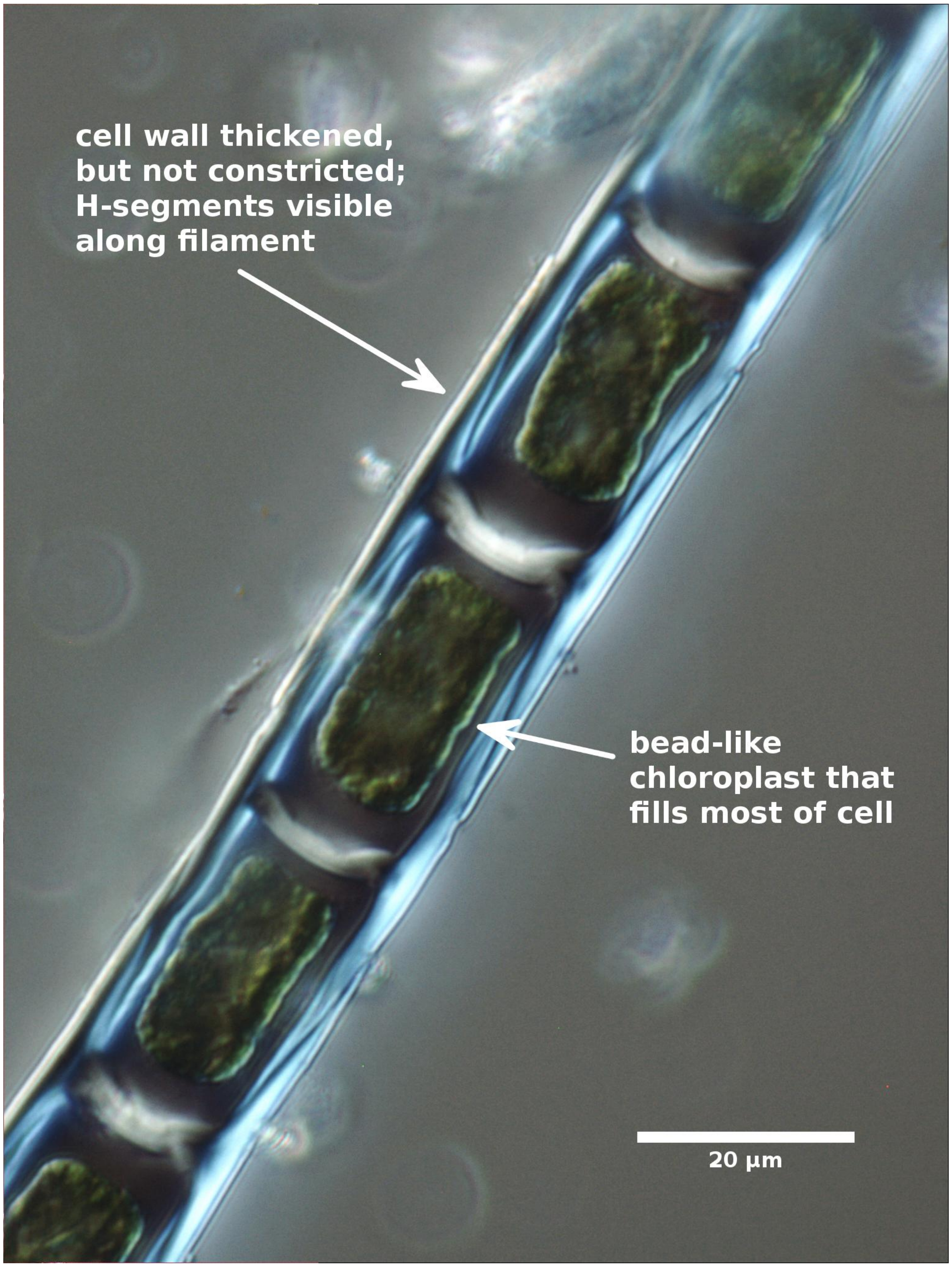


Figure 4.88: *Microspora amoena* var.1 (600x DIC), Mirror Lake, IWS water quality sampling site, Whatcom County, July 11, 2011.

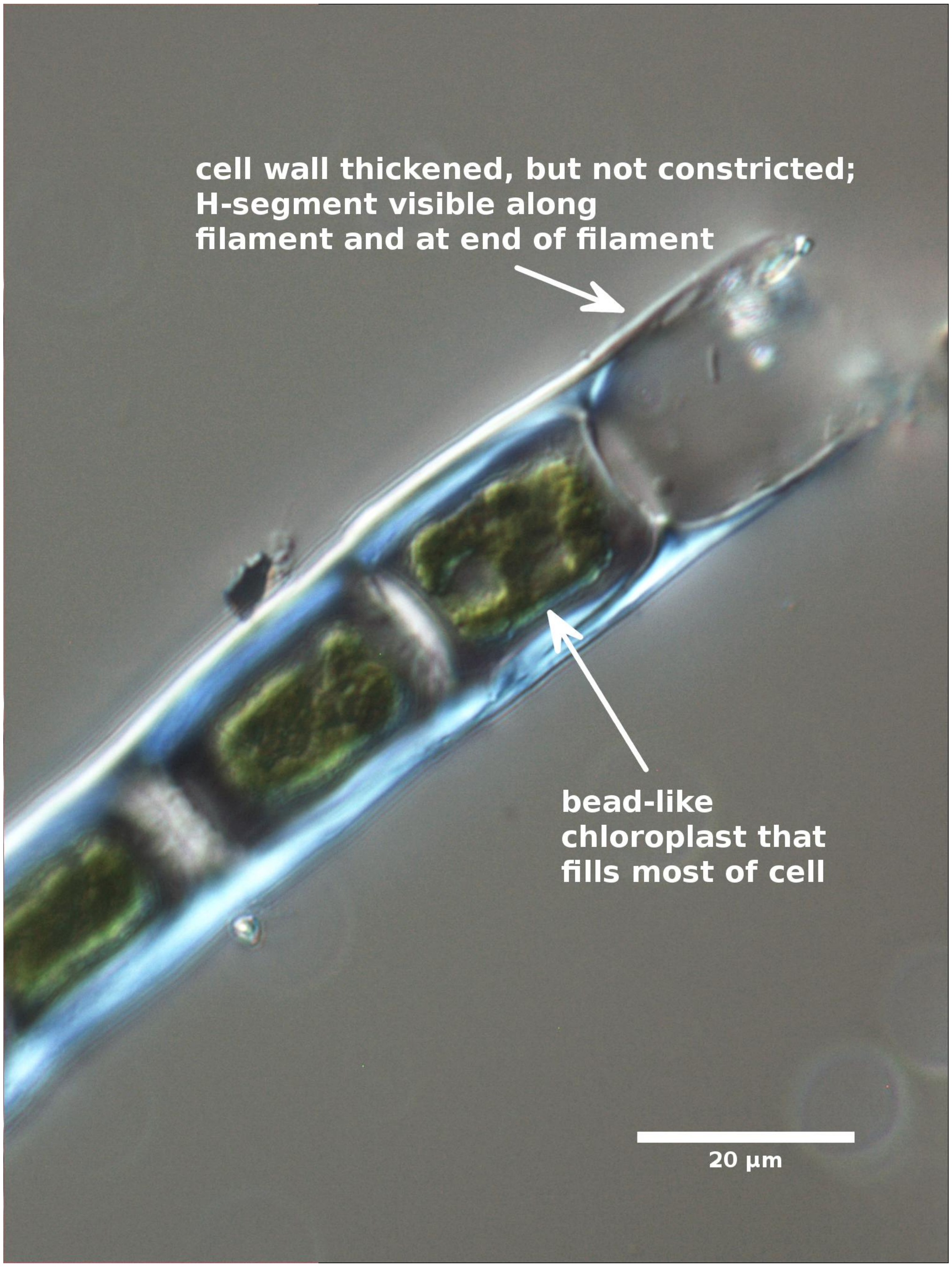


Figure 4.89: *Microspora amoena* var.1 (600x DIC), Mirror Lake, IWS water quality sampling site, Whatcom County, July 11, 2011.

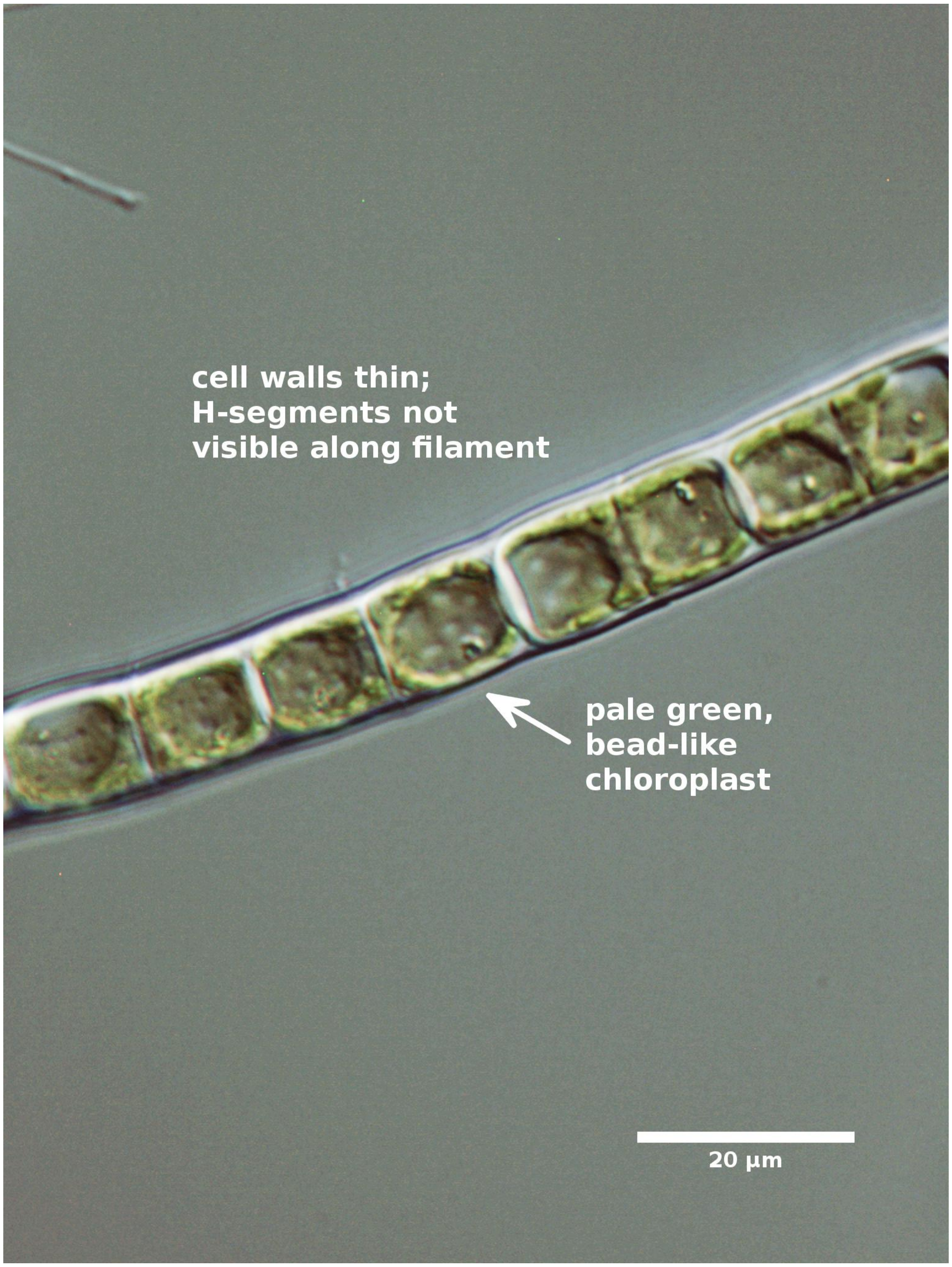


Figure 4.90: *Microspora floccosa*? (600x DIC), Lake Whatcom shoreline, IWS water quality sampling site, Whatcom County, April 24, 2013.

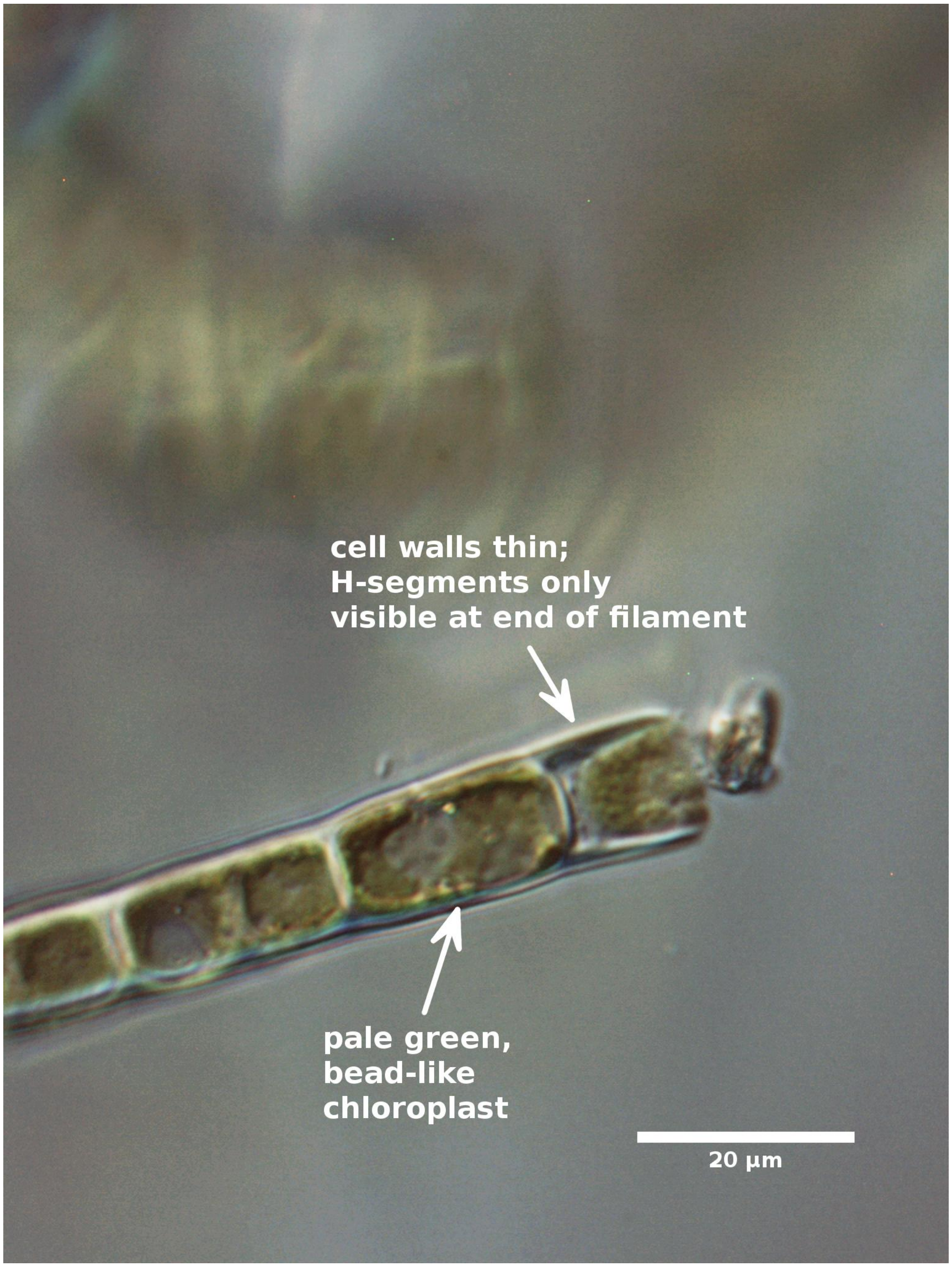


Figure 4.91: *Microspora floccosa*? (600x DIC), Lake Whatcom shoreline, IWS water quality sampling site, Whatcom County, April 24, 2013.

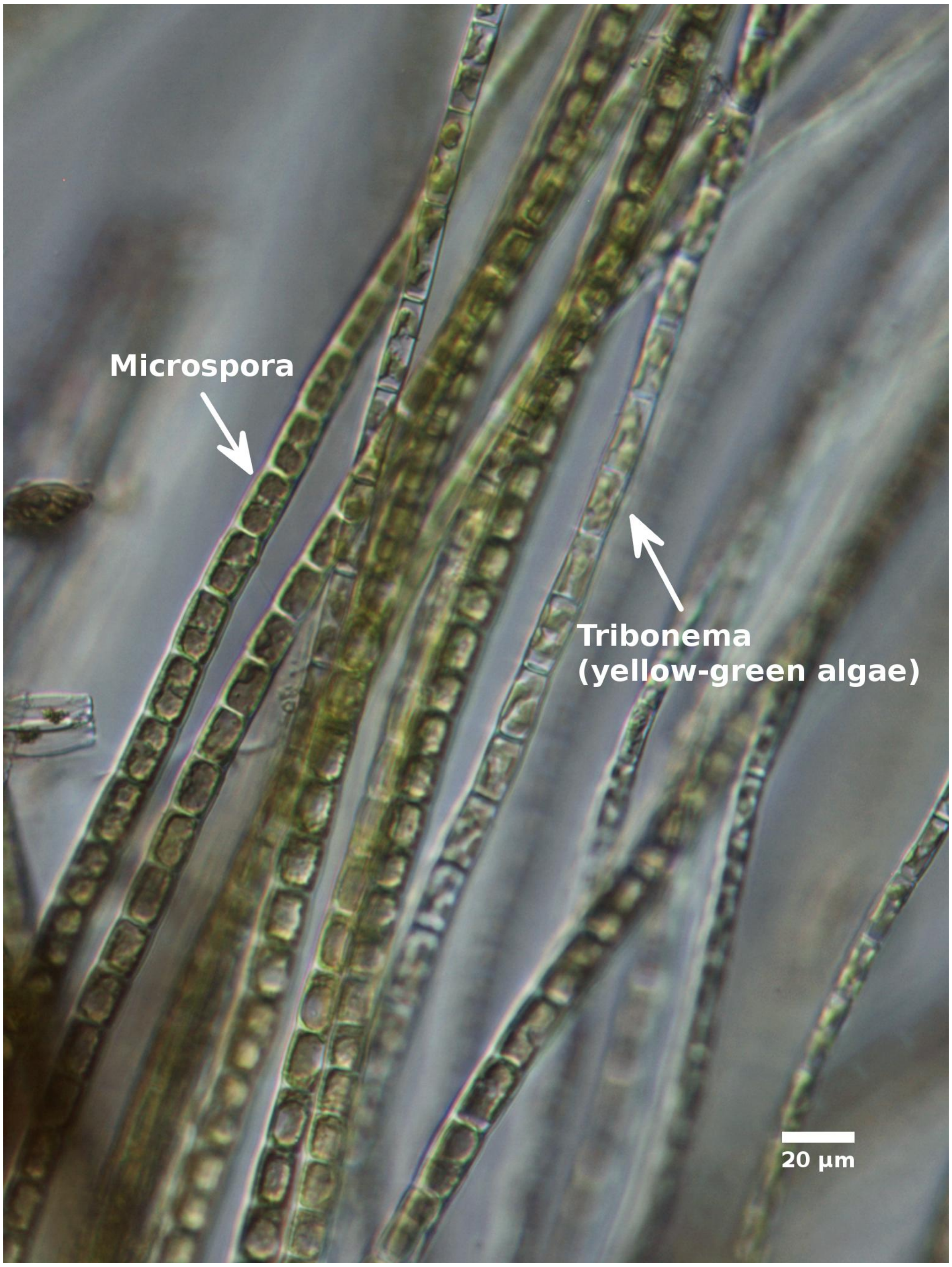


Figure 4.92: *Microspora floccosa*? (200x DIC), Lake Whatcom shoreline, IWS water quality sampling site, Whatcom County, April 24, 2013.

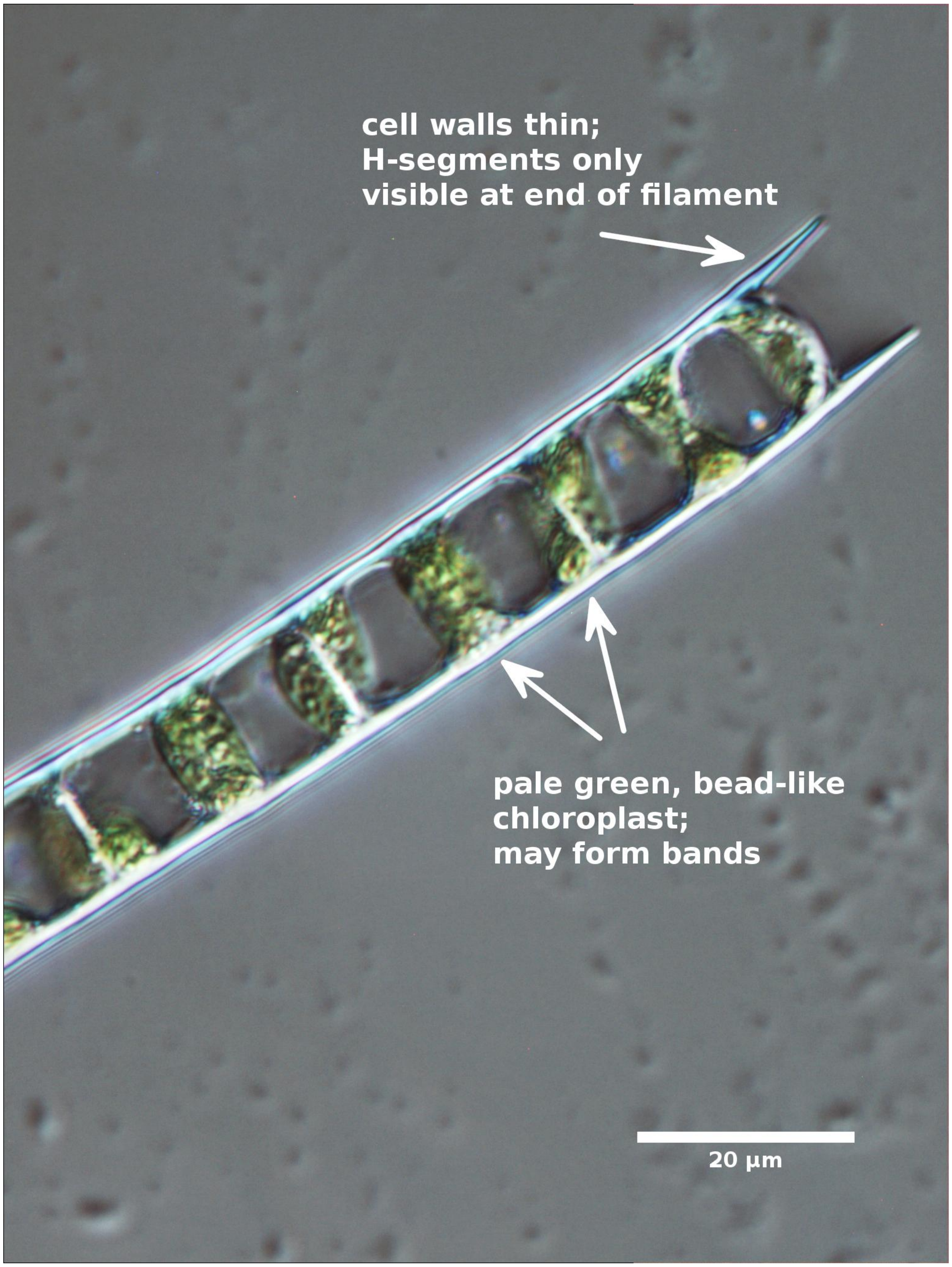


Figure 4.93: *Microspora floccosa*? (200x DIC), Tennant Lake, IWS water quality sampling site, May 5, 2009.

Figure 4.94: *Microspora pachyderma* (600x DIC), Lake Evan, IWS water quality sampling site, Snohomish County, August 6, 2012.

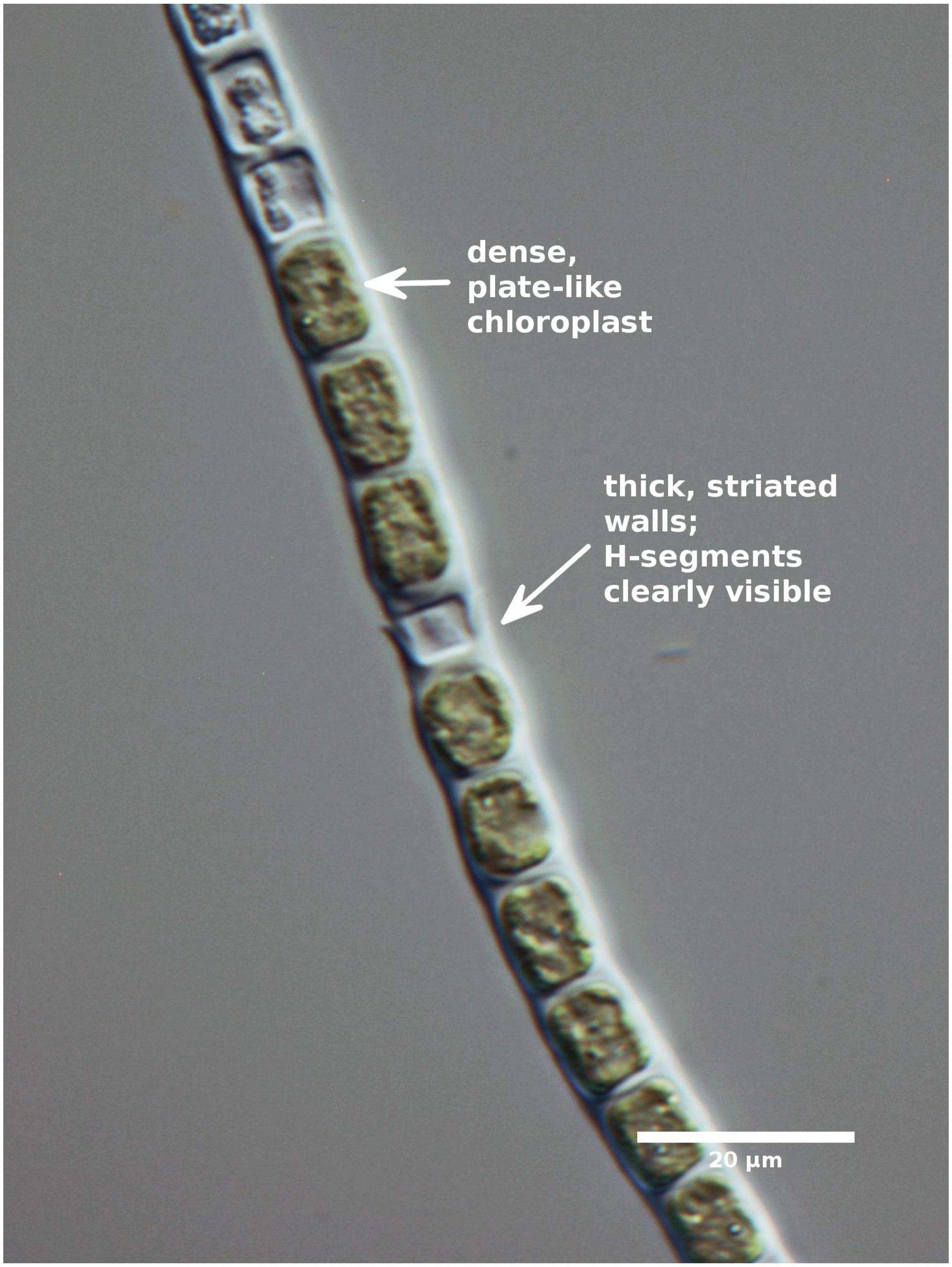


Figure 4.95: *Microspora pachyderma* (600x DIC), Barclay Lake, North Cascades along Hwy 2, July 22, 2013.

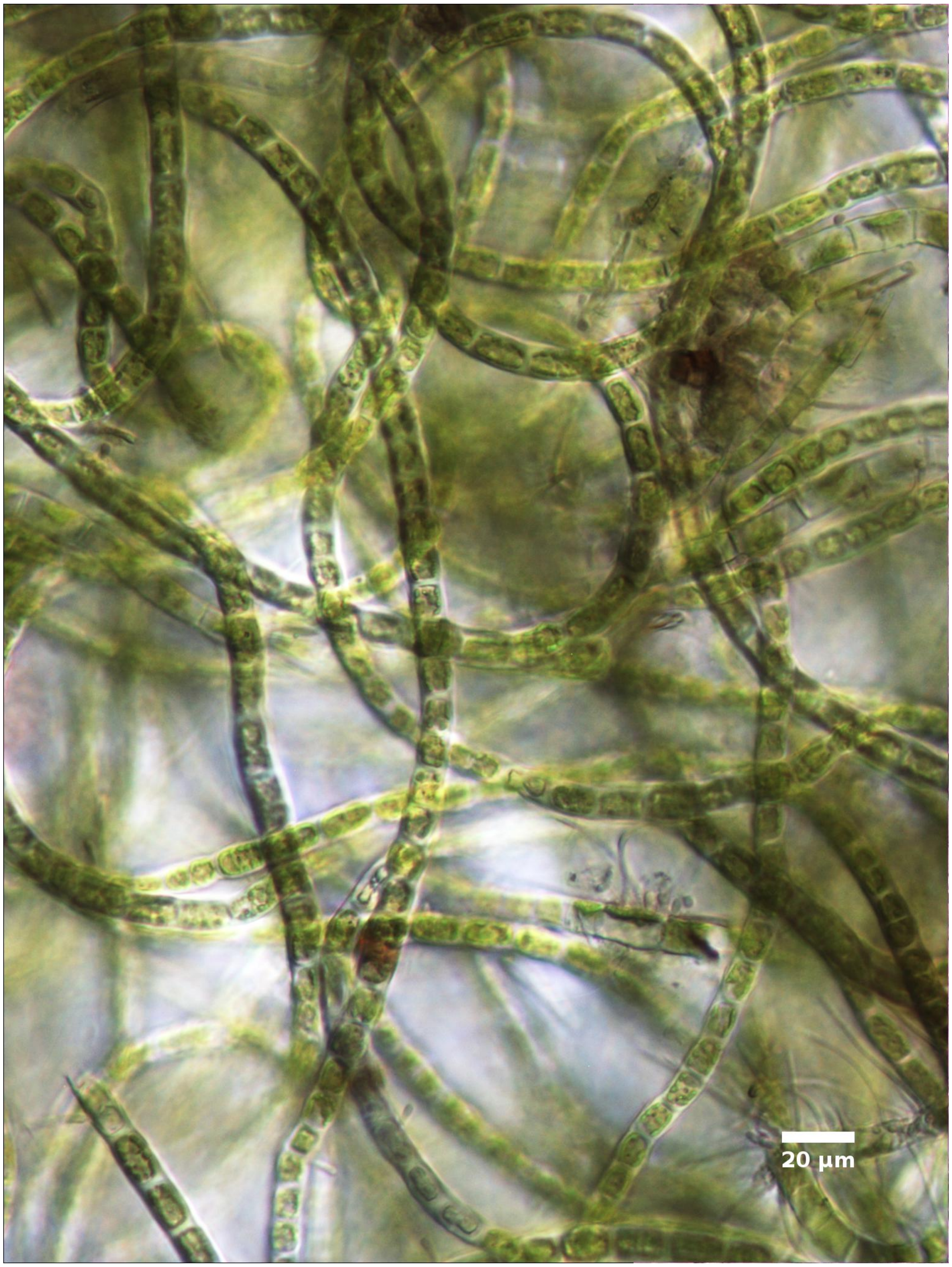


Figure 4.96: *Microspora pachyderma* (200x DIC), Bridal Veil Falls on trail to Lake Serene, Mt. Loop Hwy, August 15, 2011.

4.14 *Microthamnion* Nägeli

Local taxon

Microthamnion kuetzingianum Nägeli ex Kützing

Abundance

Infrequently collected in plankton samples; occasionally abundant as epiphyte in ponds.

Local measurements		Width	Length	Biovolume†
Microthamnion kuetzingianum	min	3.0 μm	11.6 μm	93.3 μm^3
cells (cylinder)	med	3.3 μm	14.6 μm	121 μm^3
	max	4.1 μm	25.3 μm	302 μm^3

†Calculated using original measurements, not summary values.

Description

Microthamnion kuetzingianum filaments are highly branched, containing long, cylindrical cells (Figures 4.97–4.100). Each cell contains a parietal, plate-like chloroplast that lacks visible pyrenoids.[24] New branches form immediately below cell cross-walls. The filaments are usually attached to a solid substrate around the shoreline of ponds or in slow-flowing streams. The local specimens were collected from a freshwater aquarium and in small ponds and standing water, including storm water treatment ponds.

[24]The absence of pyrenoids is not a particularly good taxonomic feature. Recent improvements in microscopy have revealed the presence of pyrenoids in species that were initially described as lacking this feature.

Figure 4.97: *Microthamnion kuetzingianum* (200x DIC), small storm water treatment pond, Whatcom County, April 13, 2015.

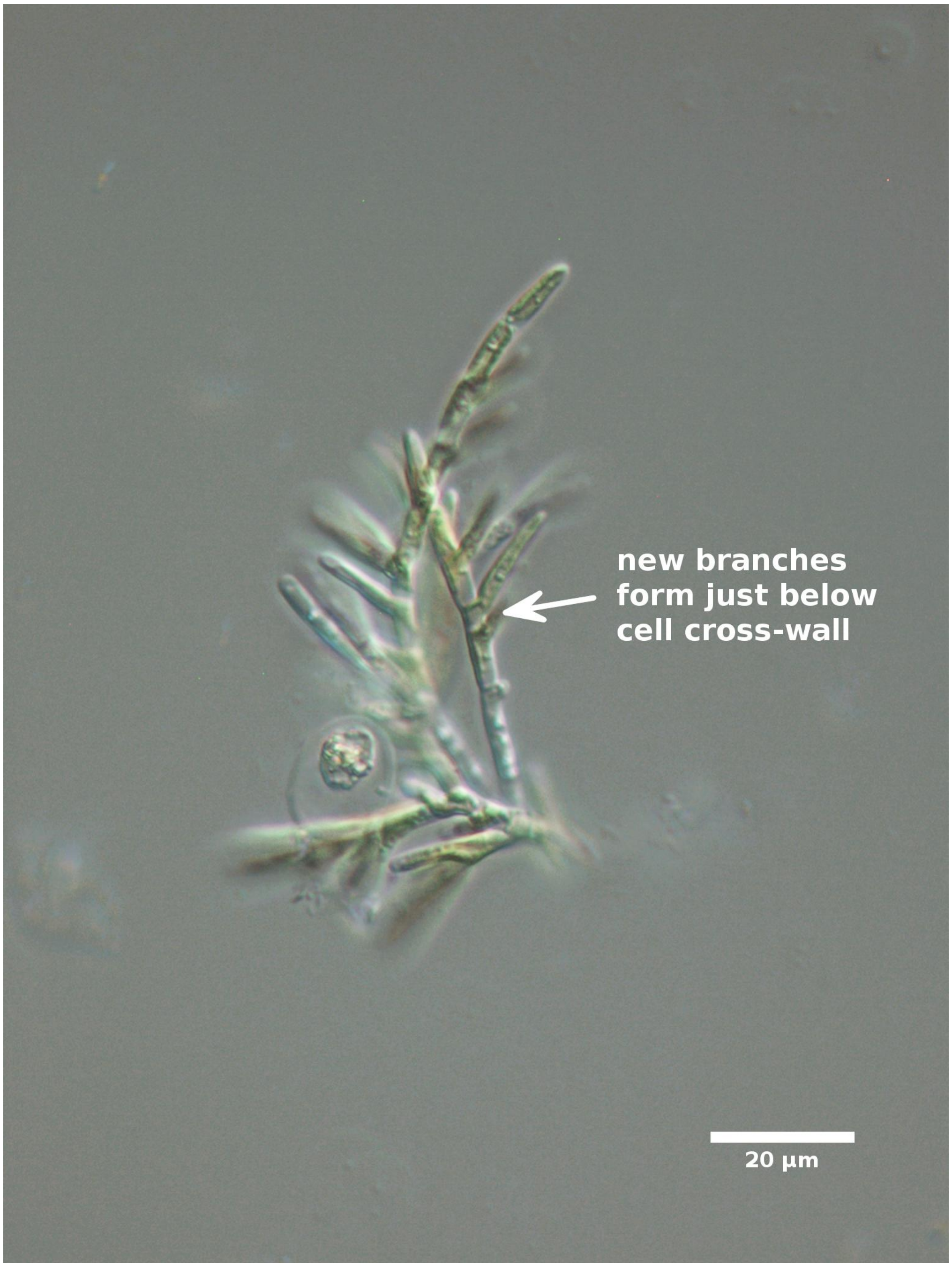


Figure 4.98: *Microthamnion kuetzingianum* (400x DIC), standing water, Whatcom County, August 31, 2012.

Figure 4.99: *Microthamnion kuetzingianum* (600x DIC), freshwater aquarium, May 16, 2011.

Figure 4.100: *Microthamnion kuetzingianum* (600x DIC), small pond near Fairhaven College, Whatcom County, April 15, 2014.

4.15 *Mougeotia* C. Agardh

Local taxa
Mougeotia spp.

Abundance
Moderately common in plankton samples, flowing water, and along shoreline; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Mougeotia spp‡	min	10.6 μm	23.5 μm	2,150 μm^3
cells (cylinder)	med	17.8 μm	109.6 μm	21,900 μm^3
	max	25.8 μm	190.5 μm	64,900 μm^3

†Calculated using original measurements, not summary values.
‡Cell dimensions represent multiple species.

Description
Mougeotia, *Spirogyra* (Section 4.19, page 691), and *Zygnema* (Section 4.23, page 749) are closely related. All three genera are members of the order **Zygnematales**, which also includes desmids.[25] Members of this order have a method of reproduction that includes the formation of *conjugation bridges* between filaments (see Figure 4.133 in Section 4.19). The resulting zygote contains genetic information from both filaments.

Mougeotia filaments are simple and unbranched, containing long cylindrical cells (Figures 4.101–4.104). The most distinctive feature is the single, flat, ribbon-like chloroplast that extends down the center of the cell. The chloroplast contains numerous dot-like pyrenoids that may be scattered or lined up down the center of the chloroplast. The chloroplast may become twisted (Figure 4.104), but does not spiral around the outside of the cell as in *Spirogyra* (Section 4.19, page 691). *Mougeotia* reproduces by forming conjugation bridges between 2 filaments, producing distinctive zygotes (Figure 4.105). Although *Mougeotia* filaments are distinctive, they can be confused with the desmid *Gonatozygon*. *Gonatozygon* cells sometimes have ribbon-like chloroplasts, but the chloroplasts will be paired, extending from a central nucleus, not single as in *Mougeotia*.

[25] See **Freshwater Algae in Northwest Washington, Volume III. Desmids**.

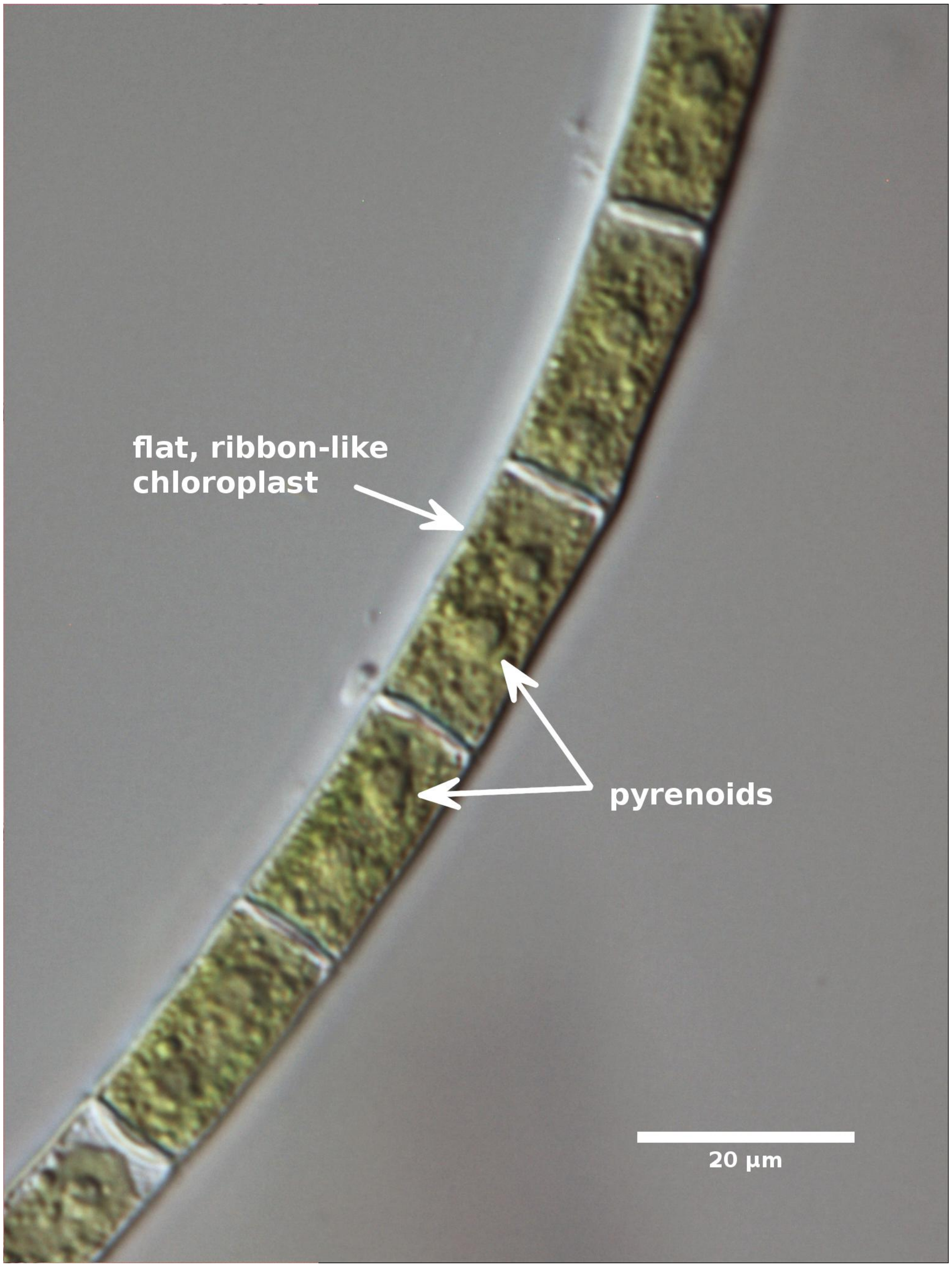


Figure 4.101: *Mougeotia* (600x DIC), Bridal Veil Falls on trail to Lake Serene, Mt. Loop Hwy, August 18, 2011.

Figure 4.102: *Mougeotia* (200x DIC), Wiser Lake, IWS water quality sampling site, Whatcom County, March 30, 2012.

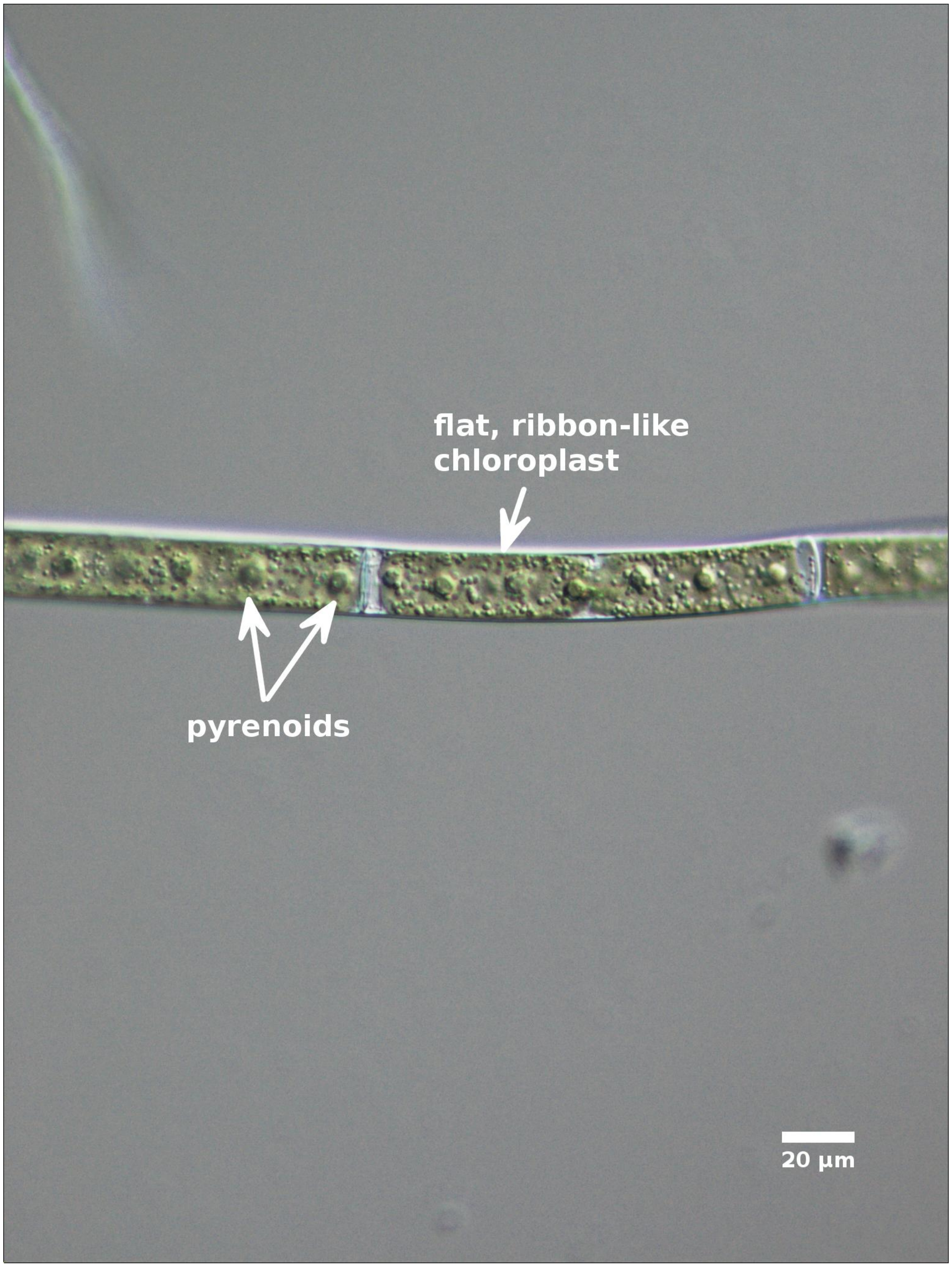


Figure 4.103: *Mougeotia* (200x DIC), Crescent Lake, Olympic National Park, November 29, 2007.

Figure 4.104: *Mougeotia* (400x DIC), freshwater pond uphill from Mud Bay, Whatcom County, May 7, 2009.

Figure 4.105: *Mougeotia* zygotes (400x DIC), freshwater pond near Graham, Pierce County, May 23, 2011.

4.16 *Oedogonium* Link ex Hirn

Local taxa
Oedogonium spp.

Abundance
Infrequently collected in plankton samples; moderately common in flowing water and along shoreline; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Oedogonium sp.1	min	5.9 μm	12.0 μm	347 μm^3
cells (cylinder)	med	7.3 μm	15.8 μm	668 μm^3
	max	7.9 μm	22.6 μm	1,110 μm^3
Oedogonium sp.1	min	15.0 μm	13.0 μm	1,570 μm^3
oogonium (spheroid)	med	18.2 μm	14.2 μm	2,510 μm^3
	max	18.7 μm	17.7 μm	3,100 μm^3
Oedogonium sp.2	min	35.9 μm	51.4 μm	64,500 μm^3
cells (cylinder)	med	41.0 μm	74.6 μm	103,000 μm^3
	max	54.0 μm	85.1 μm	174,000 μm^3
Oedogonium sp.2‡	min	36.2 μm	58.0 μm	39,800 μm^3
oogonium (spheroid)	med	60.4 μm	80.3 μm	153,000 μm^3
	max	61.8 μm	80.7 μm	161,000 μm^3
Oedogonium sp.3	min	11.9 μm	38.4 μm	4,270 μm^3
cells (cylinder)	med	13.6 μm	49.1 μm	7,710 μm^3
	max	16.7 μm	95.0 μm	14,200 μm^3
Oedogonium sp.3‡	min	37.7 μm	35.7 μm	26,600 μm^3
oogonium (spheroid)	med	39.1 μm	36.0 μm	28,800 μm^3
	max	39.8 μm	36.5 μm	30,300 μm^3

continued on next page

Local measurements		Width	Length	Biovolume†
Oedogonium sp.4	min	4.4 μm	42.2 μm	753 μm^3
cells (cylinder)	med	5.8 μm	47.0 μm	1,490 μm^3
	max	7.2 μm	85.8 μm	2,190 μm^3
Oedogonium sp.4	min	15.9 μm	15.0 μm	2,090 μm^3
oogonium (spheroid)	med	16.4 μm	15.9 μm	2,200 μm^3
	max	21.0 μm	16.8 μm	3,880 μm^3

†Calculated using original measurements, not summary values.
‡Biovolume estimate based on <5 cells.

Description
Oedogonium filaments are often collected along lake shores, from the surface of submerged aquatic macrophytes, or attached to other solid surfaces. The cylindrical cells form simple, unbranched filament (Figures 4.106–4.118). The individual cells contain a net-like (reticulated) chloroplast that circles the cell (Figure 4.106). Vegetative cell division occurs near one end of the cell, forming a series of folds called an apical cap (Figure 4.106). The filaments are usually anchored to a solid surface by a specialized basal cell called a holdfast (Figure 4.107). The filaments form distinctive sexual reproductive structures. The easiest to recognize is the inflated oogonium that contains the fertilized zygote (Figure 4.108). Sometimes you will find a small dwarf male filament attached adjacent to the oogonium (Figure 4.109). There are >1000 *Oedogonium* species listed on AlgaeBase, so species identification is beyond the scope of this guide.

Oedogonium sp.1 is the smallest local species, with long, narrow vegetative cells and oval, slightly compressed oogonia (Figures 4.110–4.111). The oogonia form within the filament (intercalary) rather than at the terminal end of the filament, and are often paired. *Oedogonium* sp.2 is the largest local species, with huge cylindrical cells containing a dense, net-like (reticulated) chloroplast and oval oogonia that form within the filament (Figures 4.112–4.115). This species has cells that are relatively short compared to the cell width. *Oedogonium* sp.3 has long narrow cells that are slightly inflated at one end and solitary oogonia that are formed within the filament (Figures 4.116–4.117). *Oedogonium* sp.4 is characterized by very long narrow vegetative cells, and strings of oogonia that form within the filament (Figure 4.118)

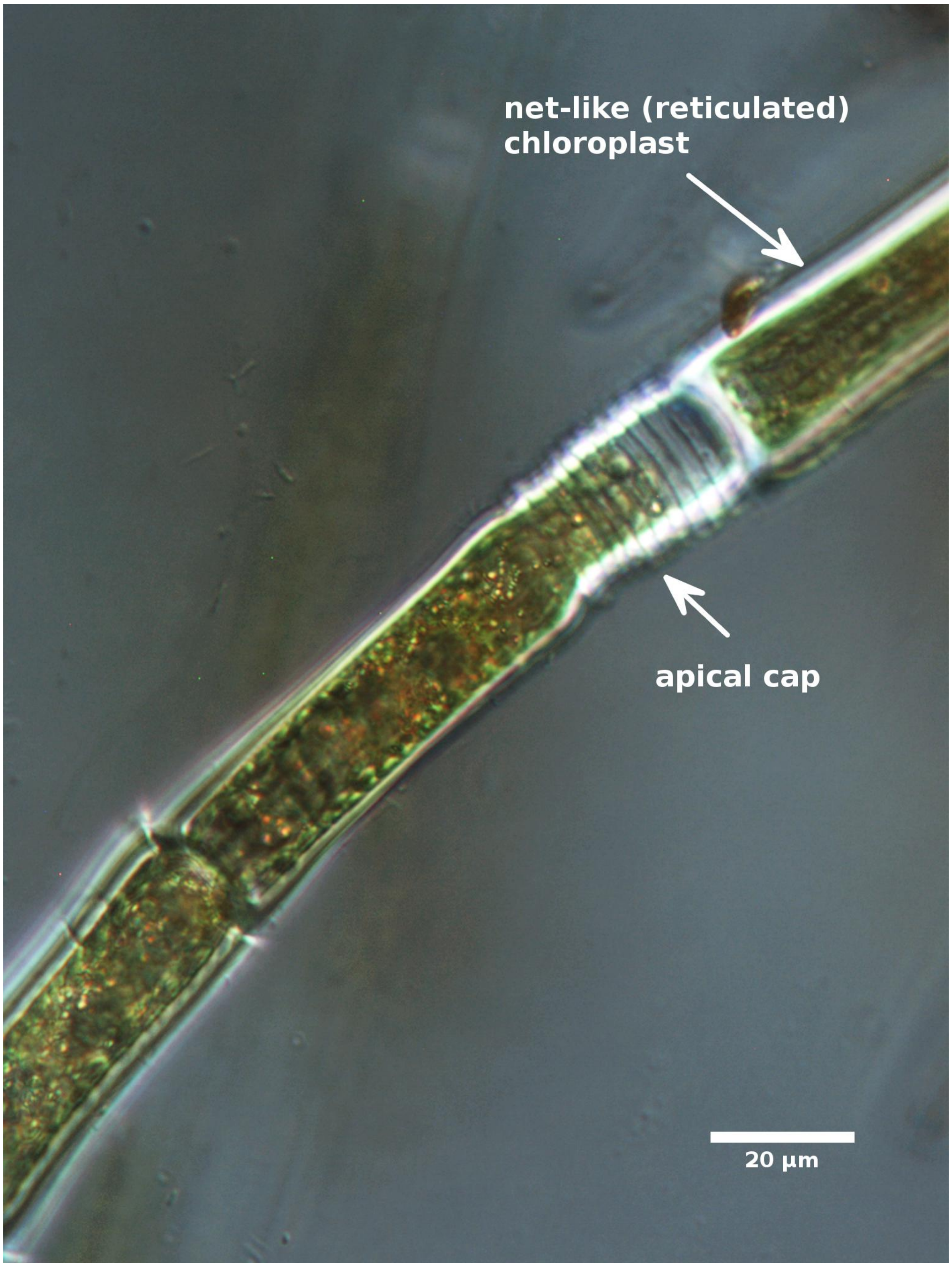


Figure 4.106: *Oedogonium* (400x DIC), Beaver Pond Lake, IWS water quality sampling site, Whatcom County, May 8, 2013.

Figure 4.107: *Oedogonium* (400x DIC), Toad Lake, IWS water quality sampling site, Whatcom County, August 19, 2009.

Figure 4.108: *Oedogonium* (200x DIC), Sunset Pond, IWS water quality sampling site, Whatcom County, August 19, 2009.

Figure 4.109: *Oedogonium* dwarf male (200x DIC), Ross Lake, Ross Lake National Recreation Area, September 27, 2010.

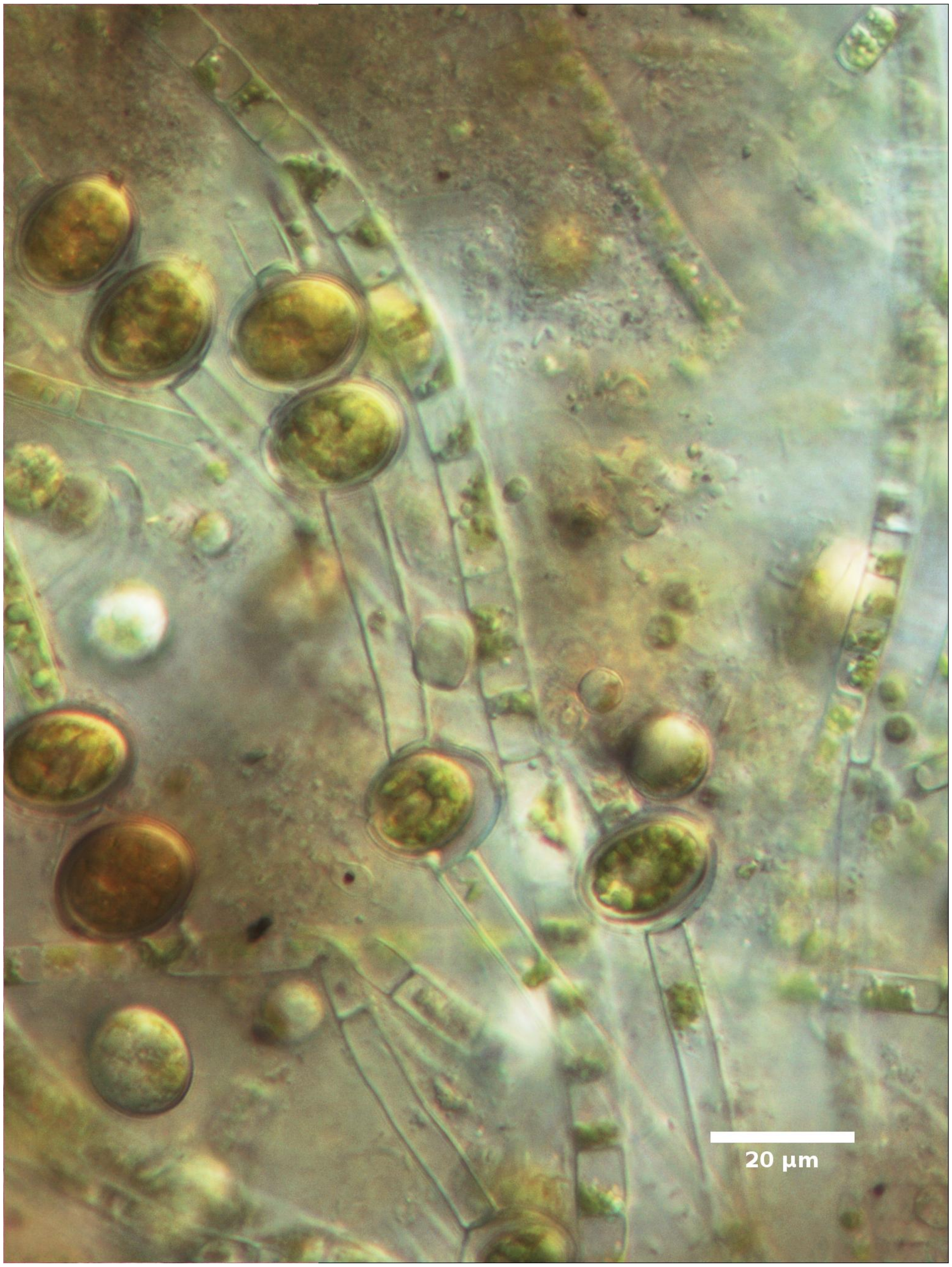


Figure 4.110: *Oedogonium* sp.1 (400x DIC), freshwater pond near Graham, Pierce County, May 13, 2011.

Figure 4.111: *Oedogonium* sp.1 oogonia (600x DIC), freshwater pond near Graham, Pierce County, May 13, 2011.

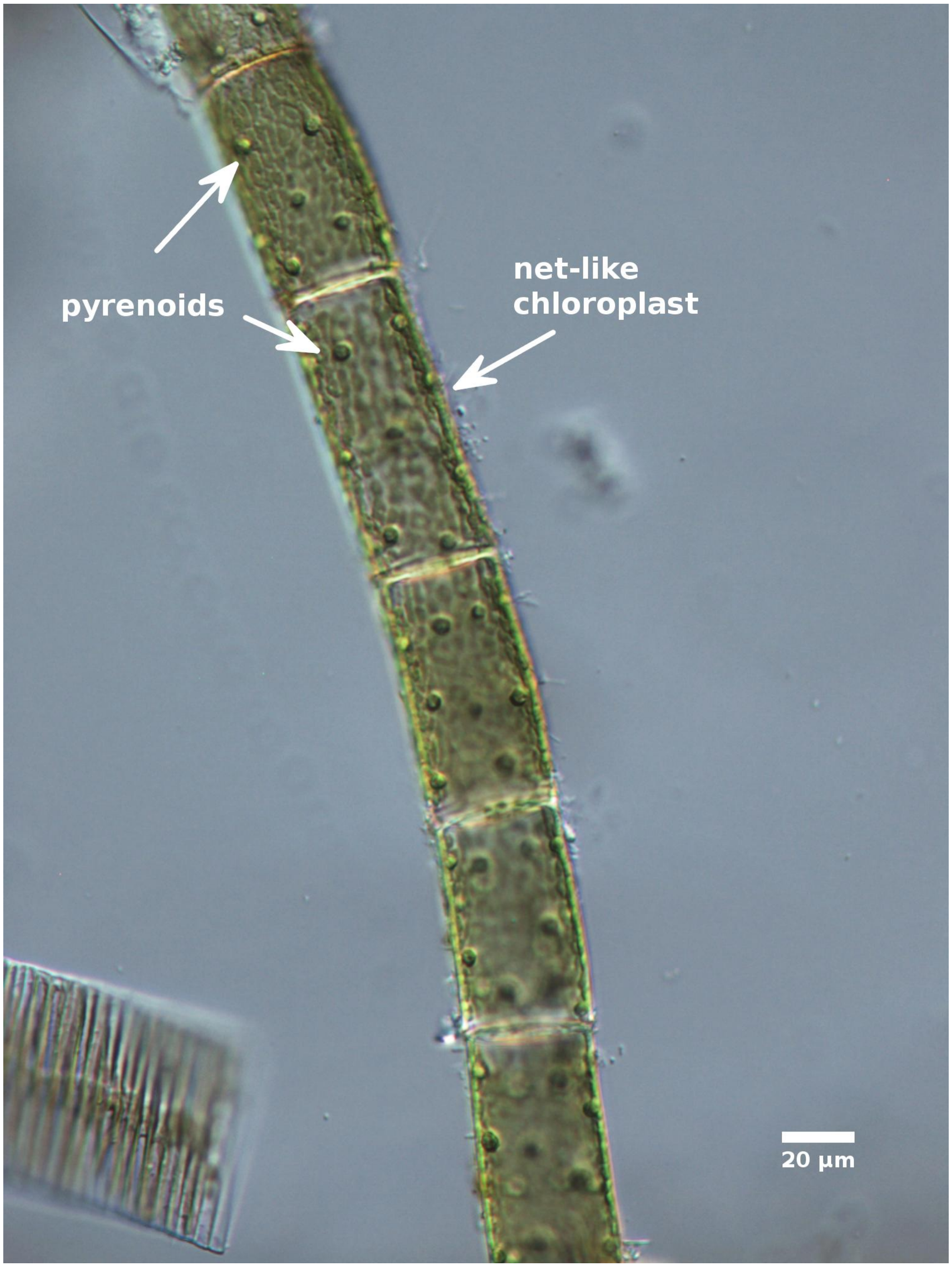


Figure 4.112: *Oedogonium* sp.2 (200x DIC), Whatcom Creek, Whatcom County, May 23, 2013.

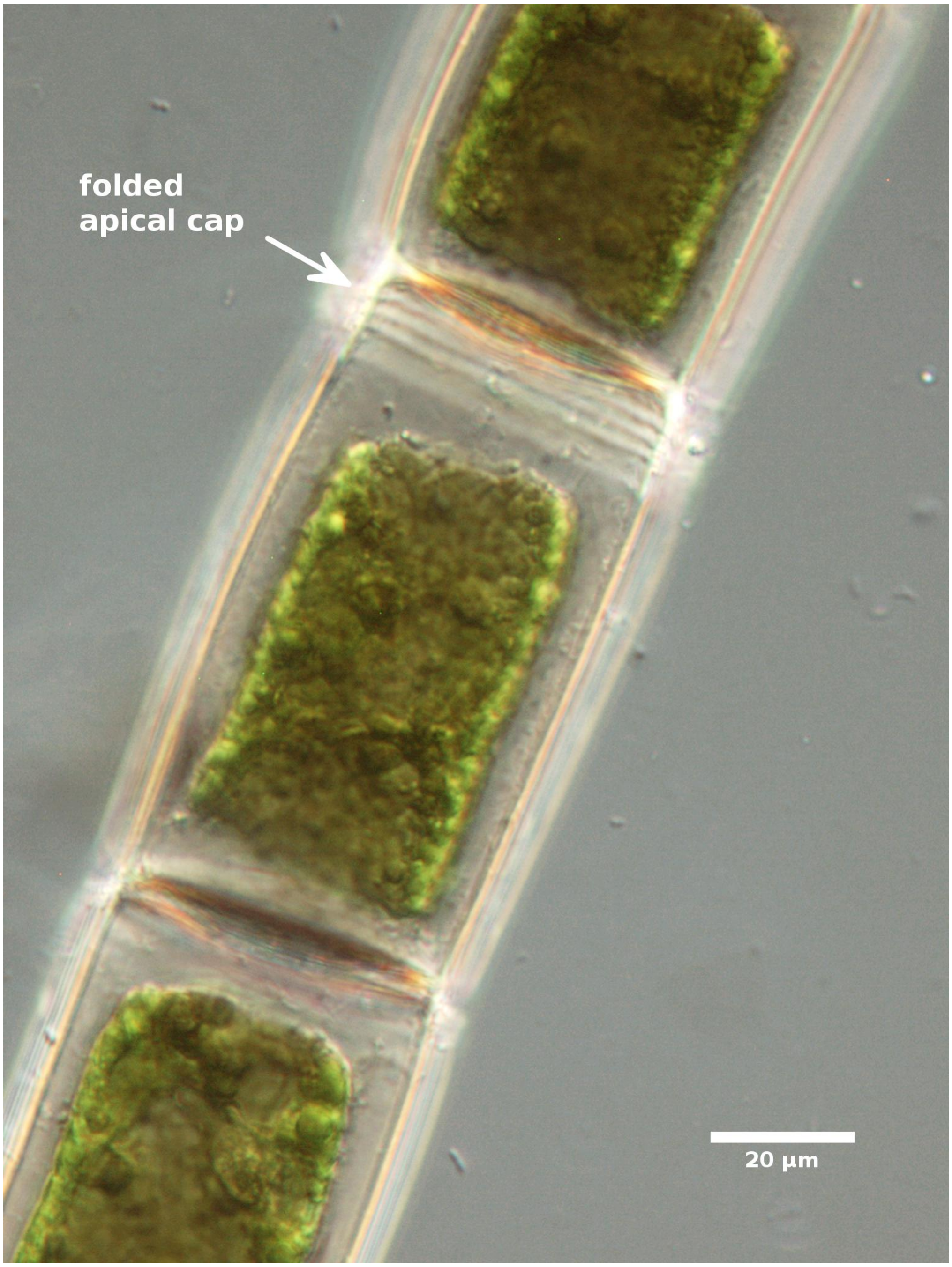


Figure 4.113: *Oedogonium* sp.2 (400x DIC), Whatcom Creek, Whatcom County, May 13, 2013.

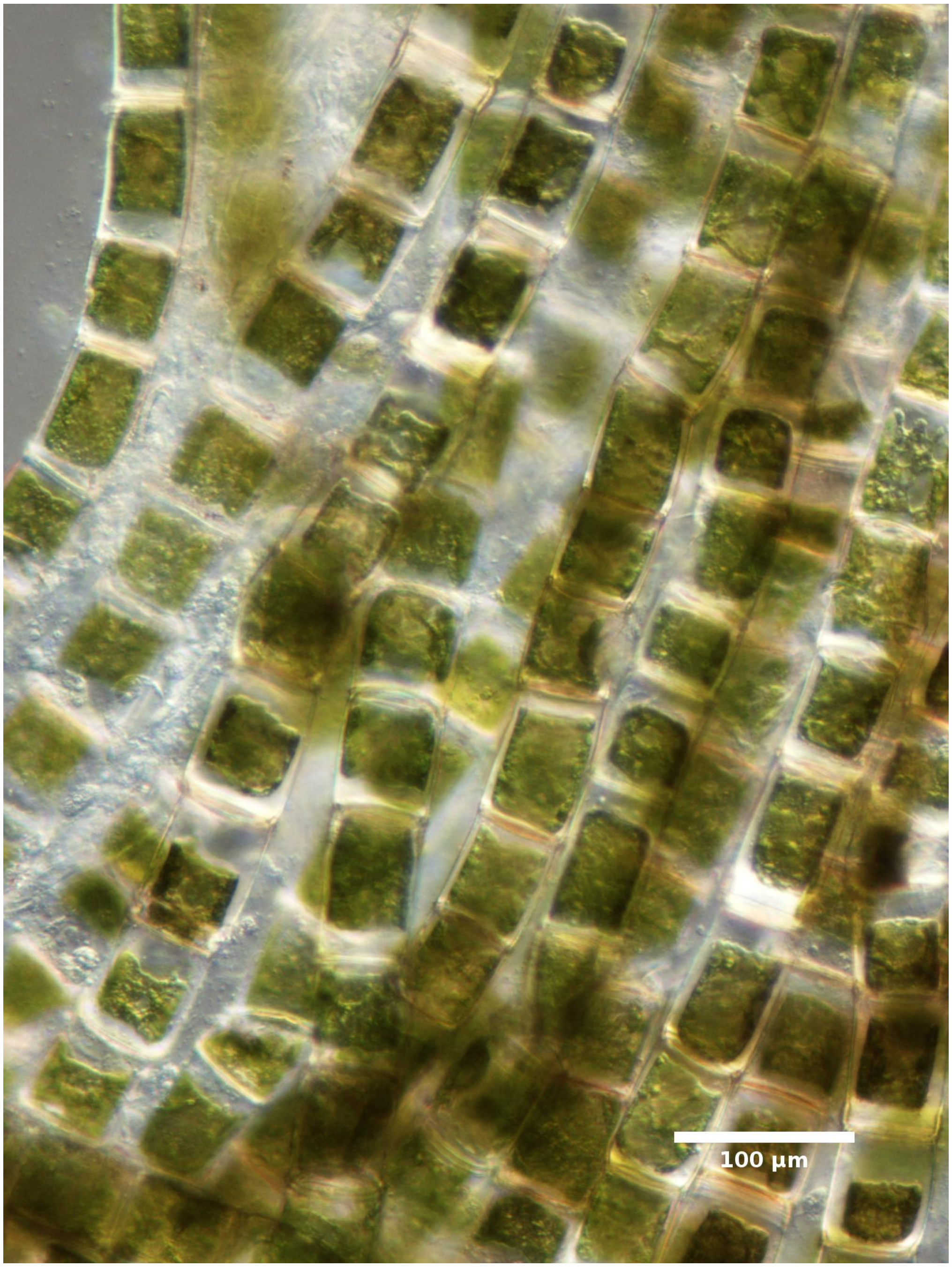


Figure 4.114: *Oedogonium* sp.2 (100x DIC), Whatcom Creek, Whatcom County, May 13, 2013.

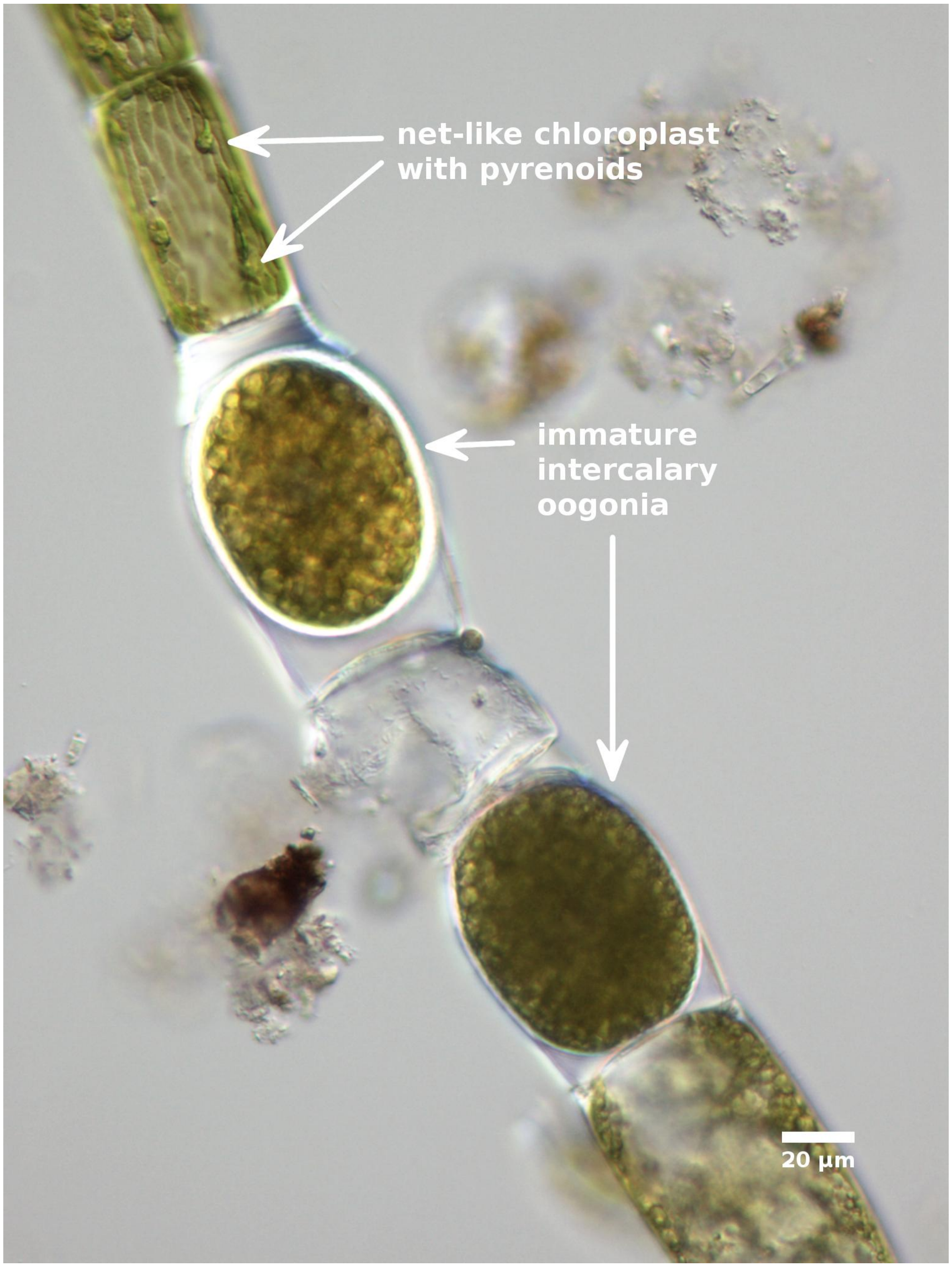


Figure 4.115: *Oedogonium* sp.2 (200x DIC), freshwater pond, Whatcom County, May 31, 2013.

Figure 4.116: *Oedogonium* sp.3 (200x DIC), small pond near Twisp, eastern Washington, May 23, 2013.

Figure 4.117: *Oedogonium* sp.3 (200x DIC), small pond near Twisp, eastern Washington, May 23, 2013.

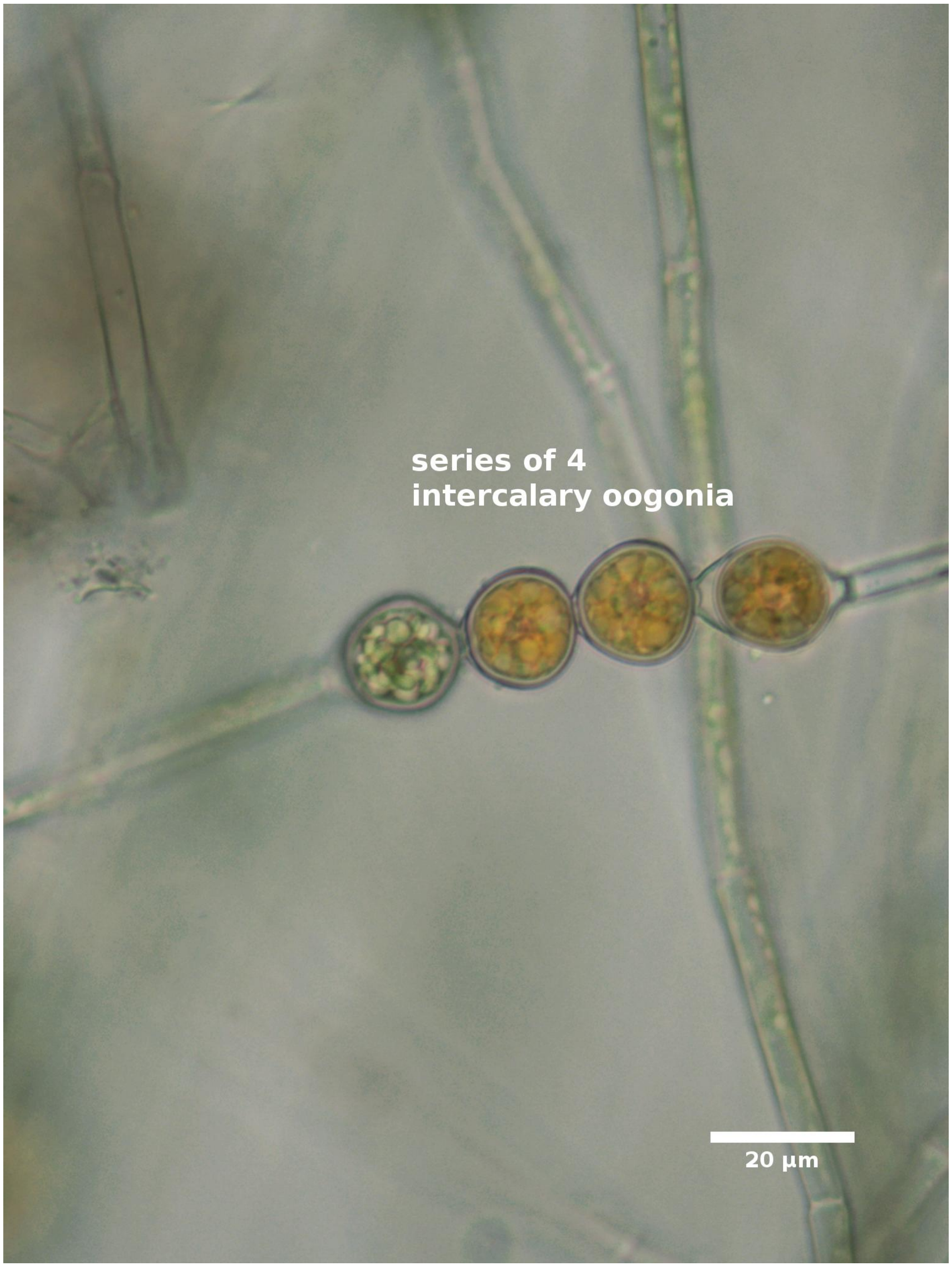


Figure 4.118: *Oedogonium* sp.4 (400x DIC), Agate Lake, Whatcom County, June 18, 2013.

4.17 *Pithophora* Wittrock

Local taxon
Pithophora roettleri (Roth) Wittrock

Abundance
Not yet collected in local lakes or streams; sample from freshwater aquarium.

Local measurements		Width	Length	Biovolume†
Pithophora roettleri	min	58.0 μm	335.5 μm	1,300,000 μm^3
cells (cylinder)	med	65.3 μm	735.3 μm	2,234,000 μm^3
	max	78.8 μm	1,287.4 μm	6,150,000 μm^3
Pithophora roettleri	min	64.1 μm	148.5 μm	332,000 μm^3
intercalary akinetes	med	84.7 μm	169.7 μm	637,000 μm^3
(spheroid)	max	93.4 μm	205.4 μm	816,000 μm^3
Pithophora roettleri	min	65.3 μm	165.8 μm	498,000 μm^3
terminal akinetes	med	78.1 μm	202.7 μm	668,000 μm^3
(spheroid)	max	113.1 μm	230.4 μm	1,400,000 μm^3

†Calculated using original measurements, not summary values.

Description
Pithophora cells are very large, sometimes exceeding 1 mm in length (Figures 4.119–4.121). The chloroplast is net-like (reticulated) and parietal, with many pyrenoids. The filaments are sparsely branched and often contain terminal and intercalary akinetes. This genus was described as tropical or subtropical by John, et al. (2011), but AlgaeBase states that the genus is also found in temperate lakes (AlgaeBase, accessed April 25, 2013). The local specimens were collected from a freshwater aquarium containing water from Rainbow Lake (San Juan Island, WA).

The local specimens will key to *Pithophora oedogonia* (Montagne) Wittrock in most taxonomic keys. This species has been renamed *Pithophora roettleri* based on genetic evidence that showed that most of the morphological variation between *Pithophora* species was caused by environmental factors (Boedeker, et al., 2012).

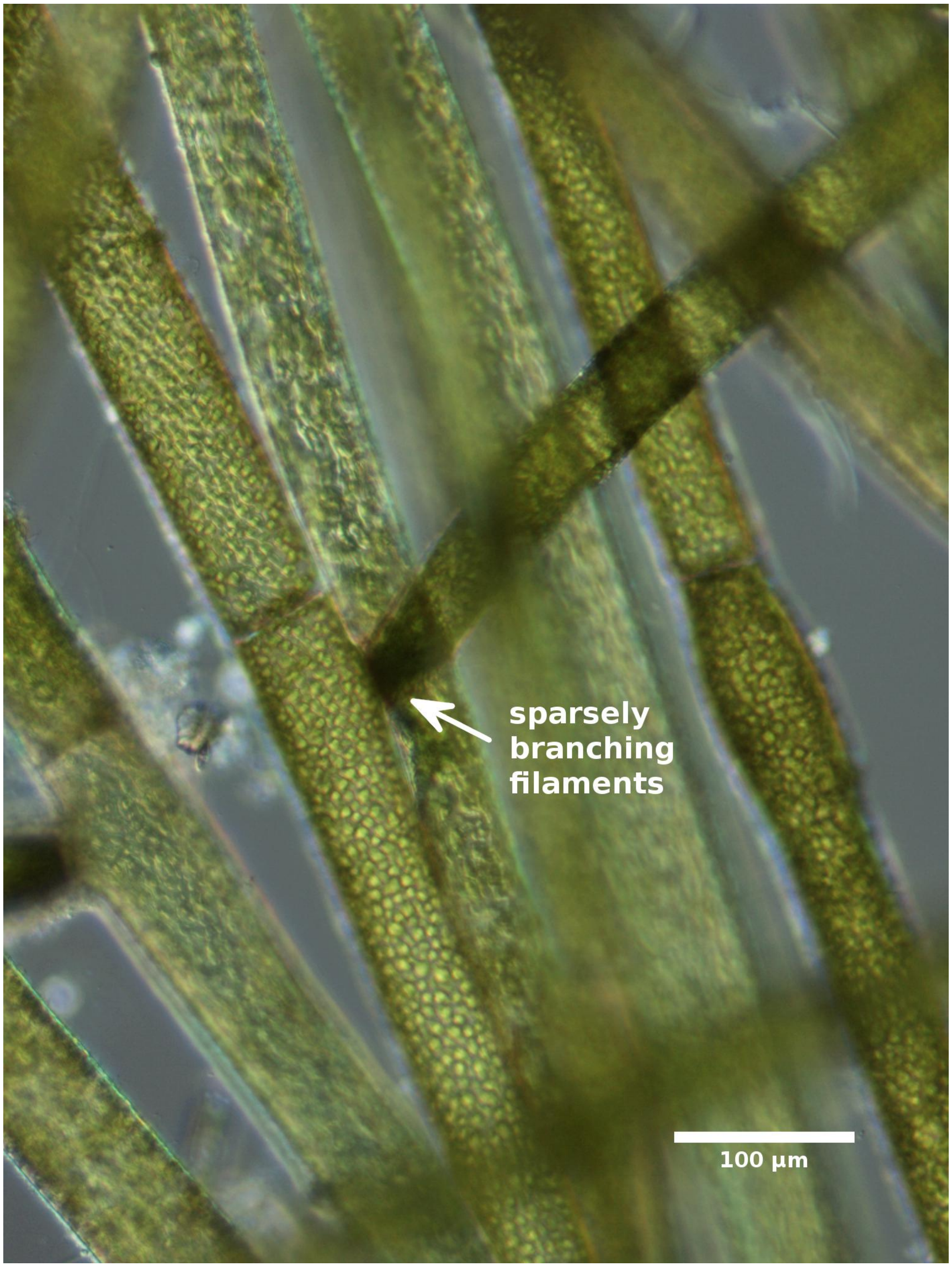


Figure 4.119: *Pithophora roettleri* (100x DIC), freshwater aquarium, source water from Rainbow Lake, San Juan Island, April 8, 2013.

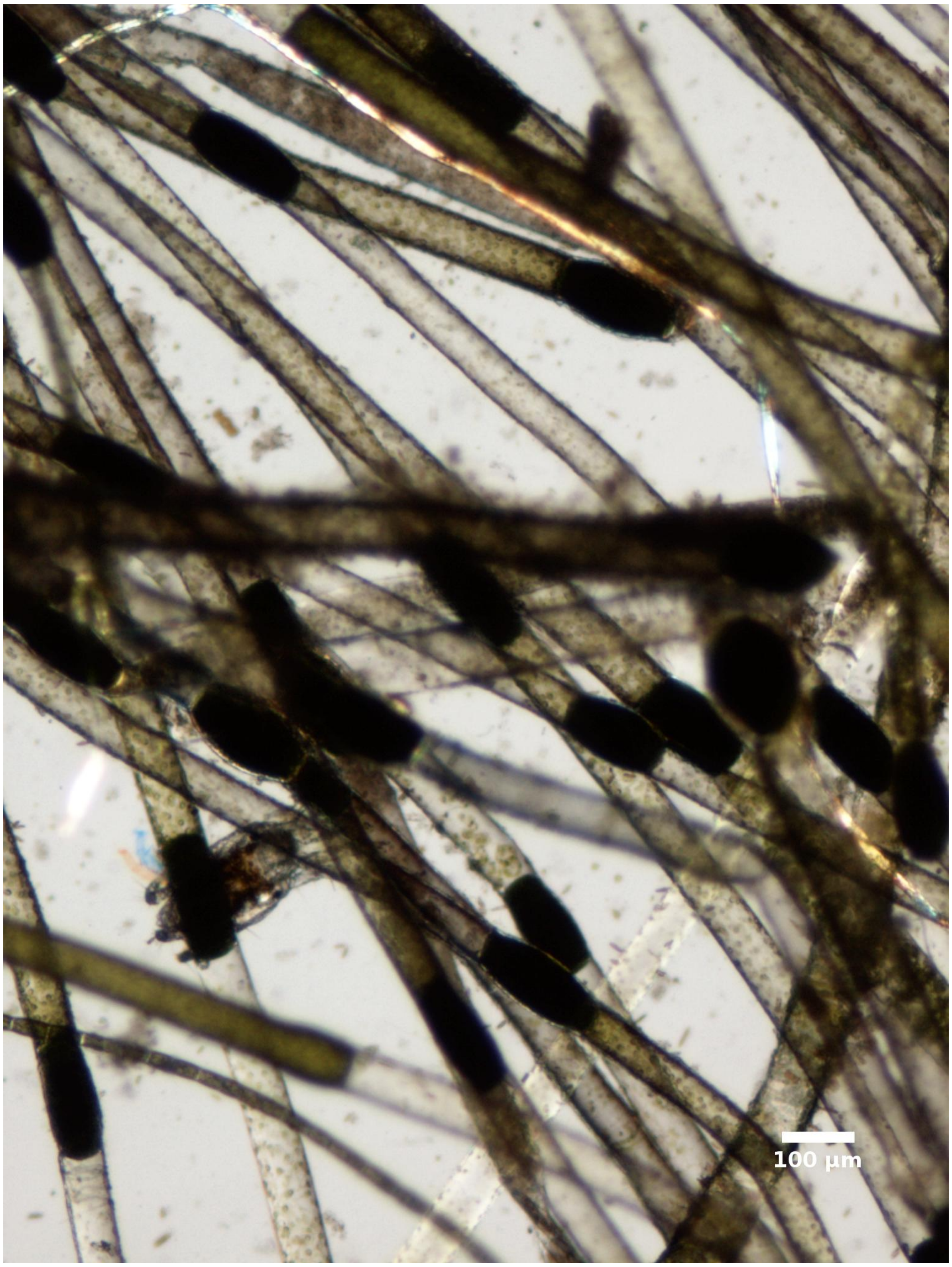


Figure 4.120: *Pithophora roettleri* (40x brightfield), freshwater aquarium, source water from Rainbow Lake, San Juan Island, April 19, 2013.

Figure 4.121: *Pithophora roettleri* (40x brightfield), freshwater aquarium, source water from Rainbow Lake, San Juan Island, April 25, 2013.

4.18 *Radiofilum* Schmidle

Local taxa

Radiofilum conjunctivum Schmidle;
Radiofilum transversale (Brébisson) Christensen
(=*Parallela transversalis* [Brésson], Novis, Lorenz, Borady, and Flint)

Abundance

Infrequently collected in plankton samples; occasionally collected in shoreline samples.

Local measurements		Width	Length	Biovolume†
Radiofilum conjunctivum	min	5.3 μm	6.0 μm	107 μm^3
cells (spheroid)	med	6.8 μm	7.2 μm	168 μm^3
	max	8.0 μm	9.4 μm	312 μm^3
Radiofilum transversale	min	8.2 μm	5.0 μm	183 μm^3
cells (spheroid)	med	10.3 μm	6.0 μm	311 μm^3
	max	13.0 μm	8.3 μm	712 μm^3

†Calculated using original measurements, not summary values.

Description

Radiofilum filaments are short, unbranched, and contain loosely connected, bead-like or compressed cells (Figures 4.122–4.130). Some species have a transverse ring where the cell halves join together. The chloroplast is parietal and cup-shaped, with one or more pyrenoids. The filaments are surrounded by a mucilage layer that may be difficult to see unless stained or viewed using phase contrast illumination. *Radiofilum* resembles some species of *Geminella* (Section 4.9, page 601), which has typically has broadly rounded, elliptical or cylindrical cells enclosed in a wide mucilage layer. *Radiofilum* and *Geminella* are often associated with soft, boggy or acidic water (John, et al., 2011), and most of the local specimens were collected in boggy mountain lakes or shallow, low elevation wetlands. Another interesting feature shared by *Radiofilum* and *Geminella* is the occasional tendency for some cells to divide parallel to the filament, resulting in cell clumps or multiseriate filaments (multiple rows) enclosed in the common mucilage layer (e.g., Figure 4.130 and Figure 4.59 in Section 4.9).

Radiofilum conjunctivum cells are nearly spherical and have a distinct transverse ring around the center of each cell (Figures 4.122–4.126). The cells in the filament form a single, unbranched chain surrounded by a wide, diffuse, indistinct mucilage. When stained with methylene blue, however, the mucilage reveals distinct striations (Figure 4.125). The cells are usually adjacent to each other in the filament, but may also be slightly separated and connected by a thin mucilage strand (Figure 4.126). The presence of a connecting strand of mucilage is why some authorities place this species in the genus *Interfilum* Chodat (no image available), which also has bead-like cells connected by mucilage strands.

Radiofilum transversale cells are compressed, lens-shaped, and much wider than *Radiofilum conjunctivum* (Figures 4.127–4.130). The cells do not have a transverse ring encircling the cell, but may have small equatorial protuberances associated with cell division (Novis, et al., 2010). The cells form pairs that are slightly separated from adjacent cells (pseudofilament), and are not interconnected mucilage strands. The cells are surrounded by a narrow, but clearly visible mucilage layer. Most of the cells divide perpendicular to the length of the filament, but division parallel to the filament is fairly common, and creates multiseriate filaments (multiple rows of cells) or cell clumps enclosed in the common mucilage layer (Figure 4.127 and 4.130). This species has been renamed *Parallela transversalis*, reflecting both morphological and genetic differences from other species of *Radiofilum*.

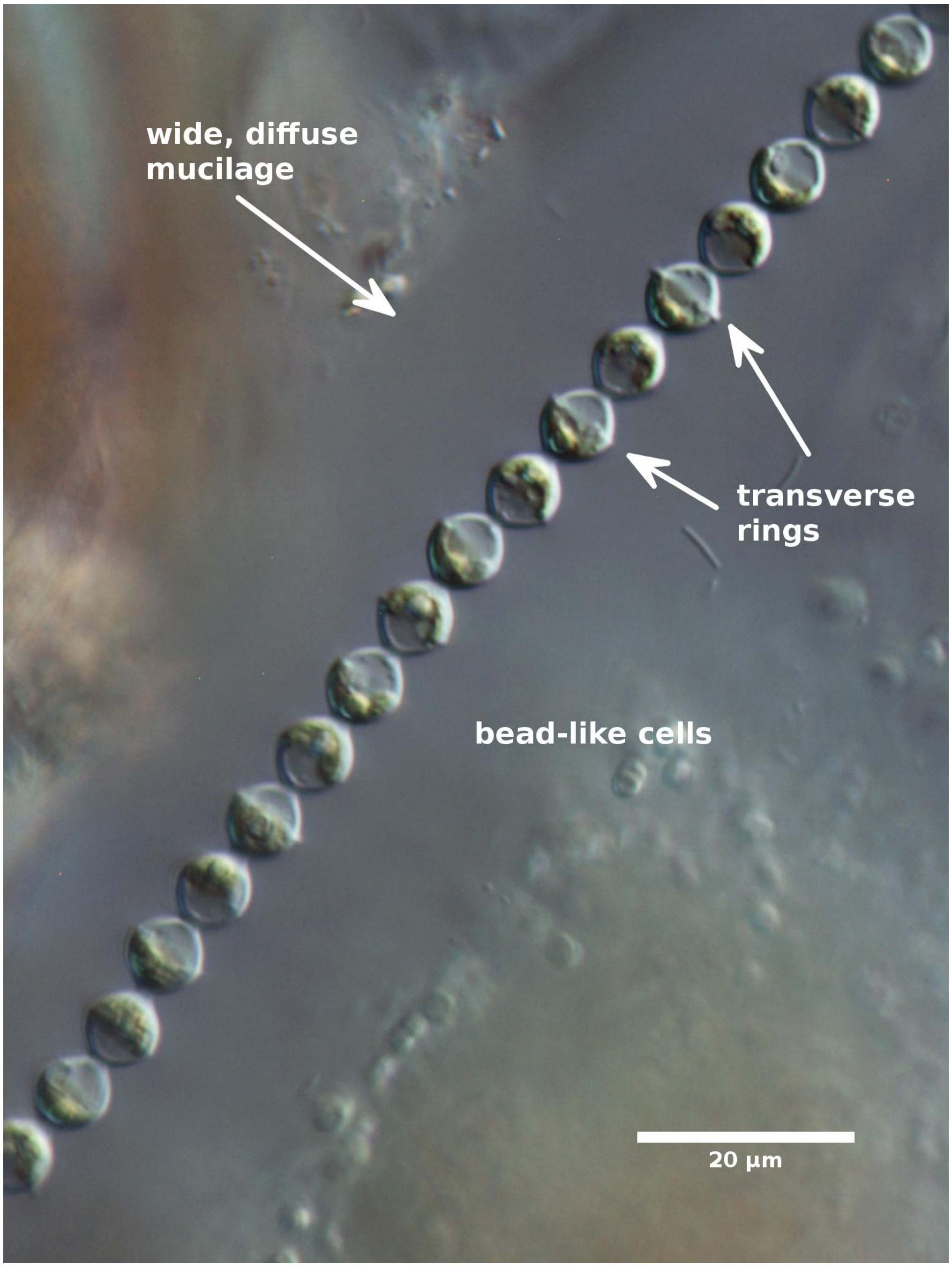


Figure 4.122: *Radiofilum conjunctivum* (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 29, 2013.

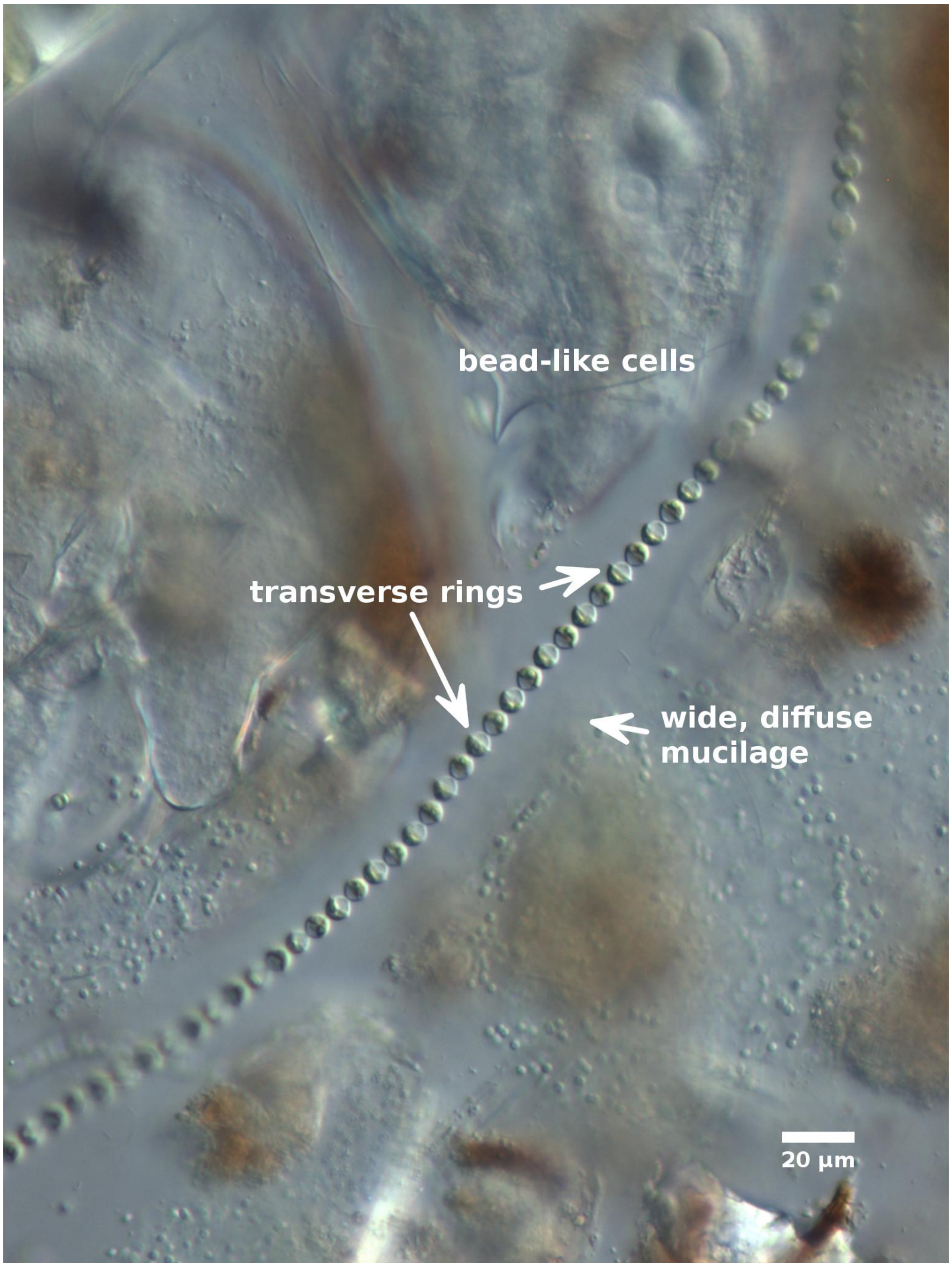


Figure 4.123: *Radiofilum conjunctivum* (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 29, 2013.

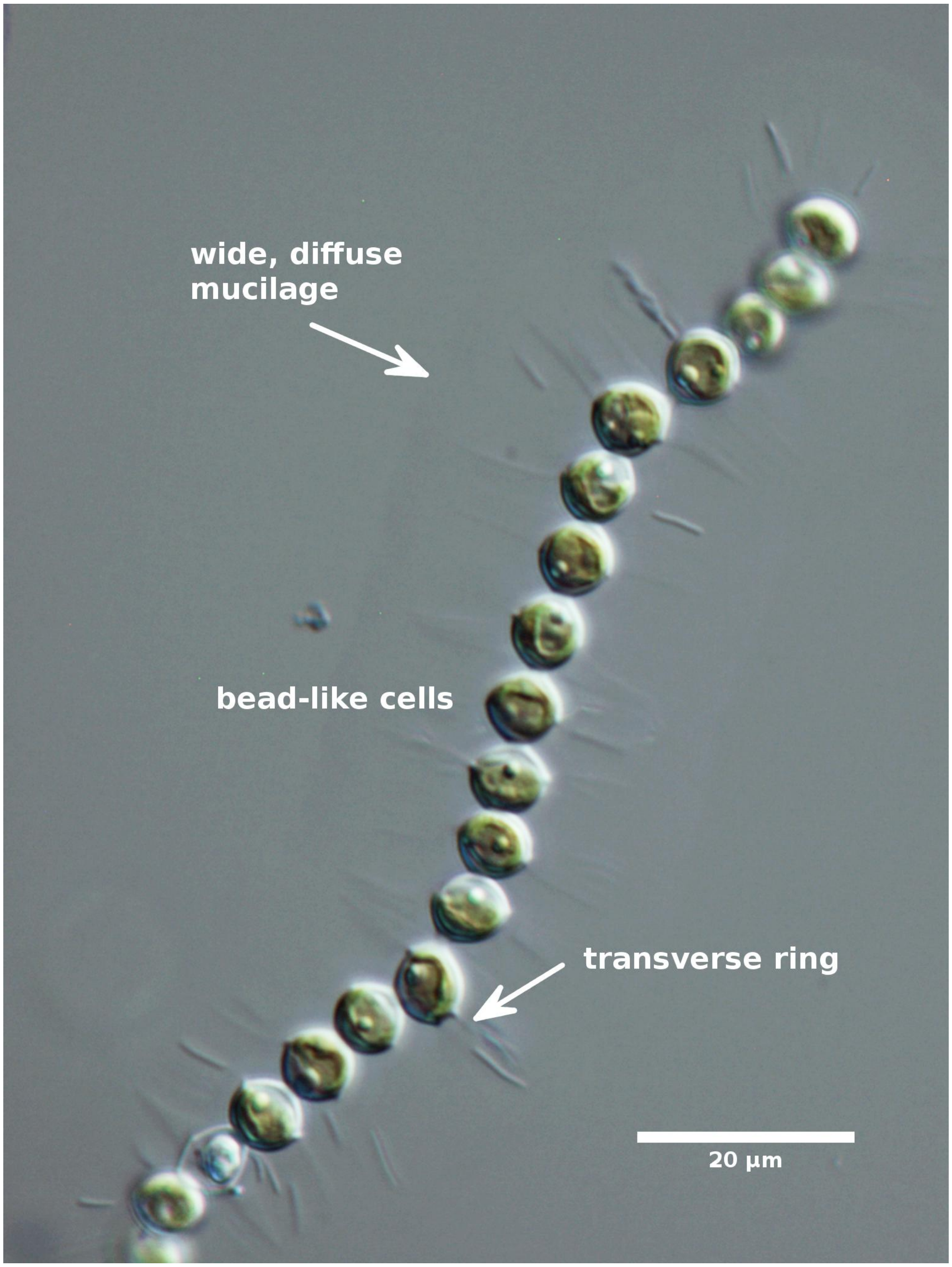


Figure 4.124: *Radiofilum conjunctivum* lightly stained with methylene blue (600x DIC), Lake Howard, IWS water quality sampling site, Snohomish County, August 2, 2012.

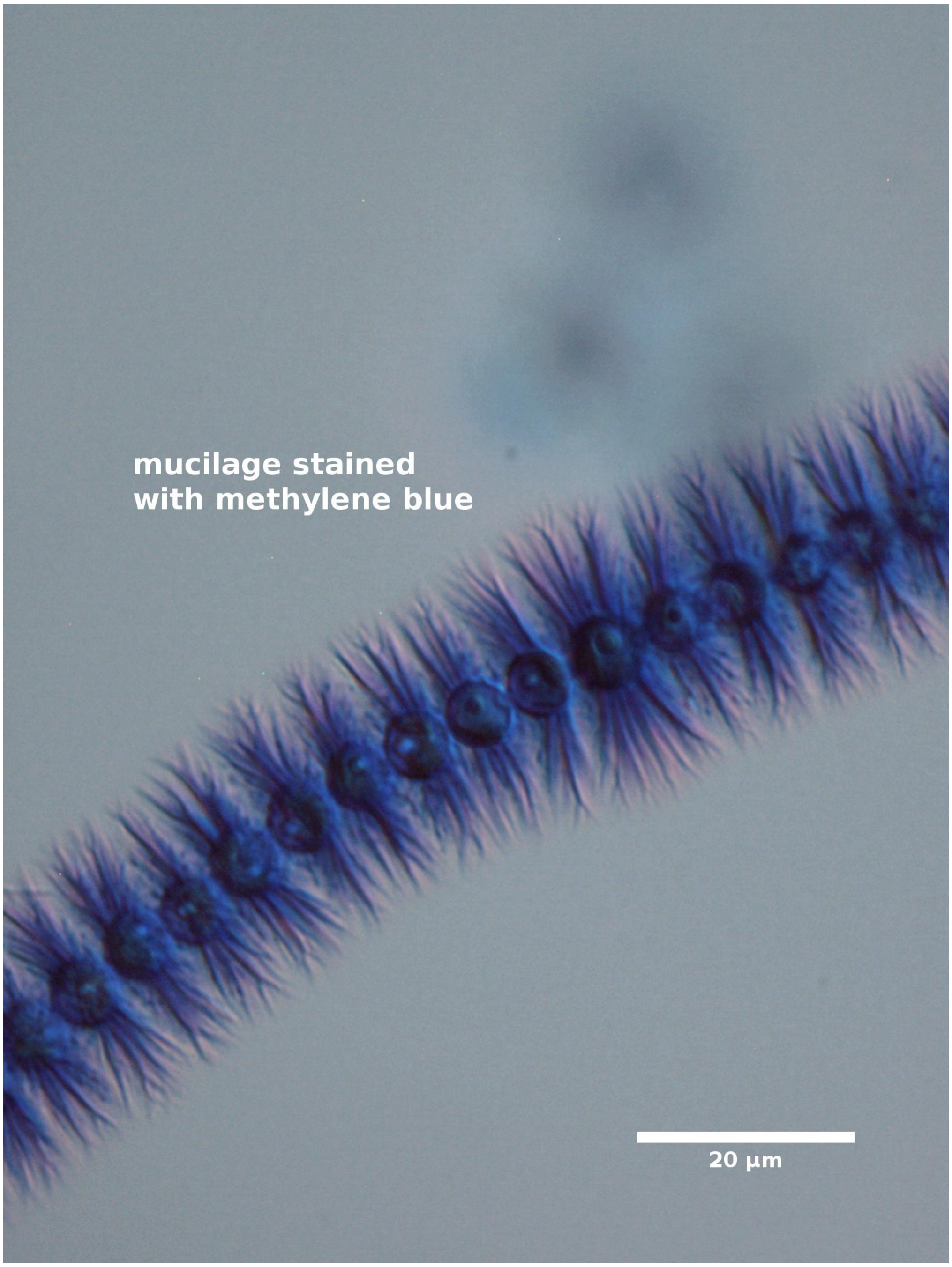


Figure 4.125: *Radiofilum conjunctivum* heavily stained with methylene blue (600x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, July 30, 2013.

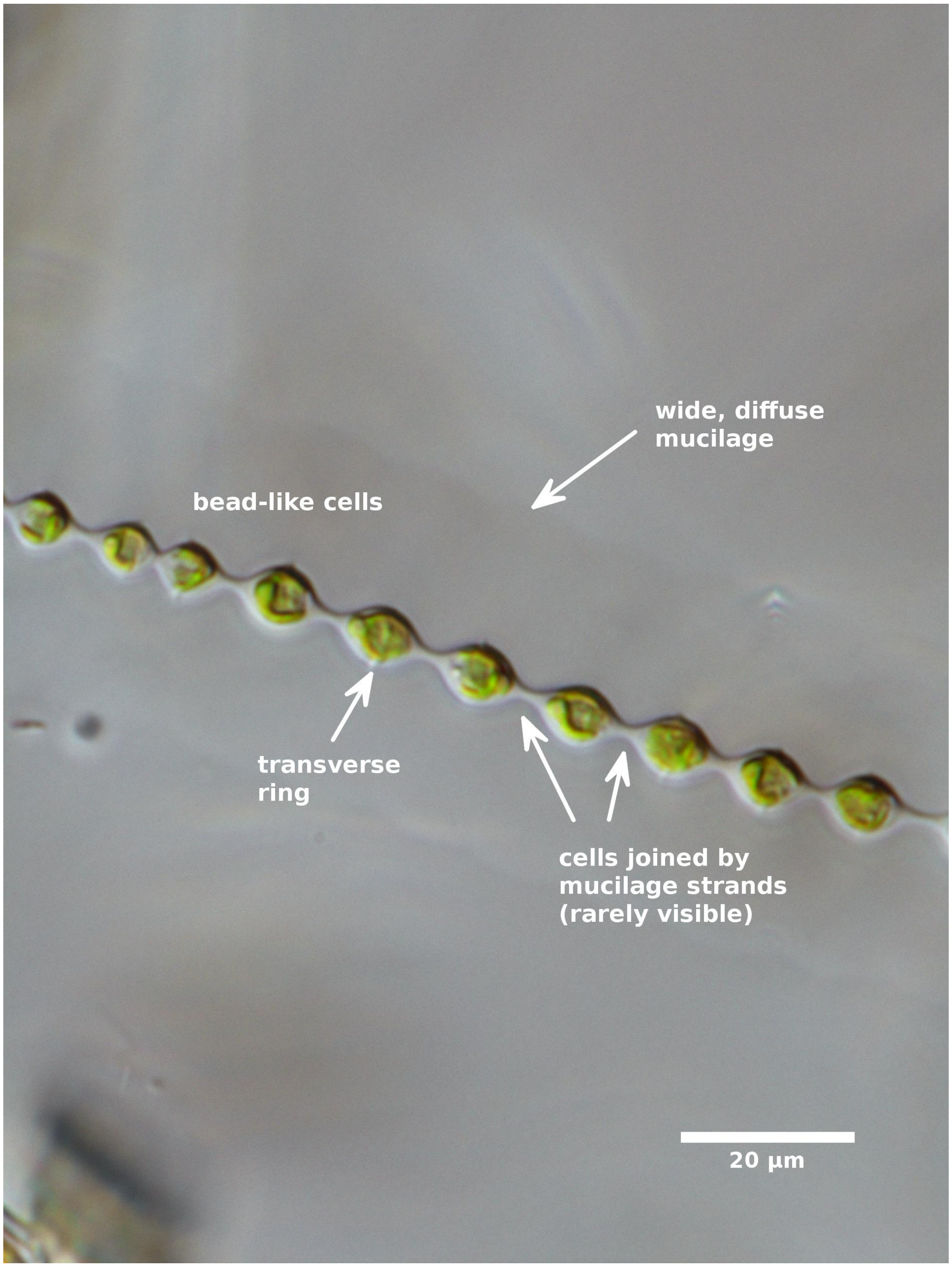


Figure 4.126: *Radiofilum conjunctivum* heavily (600x DIC), Lake Everett, IWS water quality sampling site, Skagit County, August 5, 2015.

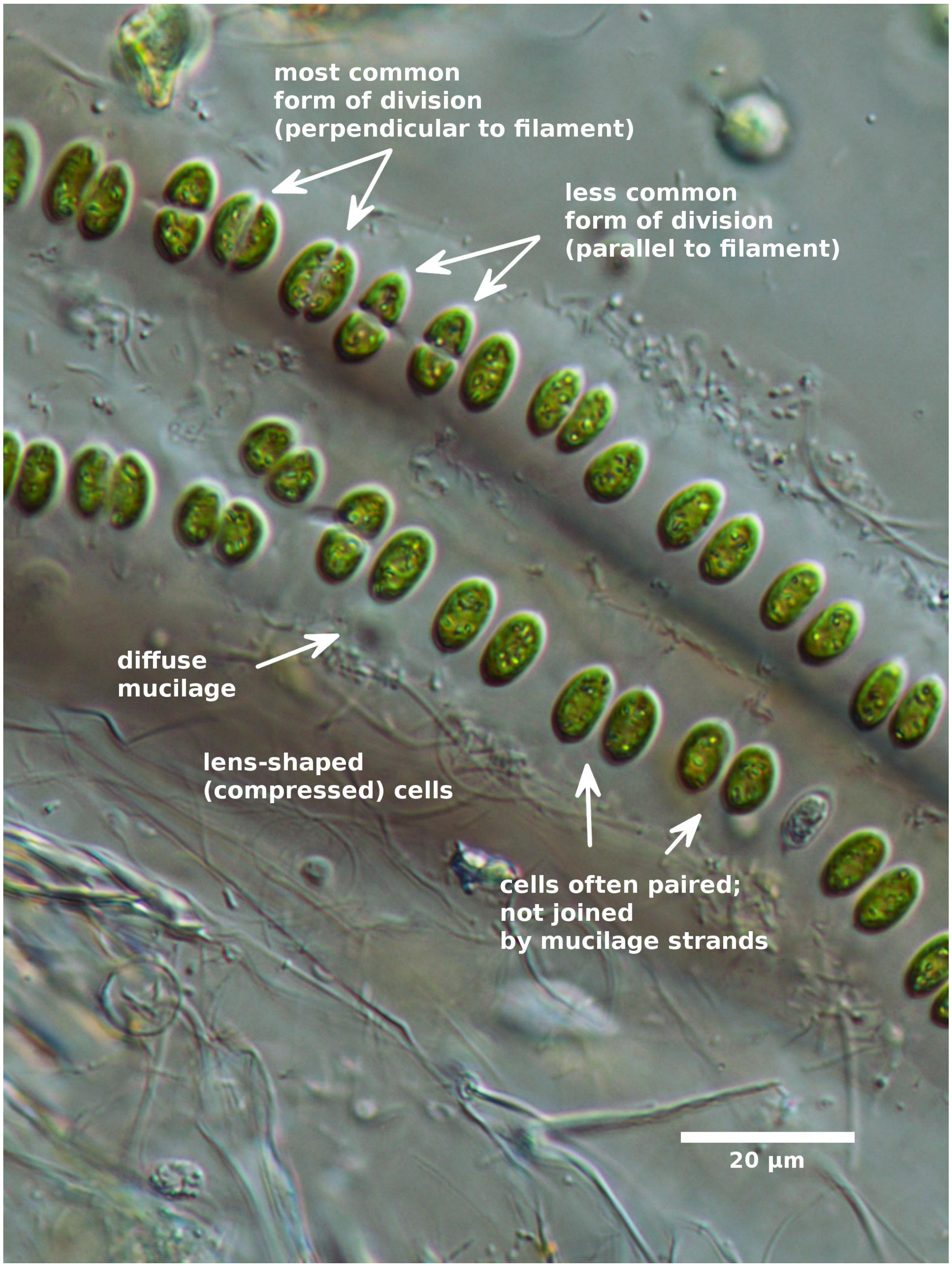


Figure 4.127: *Radiofilum transversale* (600x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, July 8, 2015.

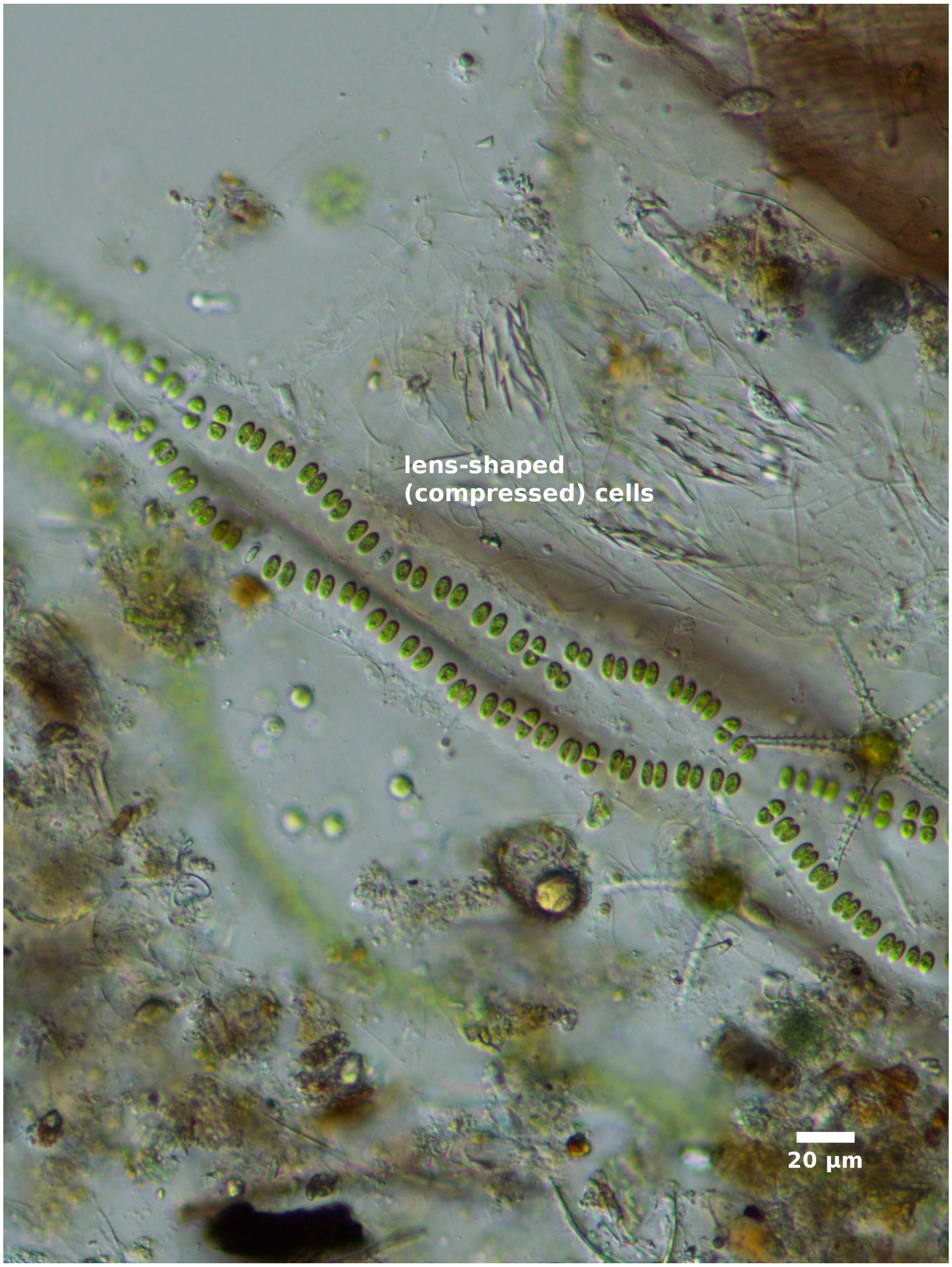


Figure 4.128: *Radiofilum transversale* (200x DIC), Vogler Lake, IWS water quality sampling site, Skagit County, July 8, 2015.

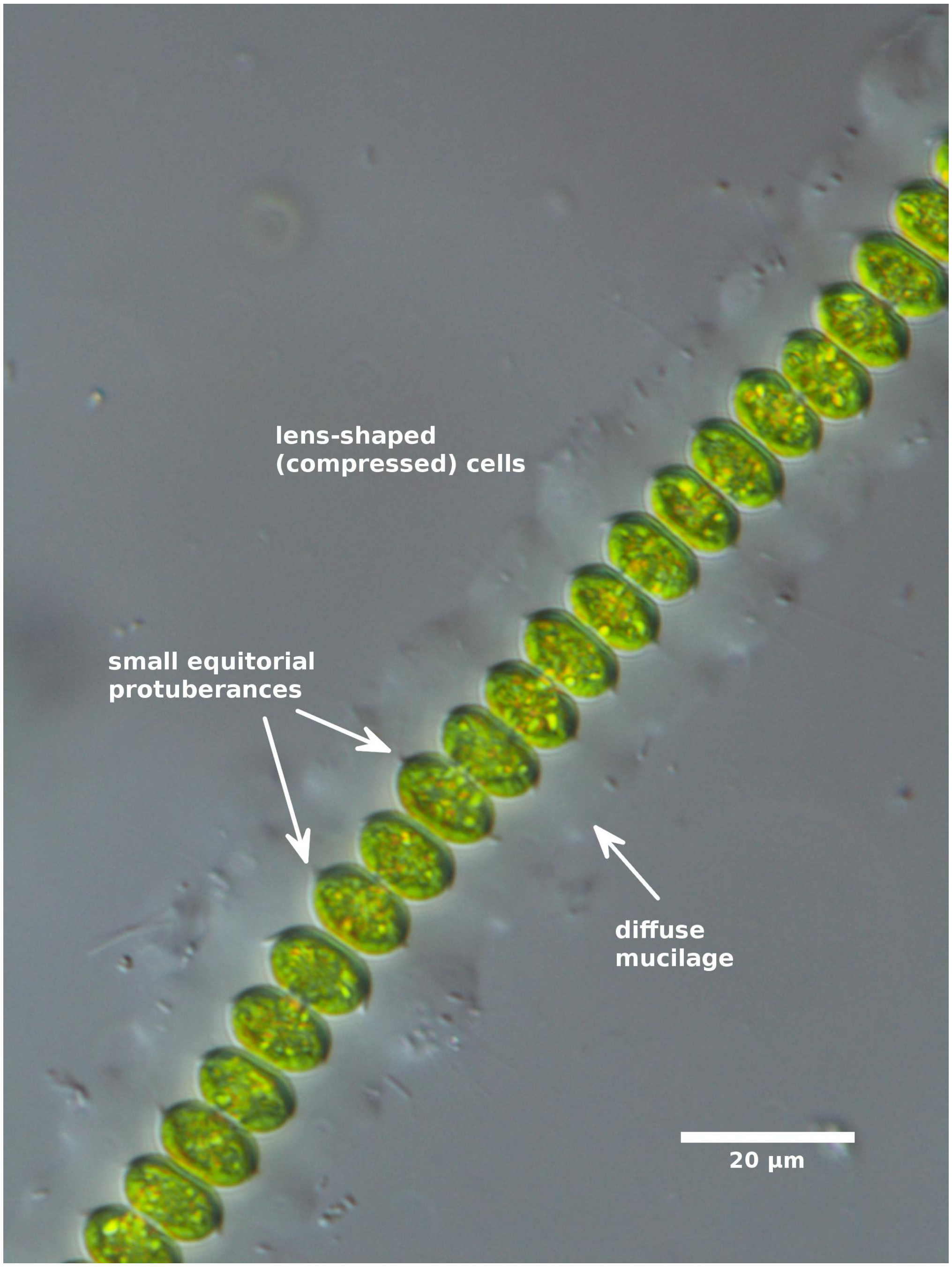


Figure 4.129: *Radiofilum transversale* (600x DIC), small lake north of Sultan, Snohomish County, April 27, 2015.

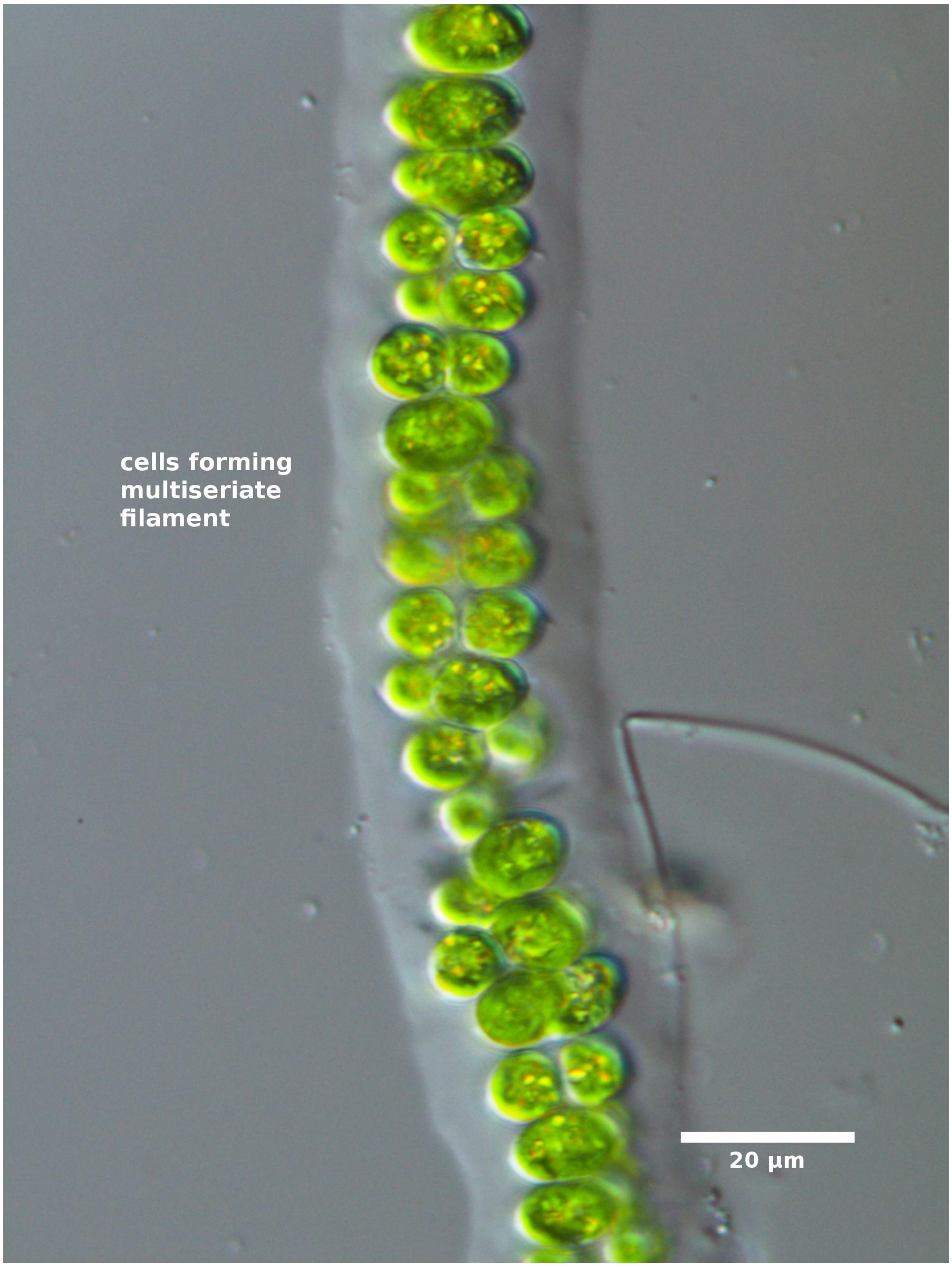


Figure 4.130: *Radiofilum transversale* (600x DIC), small lake north of Sultan, Snohomish County, April 28, 2015.

4.19 *Spirogyra* Link

Local taxa
Spirogyra crassa (Kützing) Kützing?;
Spirogyra majuscula Kützing?;
Spirogyra nitida (Müller) Leiblein?;
Spirogyra varians (Hassal) Kützing?;
Spirogyra spp.

Abundance
Moderately common in plankton samples and along shorelines; very common in flowing water; may form planktonic blooms; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Spirogyra crassa?	min	111.8 μm	115.2 μm	1,230,000 μm^3
cells (cylinder)	med	161.1 μm	239.4 μm	5,740,000 μm^3
	max	191.7 μm	383.4 μm	10,600,000 μm^3
Spirogyra majuscula?	min	49.5 μm	63.8 μm	120,000 μm^3
cells (cylinder)	med	58.8 μm	119.8 μm	312,000 μm^3
	max	78.5 μm	167.7 μm	755,000 μm^3
Spirogyra majuscula?	min	57.7 μm	69.5 μm	131,000 μm^3
zygotes (spheroid)	med	63.6 μm	73.4 μm	154,000 μm^3
	max	73.8 μm	75.7 μm	213,000 μm^3
Spirogyra nitida?	min	65.2 μm	54.8 μm	270,000 μm^3
cells (cylinder)	med	77.3 μm	79.43 μm	371,000 μm^3
	max	93.1 μm	126.6 μm	718,000 μm^3
Spirogyra nitida?	min	70.6 μm	108.7 μm	284,000 μm^3
zygotes (spheroid)	med	78.8 μm	118.8 μm	399,000 μm^3
	max	81.9 μm	130.4 μm	428,000 μm^3

continued on next page

Local measurements		Width	Length	Biovolume[†]
Spirogyra varians?	min	25.7 μm	58.7 μm	34,800 μm^3
cells (cylinder)	med	33.3 μm	115.1 μm	119,000 μm^3
	max	43.8 μm	233.8 μm	205,000 μm^3
Spirogyra varians?	min	22.1 μm	33.5 μm	9,940 μm^3
zygotes (spheroid)	med	36.5 μm	60.5 μm	44,600 μm^3
	max	44.4 μm	69.5 μm	69,000 μm^3
Spirogyra type 1	min	20.1 μm	125.3 μm	40,000 μm^3
cells (cylinder)	med	40.5 μm	321.1 μm	430,000 μm^3
	max	47.0 μm	598.2 μm	893,000 μm^3
Spirogyra type 1	min	47.5 μm	77.9 μm	125,000 μm^3
zygotes (spheroid)	med	55.0 μm	107.0 μm	170,000 μm^3
	max	62.2 μm	129.4 μm	220,000 μm^3
Spirogyra type 2	min	43.8 μm	171.2 μm	278,000 μm^3
cells (cylinder)	med	49.1 μm	310.2 μm	708,000 μm^3
	max	70.1 μm	516.6 μm	1,220,000 μm^3
Spirogyra type 2	min	40.8 μm	56.8 μm	55,100 μm^3
zygotes (spheroid)	med	43.7 μm	60.2 μm	57,300 μm^3
	max	44.5 μm	63.2 μm	62,700 μm^3
Spirogyra type 3	min	16.6 μm	63.8 μm	20,500 μm^3
cells (cylinder)	med	20.9 μm	101.7 μm	32,300 μm^3
	max	24.1 μm	269.8 μm	102,000 μm^3
Spirogyra type 4[‡]	min	27.4 μm	474.6 μm	293,000 μm^3
cells (cylinder)	med	28.5 μm	495.6 μm	316,000 μm^3
	max	38.0 μm	496.6 μm	538,000 μm^3

[†]Calculated using original measurements, not summary values.
[‡]Biovolume estimate based on <5 cells.

Description

Spirogyra, *Mougeotia* (Section 4.15, page 655), and *Zygnema* (Section 4.23, page 749) are closely related. All three genera are members of the order **Zygnematales**, which also includes desmids.[26] Members of this order reproduce by forming conjugation bridges between filaments. The resulting zygote contains genetic information from both filaments. The genus *Spirogyra* has distinctive, ribbon-like, spiraling chloroplasts dotted with pyrenoids (Figures 4.131–4.155). Cells contain one or more chloroplast that spiral around the inside of the cell wall. The end wall between adjacent cells may be folded (Figure 4.133) or flat (Figure 4.134). Sexual reproduction occurs when 2 filaments join via conjugation bridges, producing thick-walled zygotes (Figures 4.134–4.135). *Spirogyra* cells also reproduce vegetatively through simple cellular division and filament fragmentation.

Spirogyra filaments are usually unmistakable, but the cells can be confused with *Spirotaenia*, a solitary desmid with a spiraling chloroplast. In addition, some species of the desmid *Gonatozygon* form short filaments with irregularly spiraling, ribbon-like chloroplasts, but the chloroplasts lack the regular spiraling structure that defines *Spirogyra*. While the genus *Spirogyra* is easy to recognize, species identification is difficult, not only because there are hundreds of described species, but also because accurate identification requires careful examination of the vegetative cells, conjugating filaments, and mature zygotes. Species identification is beyond the scope of this guide, so only a few local *Spirogyra* taxa have been tentatively identified to species, and the rest are described by morphological type.

Spirogyra crassa has extremely wide cells (>100 μm), making it one of the more easily identified species of *Spirogyra* (Figures 4.136–4.137). The cells are relatively short (often wider than long), with flat end walls. Each cell contains many narrow chloroplasts (6–12) that spiral 0.5–1 times around the inside of the cell. No mature zygotes were collected in the local samples.

Spirogyra majuscula has moderately wide cells (>50 μm) that are usually slightly longer than wide (Figures 4.138–4.140). The cells have flat end walls, and contain >5 chloroplasts that make less than one full spiral around the inside of the cell. The zygotes are broadly lens-shaped (circular in cross-section). The conjugation bridges extend from both of the paired filaments. The cells that contain zygotes are often slightly inflated compared to the uninflated cells in the opposite filament.

[26] See **Freshwater Algae in Northwest Washington, Volume III. Desmids**.

Spirogyra nitida resembles *Spirogyra majuscula*, with moderately wide cells (>70 μm) that are longer than wide and have flat end walls. *Spirogyra nitida* can be distinguished by its slightly larger cells that contain fewer chloroplasts (3–5) and make up to one full turn around the inside of the cell (Figures 4.141–4.142). The zygotes are larger and slightly more elliptical than *Spirogyra majuscula* zygotes, but the conjugation bridges and fertilized cells share similar morphological features (bridges form from both filaments; fertilized cells are often slightly inflated).

Spirogyra varians has long cylindrical cells with flat end walls and a single chloroplast that spirals approximately 1–5 times around the inside of the cell (Figures 4.143–4.146). Conjugation bridges extend from both filaments. The elliptical zygotes are contained inside slightly to moderately inflated cells. The empty cells immediately opposite zygotes are usually not inflated, but other cells along the filaments may be enlarged. This species is noted for its morphological variability, which may represent hybridization with several other *Spirogyra* species (John, et al., 2011).

Spirogyra type 1 cells are very long, narrow, and lack end wall folds. The cells contain approximately 3–4 chloroplasts that spiral 3–5 times around the inside of the cell (Figures 4.147–4.149). Conjugation bridges extend from both filaments. The zygotes are broadly elliptical or lens-shaped, and form inside slightly inflated cells; empty cells on the opposite filament are not inflated. This species was collected in several high elevation mountain lakes.

Spirogyra type 2 cells are also very long, narrow, and lack end wall folds (Figures 4.150–4.152). The cells contain 4–6 chloroplasts that are nearly straight, or make no more than one spiral inside the cell. The zygotes are oval or elliptical, and form inside inflated cells.

Spirogyra type 3 and *Spirogyra* type 4 are both characterized by long, narrow cells with distinctive end wall folds (Figures 4.153–4.157). *Spirogyra* type 3 has a single chloroplast that makes approximately 2–6 spirals around the inside of the cell twice inside the cell. *Spirogyra* type 4 has two chloroplasts that complete 2 spirals inside the cell. No zygotes were collected for either of these taxa.

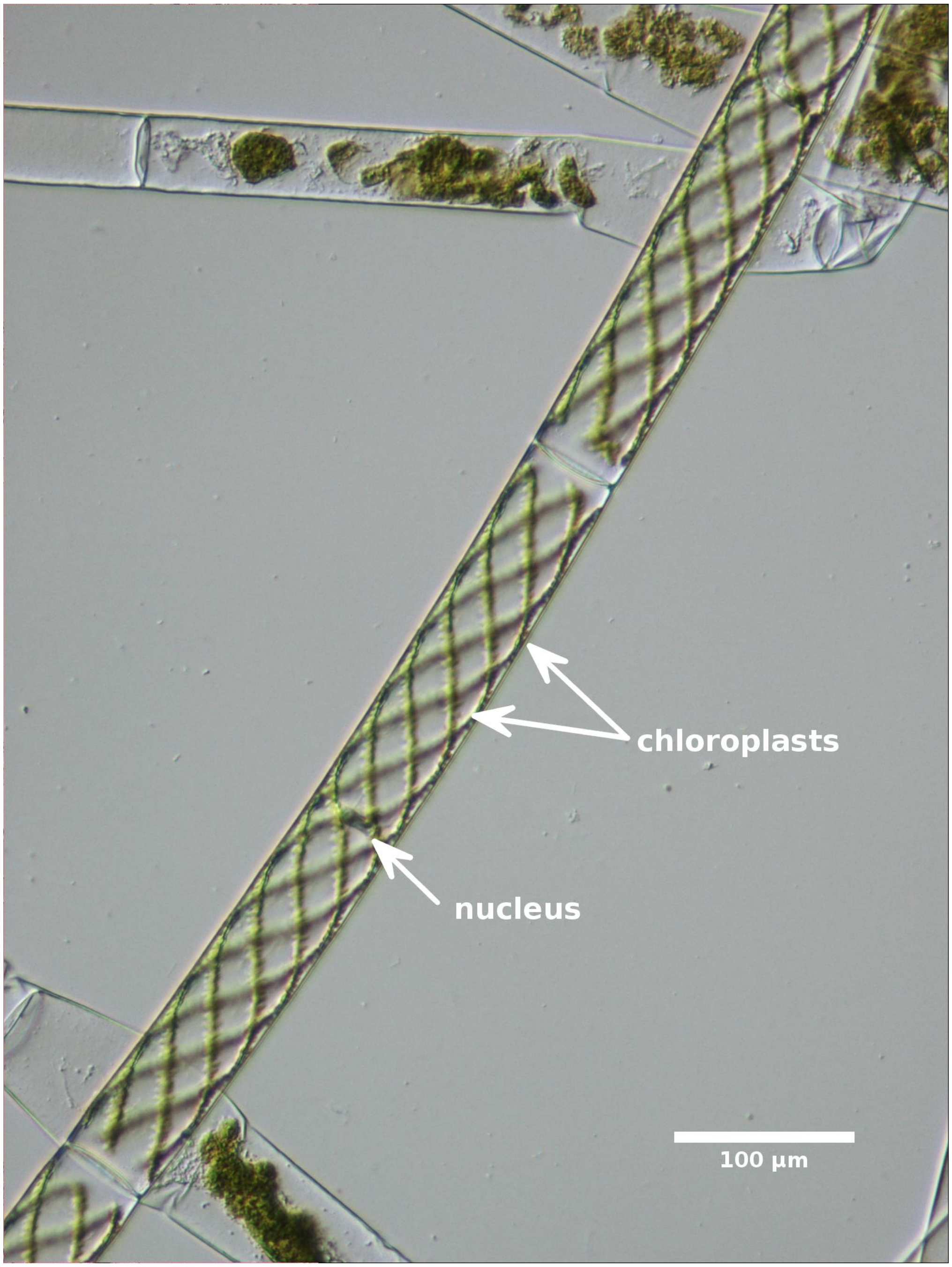


Figure 4.131: Typical *Spirogyra* filament (100x DIC), Carolina Biological Supply Co., May 25, 2011.

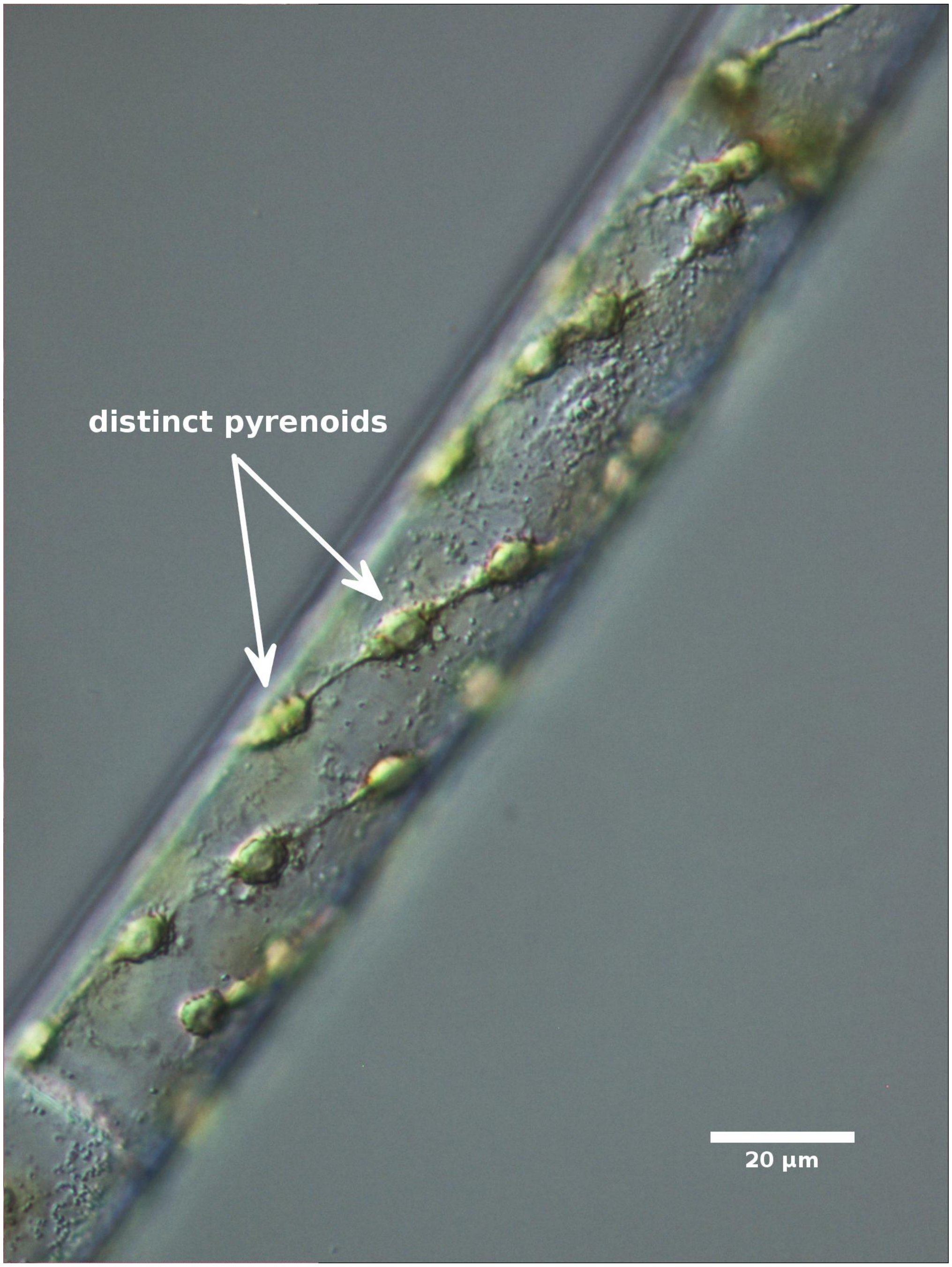


Figure 4.132: *Spirogyra* pyrenoids (400x DIC), Clear Lake, IWS water quality sampling site, Skagit County, July 28, 2011.

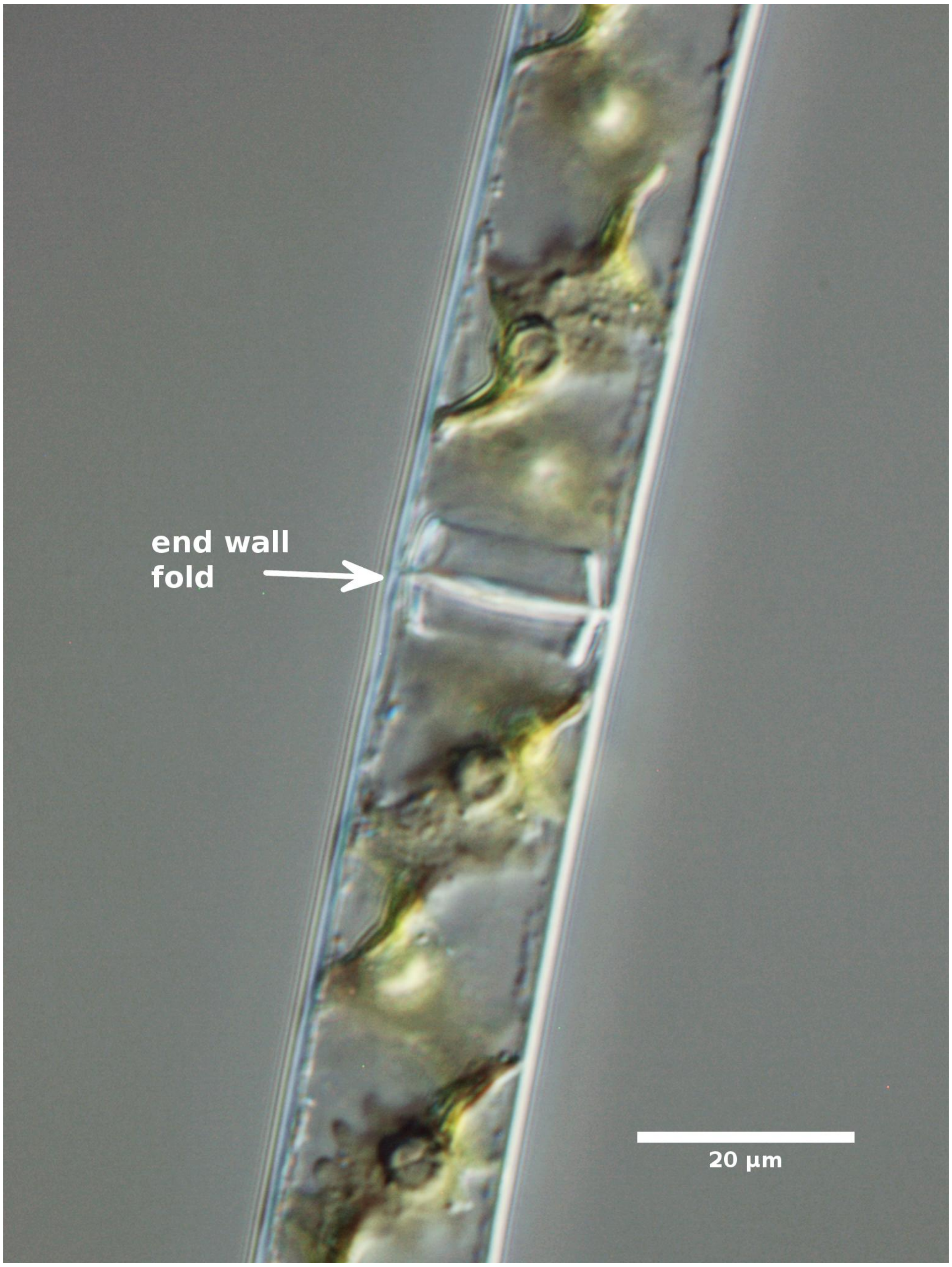


Figure 4.133: *Spirogyra* end wall fold (600x DIC), Lower Bagley Lake, IWS water quality sampling site, Whatcom County, October 12, 2012.

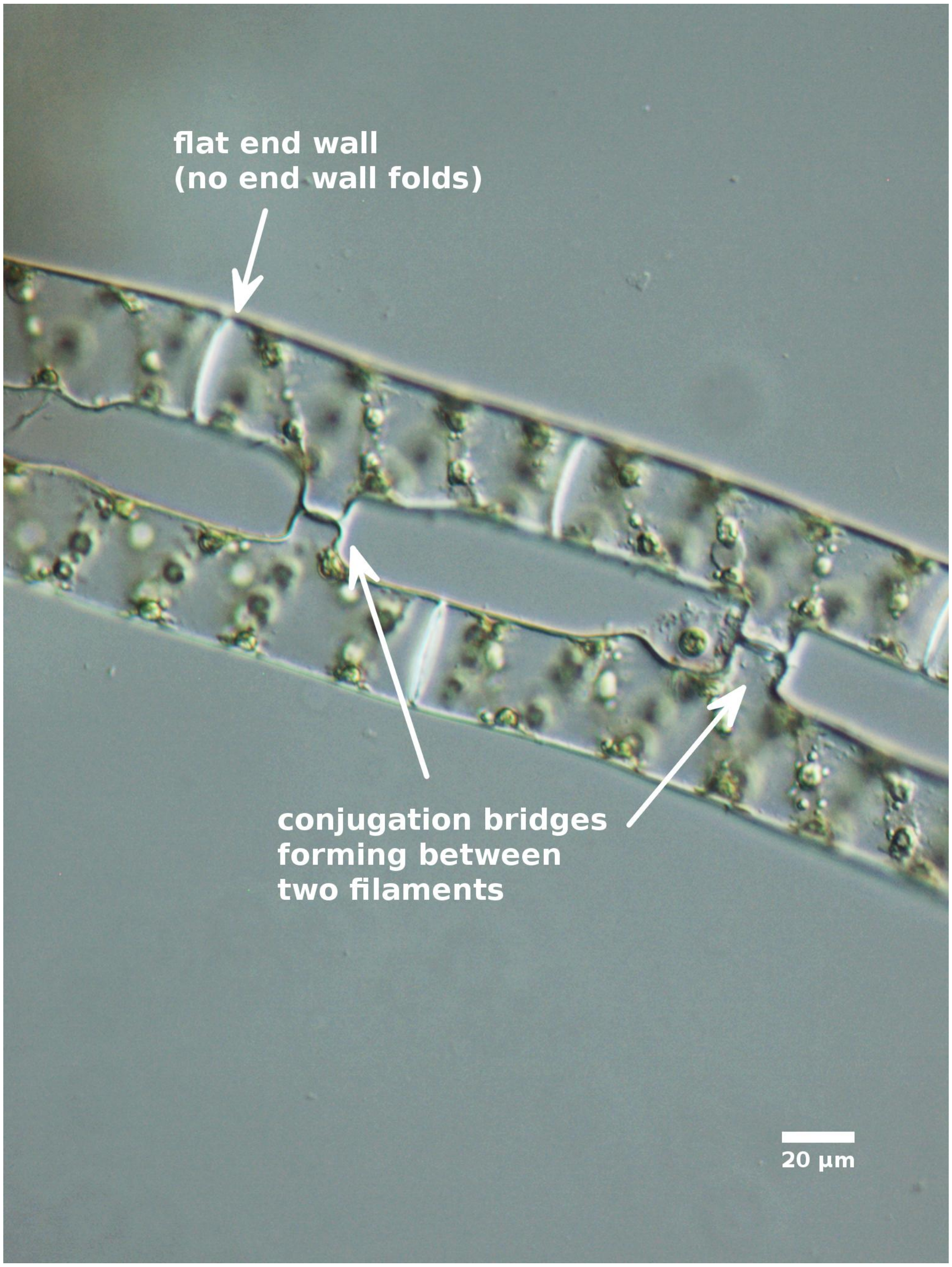


Figure 4.134: *Spirogyra* conjugation bridge (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 9, 2013.

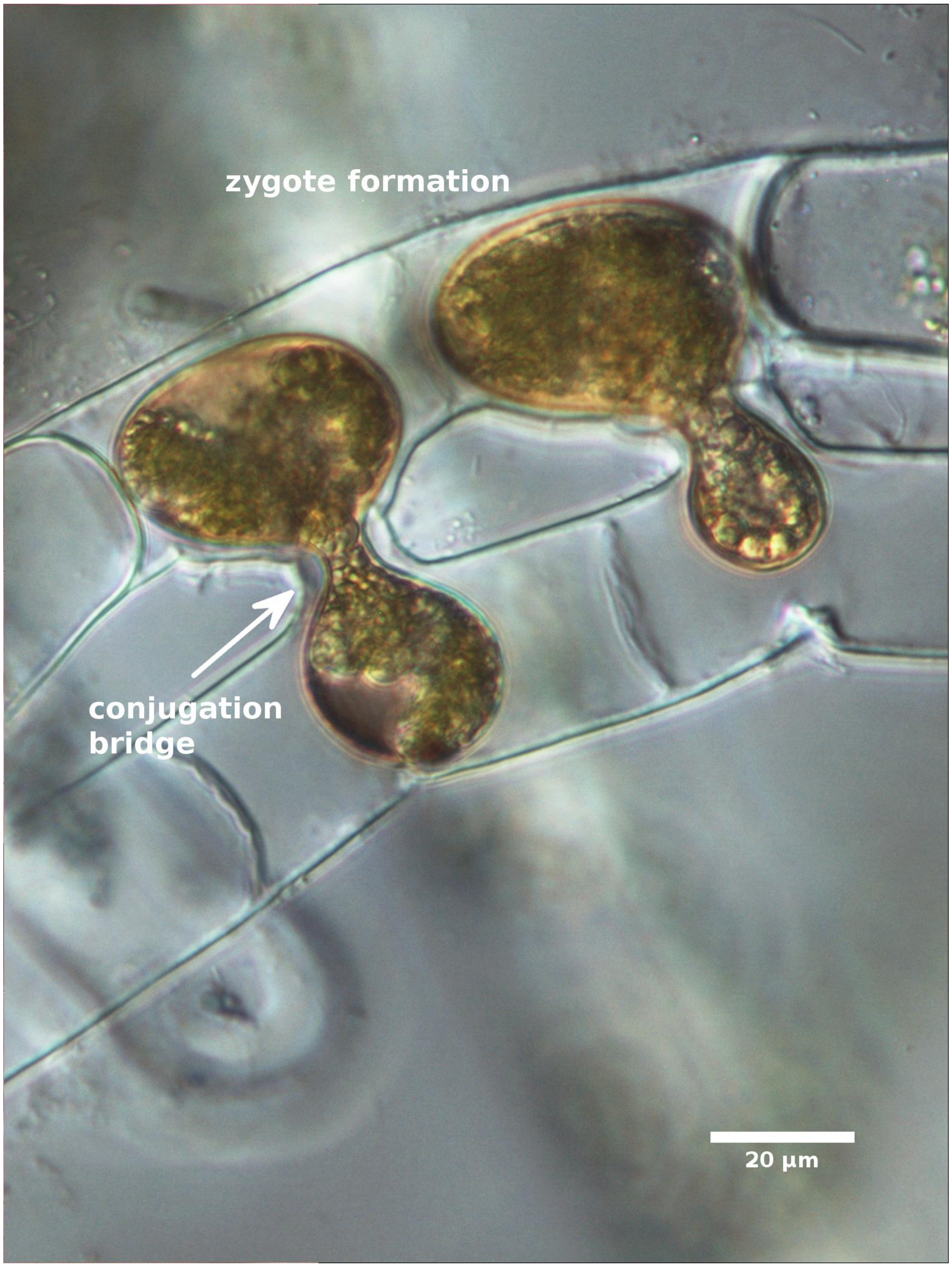


Figure 4.135: *Spirogyra* zygote formation (400x DIC), Scudder's Pond (Lake Whatcom watershed), Whatcom County, May 25, 2011.

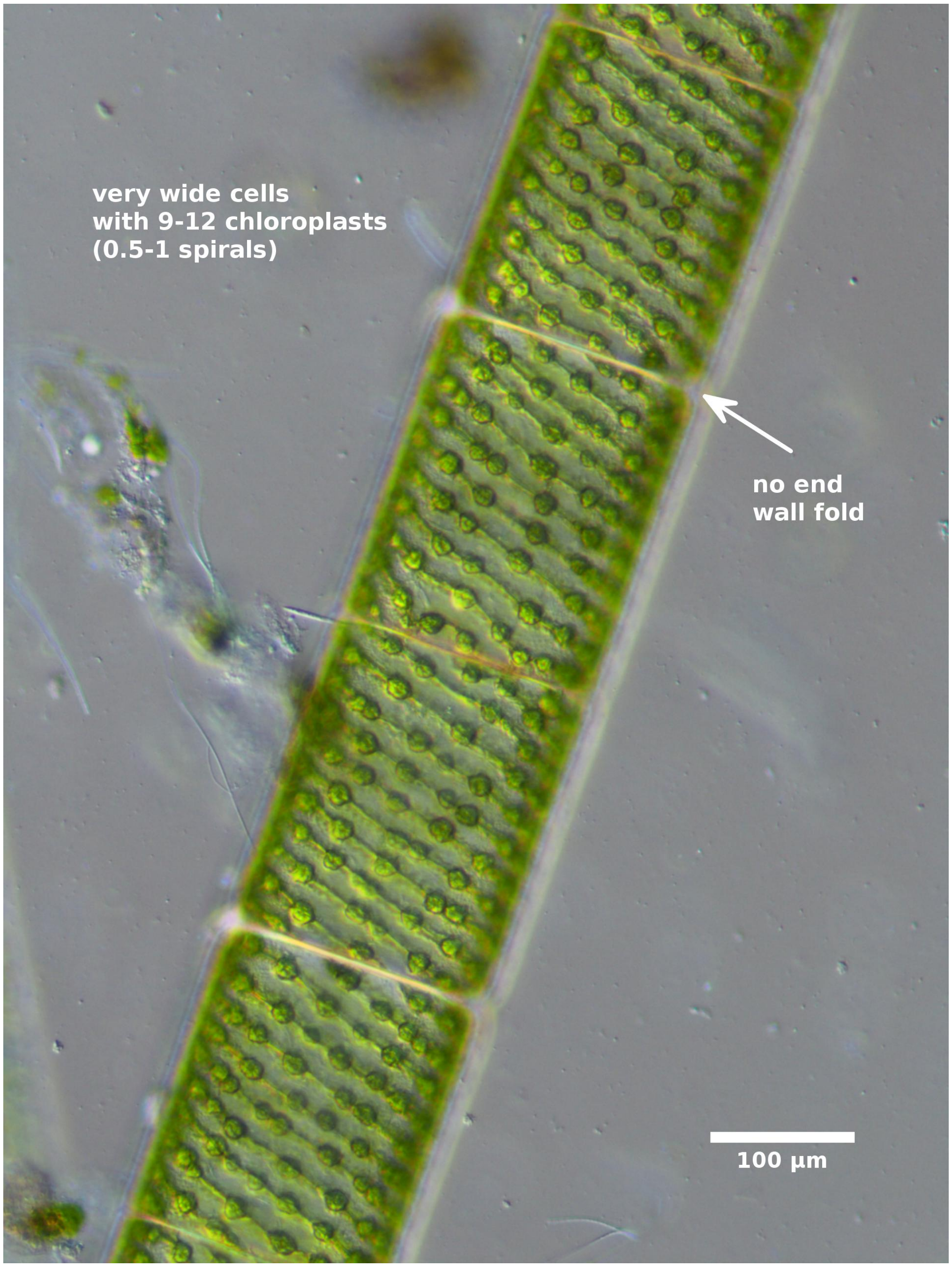


Figure 4.136: *Spirogyra crassa*? (100x DIC), small pond near Lynnwood, Snohomish County, May 13, 2015.

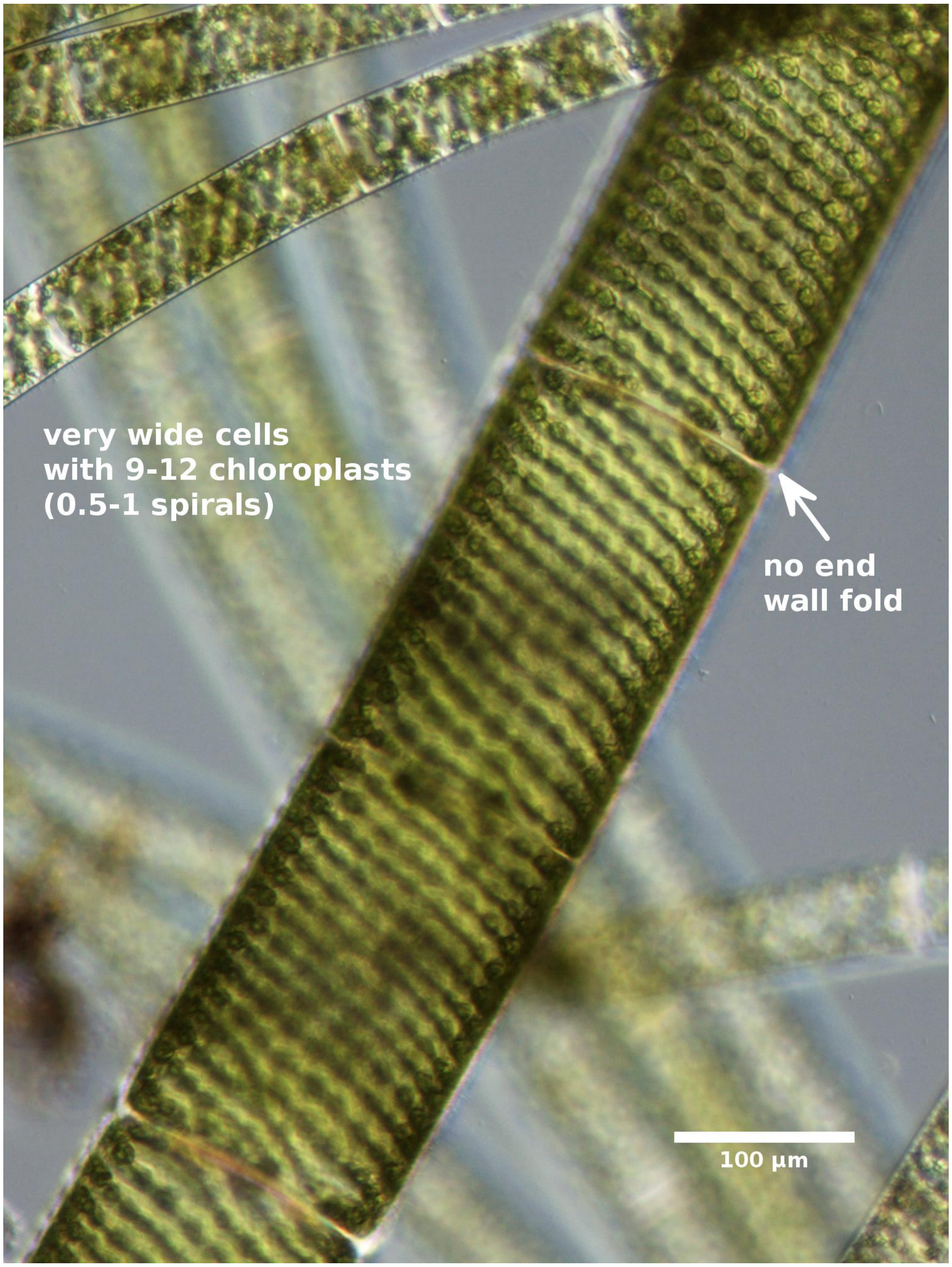


Figure 4.137: *Spirogyra crassa*? (100x DIC), Tennant Lake, IWS water quality sampling site, Whatcom County, July 29, 2013.

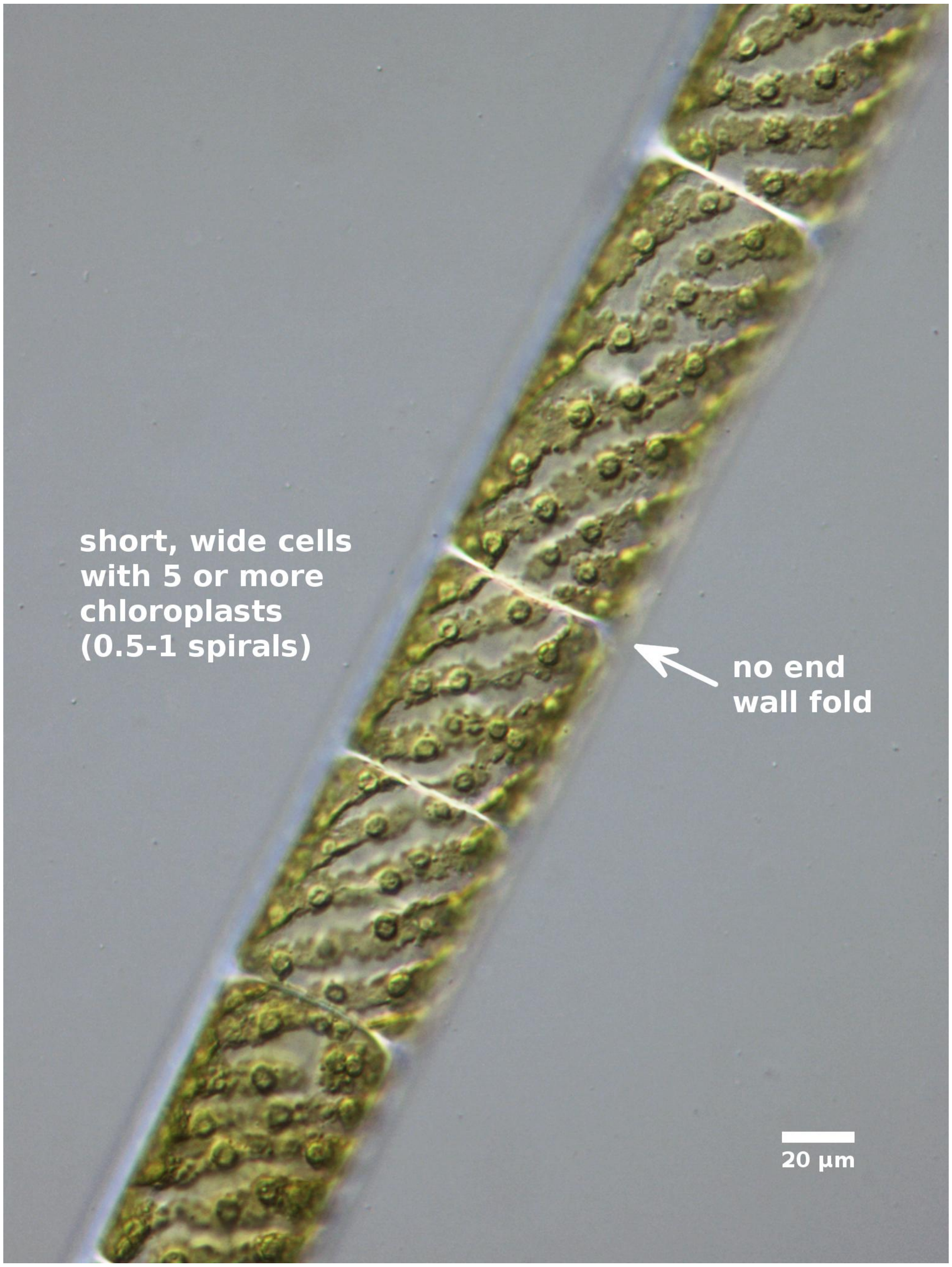


Figure 4.138: *Spirogyra majuscula*? (200x DIC), standing water, Whatcom County, May 24, 2013.

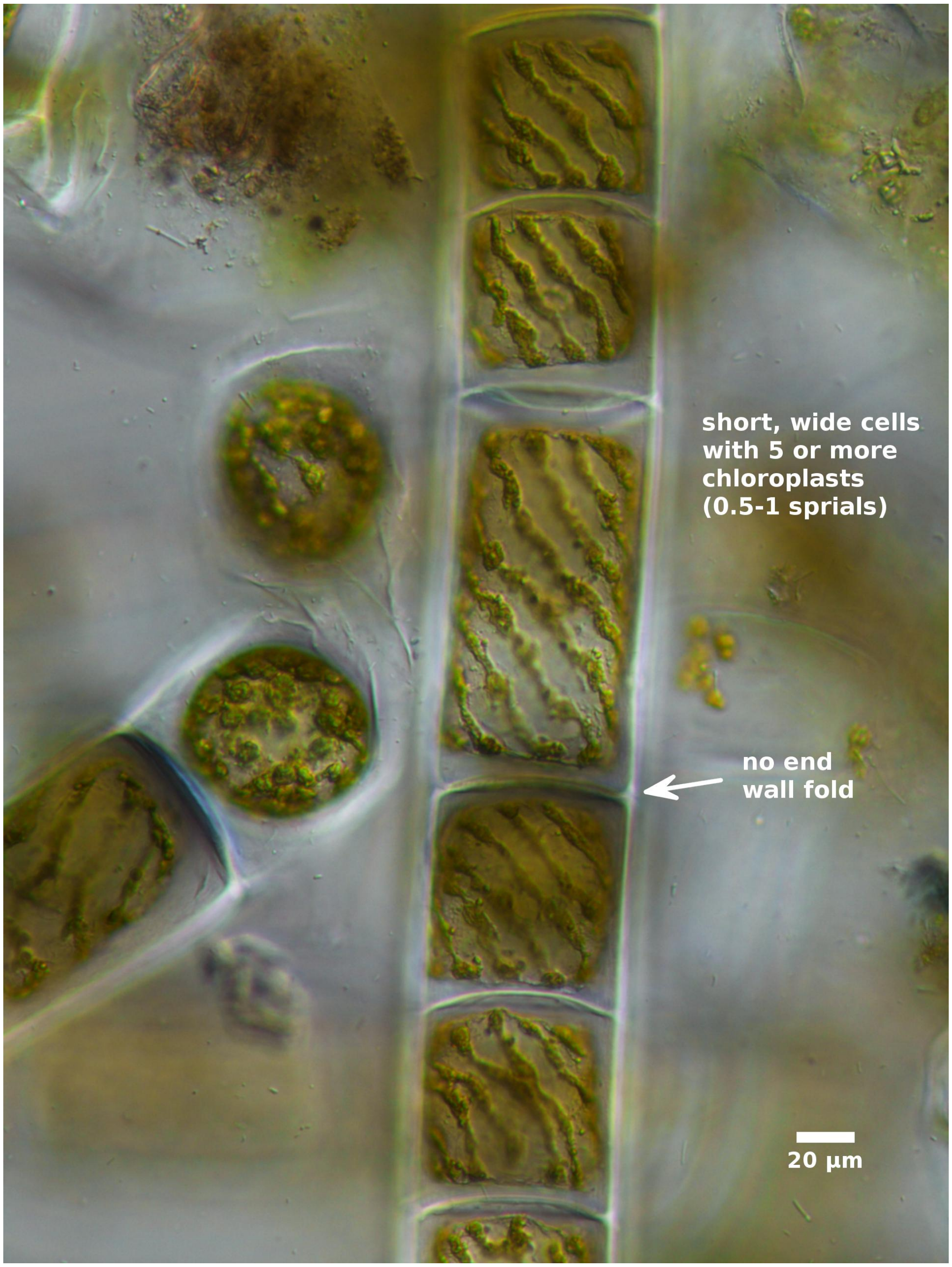


Figure 4.139: *Spirogyra majuscula*? (200x DIC), small pond near Lynnwood, Snohomish County, May 13, 2015.

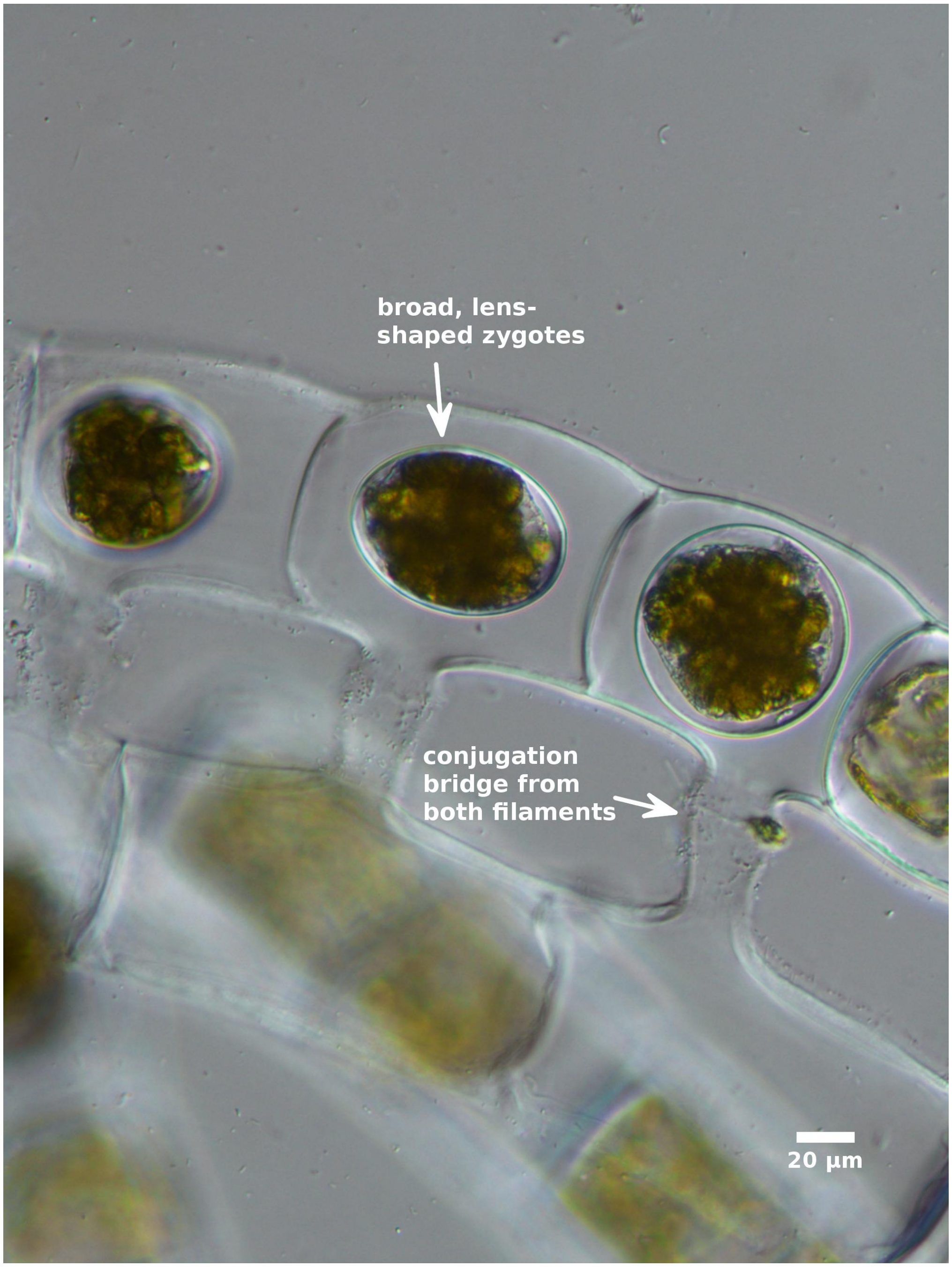


Figure 4.140: *Spirogyra majuscula*? zygotes (200x DIC), small pond near Lynnwood, Snohomish County, May 13, 2015.

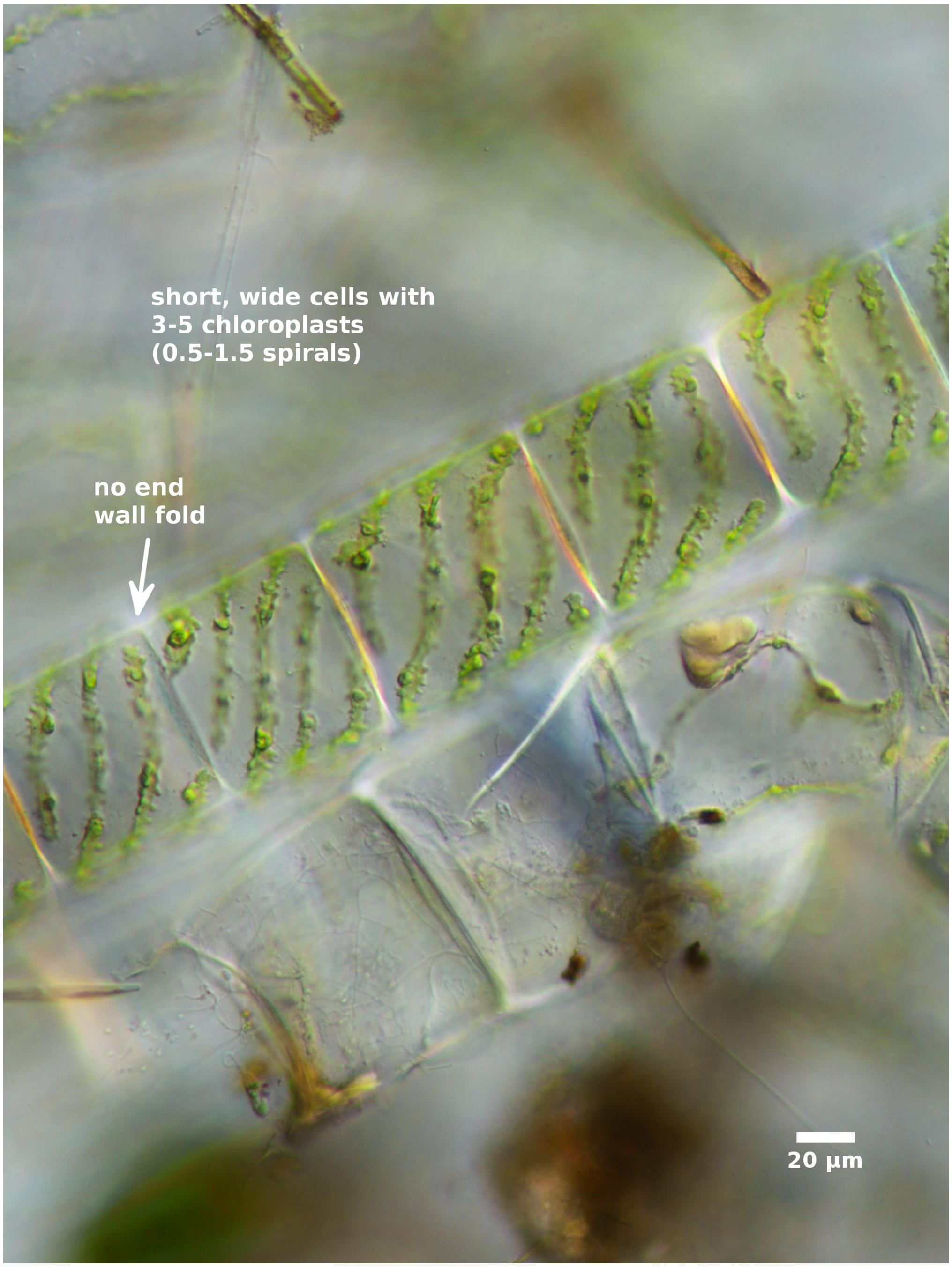


Figure 4.141: *Spirogyra nitida*? (200x DIC), Silver Lake, IWS water quality sampling site, Whatcom County, May 11, 2015.

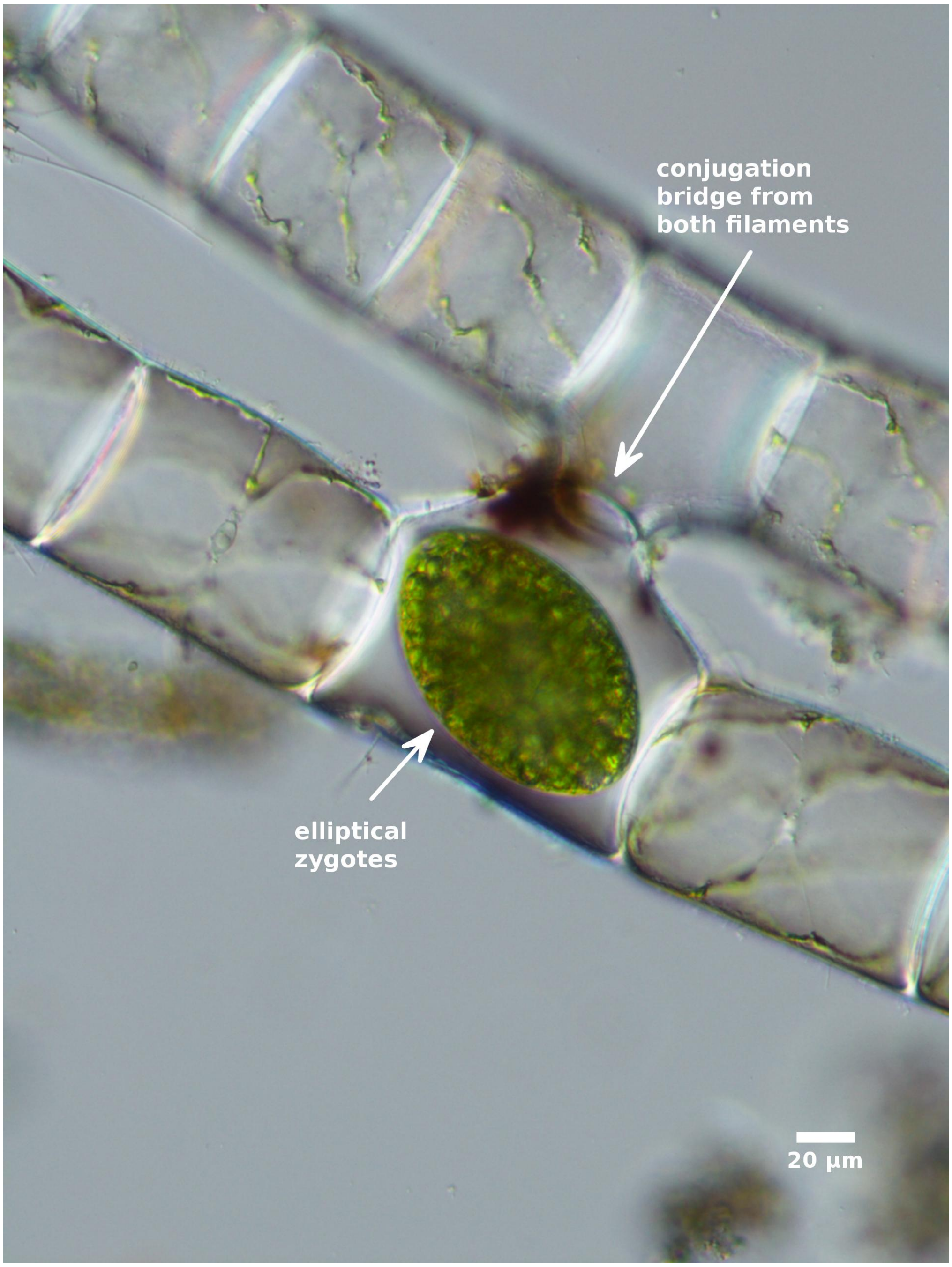


Figure 4.142: *Spirogyra nitida* zygote? (200x DIC), Silver Lake, IWS water quality sampling site, Whatcom County, May 11, 2015.

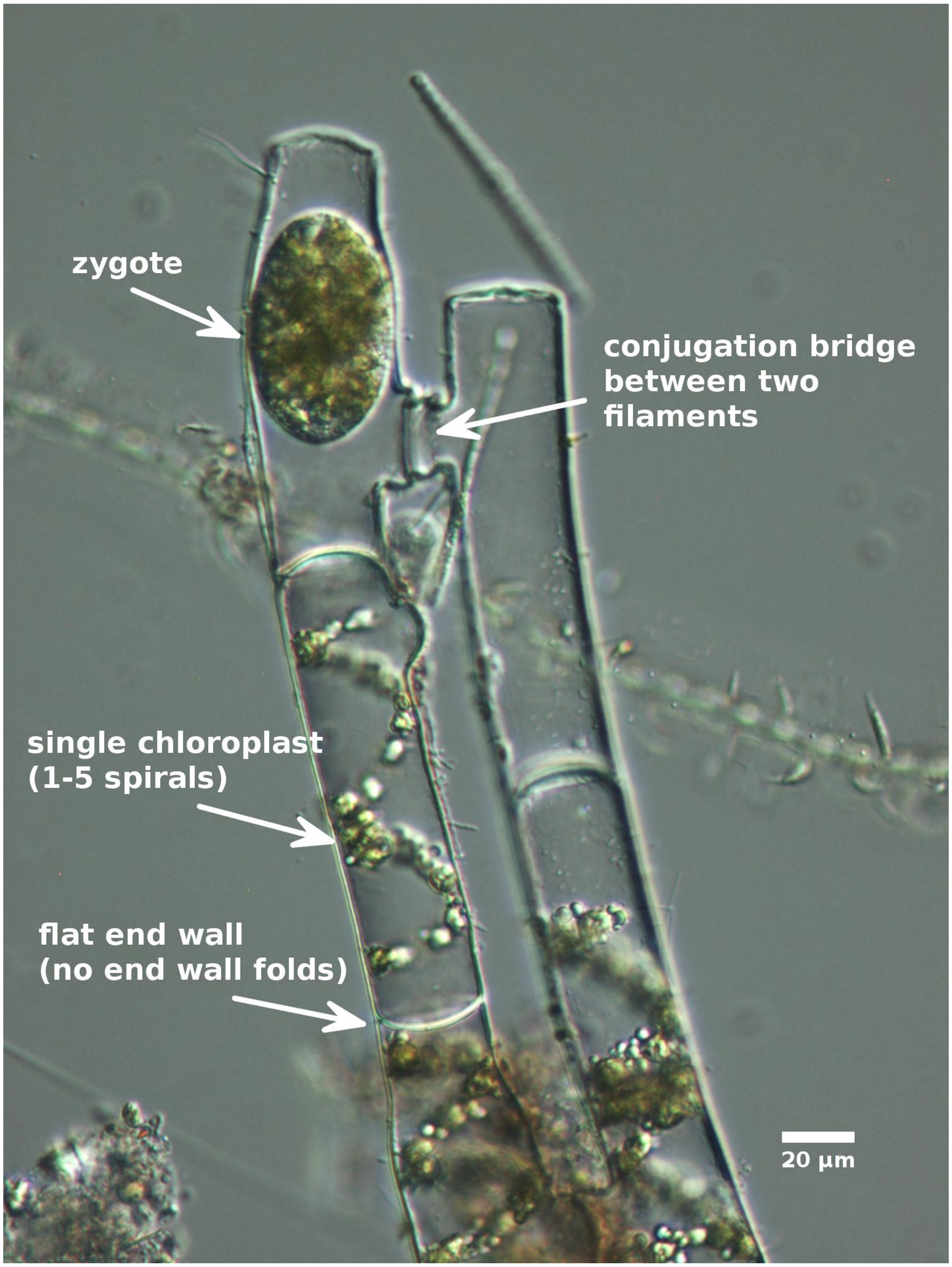


Figure 4.143: *Spirogyra varians*? (200x DIC), Lake Terrell, IWS water quality sampling site, Whatcom County, August 9, 2013.

Figure 4.144: *Spirogyra varians*? (200x DIC), Scudder's Pond, Lake Whatcom watershed, Whatcom County, May 25, 2011.

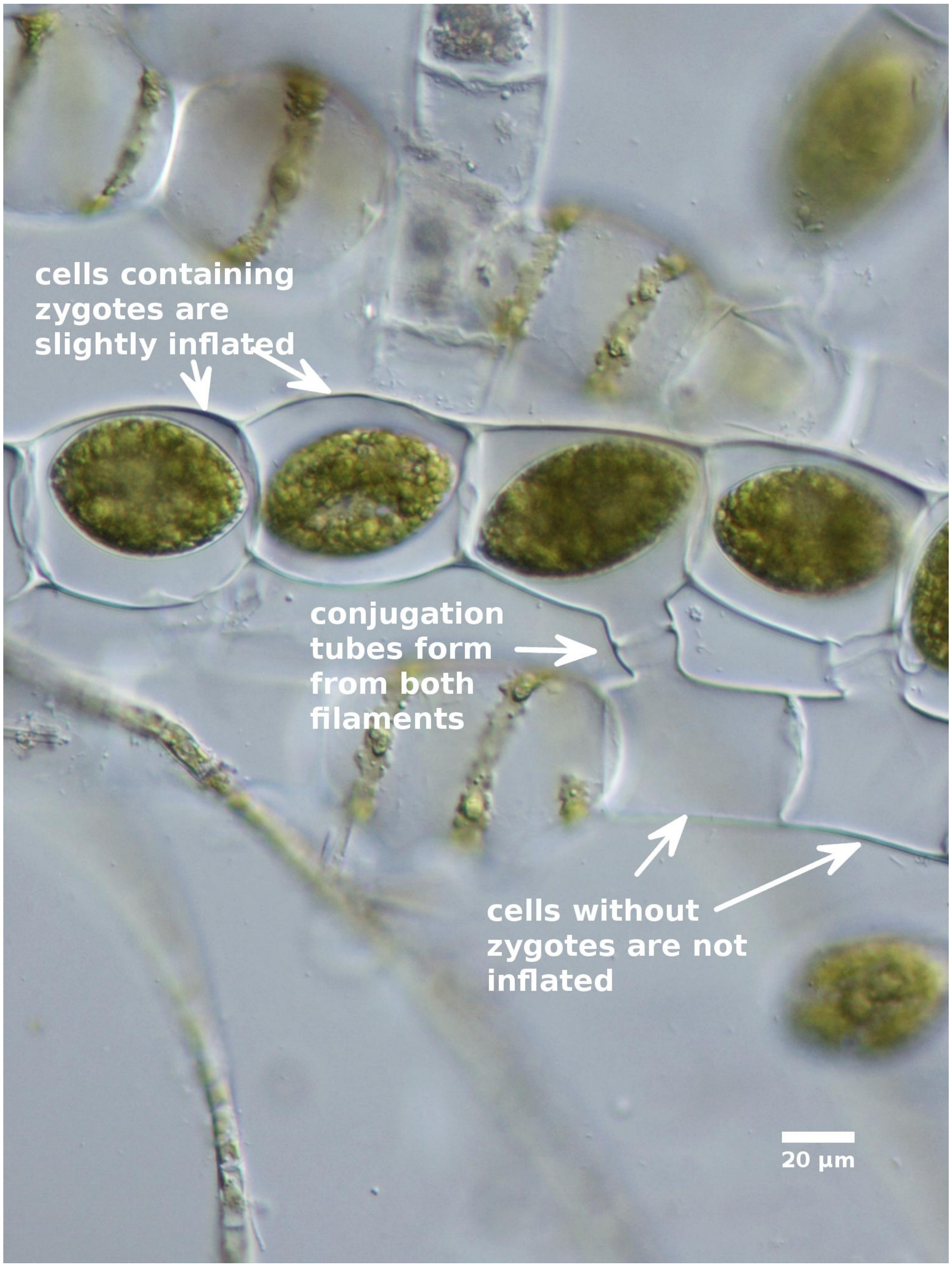


Figure 4.145: *Spirogyra varians*? zygotes (200x DIC), outdoor fish pond, Maple Valley, King County, May 10, 2013.

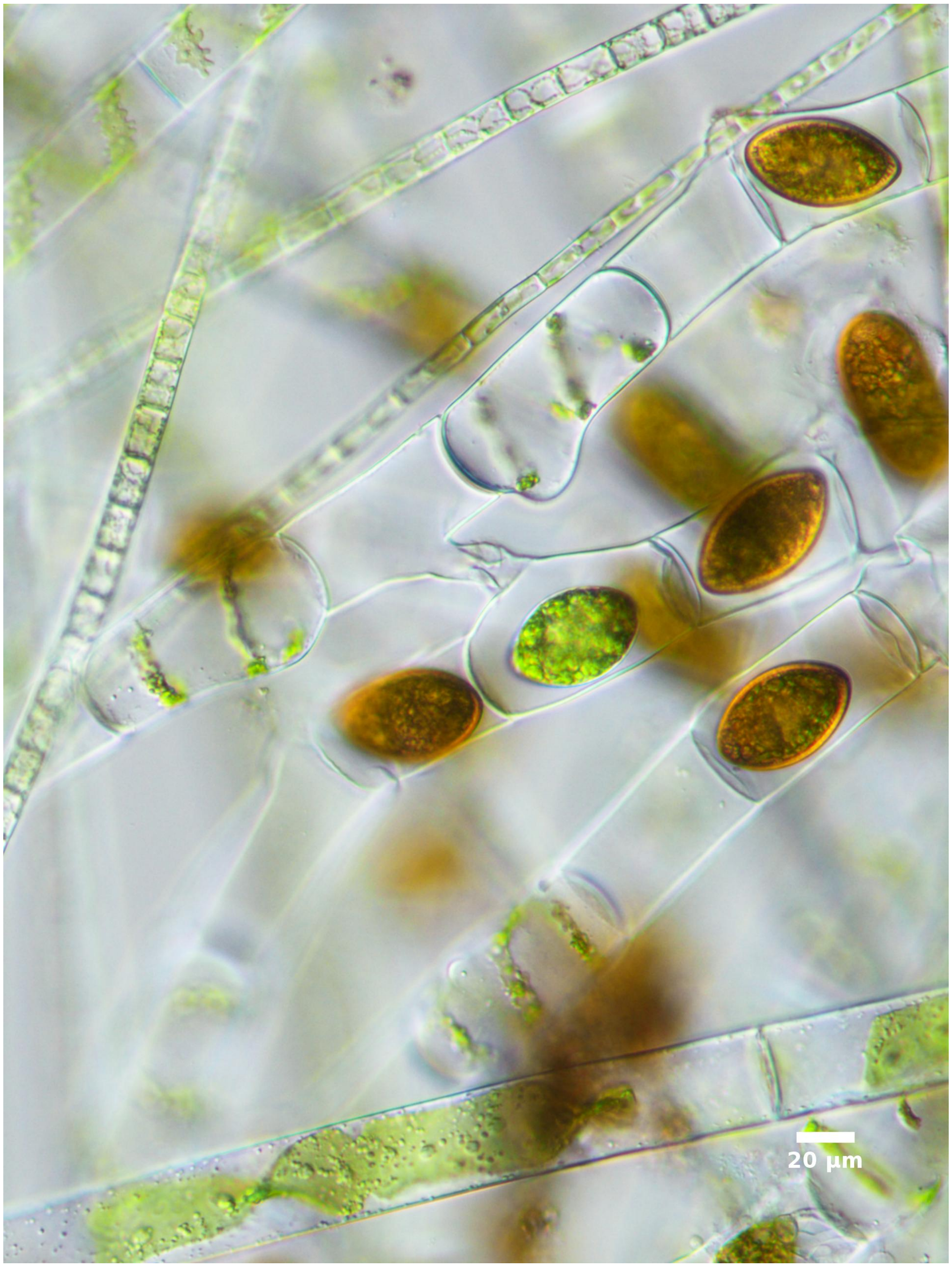


Figure 4.146: *Spirogyra varians*? zygotes (200x DIC), standing water in Fairhaven Park, Whatcom County, May 22, 2015.

Figure 4.147: *Spirogyra* type 1 (100x DIC), Coal Lake, IWS water quality sampling site, Snohomish County, August 21, 2013.

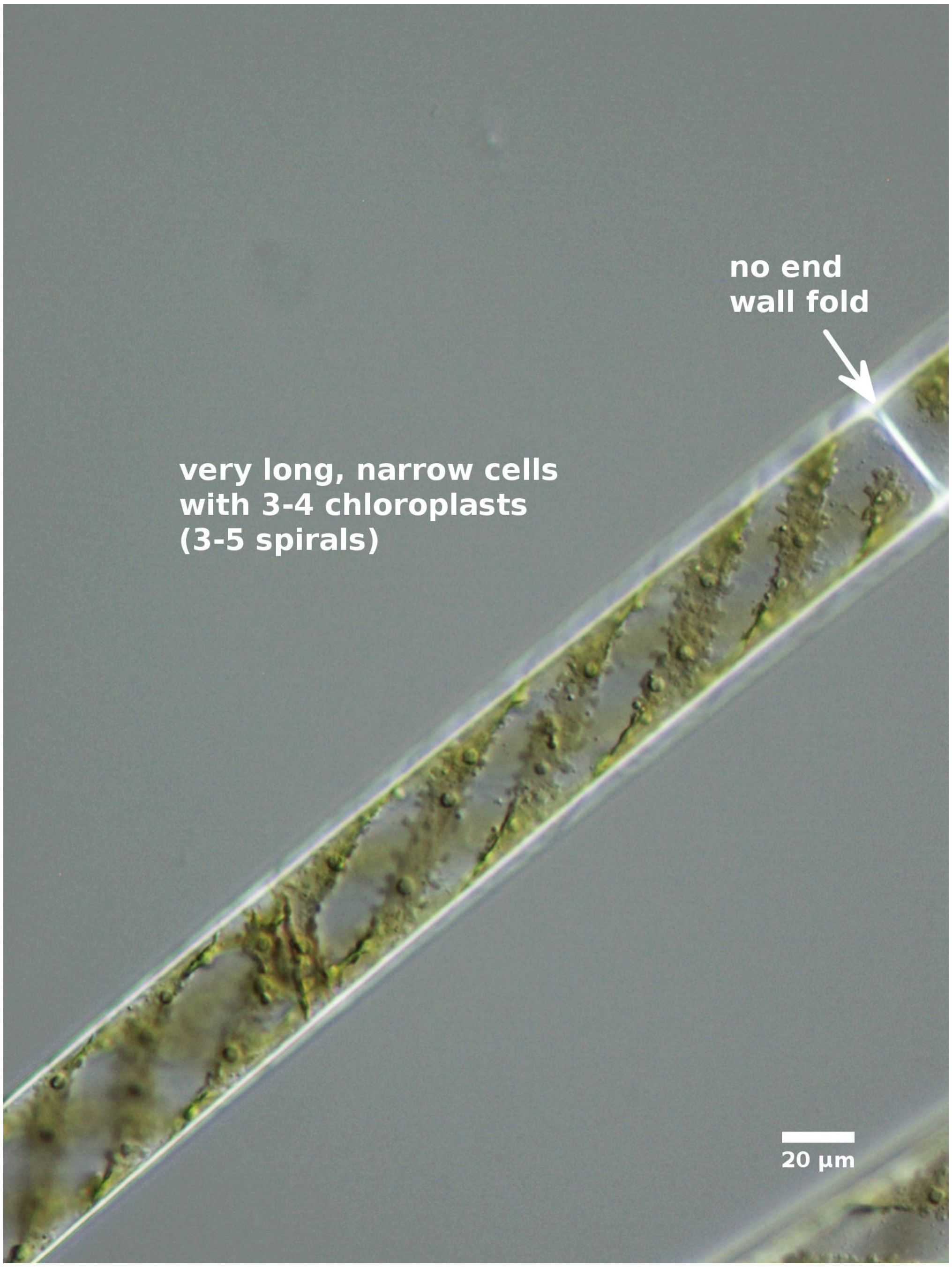


Figure 4.148: *Spirogyra* type 1 (200x DIC), Coal Lake, IWS water quality sampling site, Snohomish County, August 21, 2013.

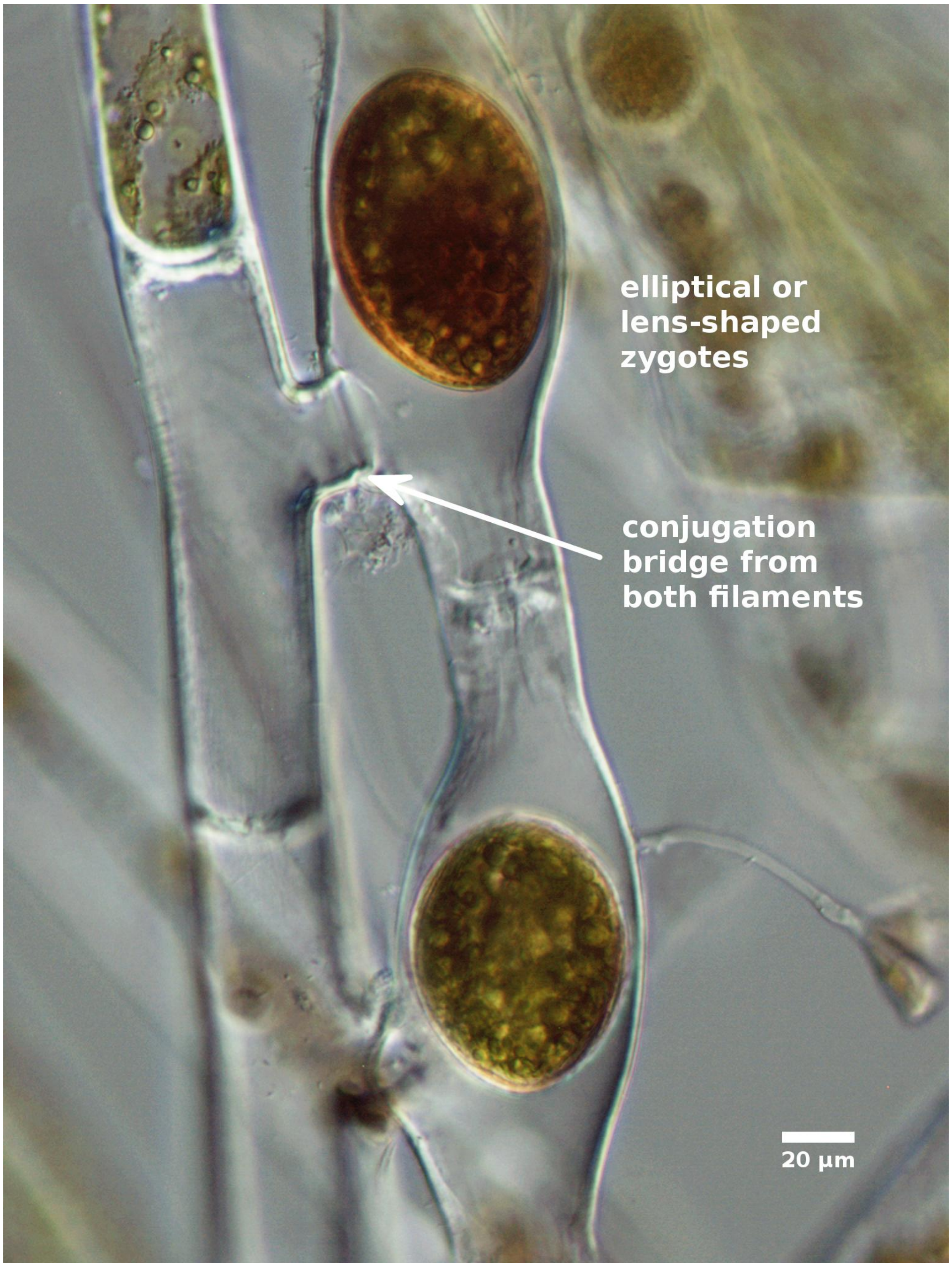


Figure 4.149: *Spirogyra* type 1 zygote (200x DIC), Coal Lake, IWS water quality sampling site, Snohomish County, August 21, 2013.

Figure 4.150: *Spirogyra* type 2 (100x DIC), Beaver Pond Lake, IWS water quality sampling site, Whatcom County, July 8, 2015.

Figure 4.151: *Spirogyra* type 2 (100x DIC), Tennant Lake, IWS water quality sampling site, Whatcom County, July 30, 2013.

Figure 4.152: *Spirogyra* type 2 zygotes (200x DIC), Squalicum Lake, IWS water quality sampling site, Whatcom County, June 29, 2015.

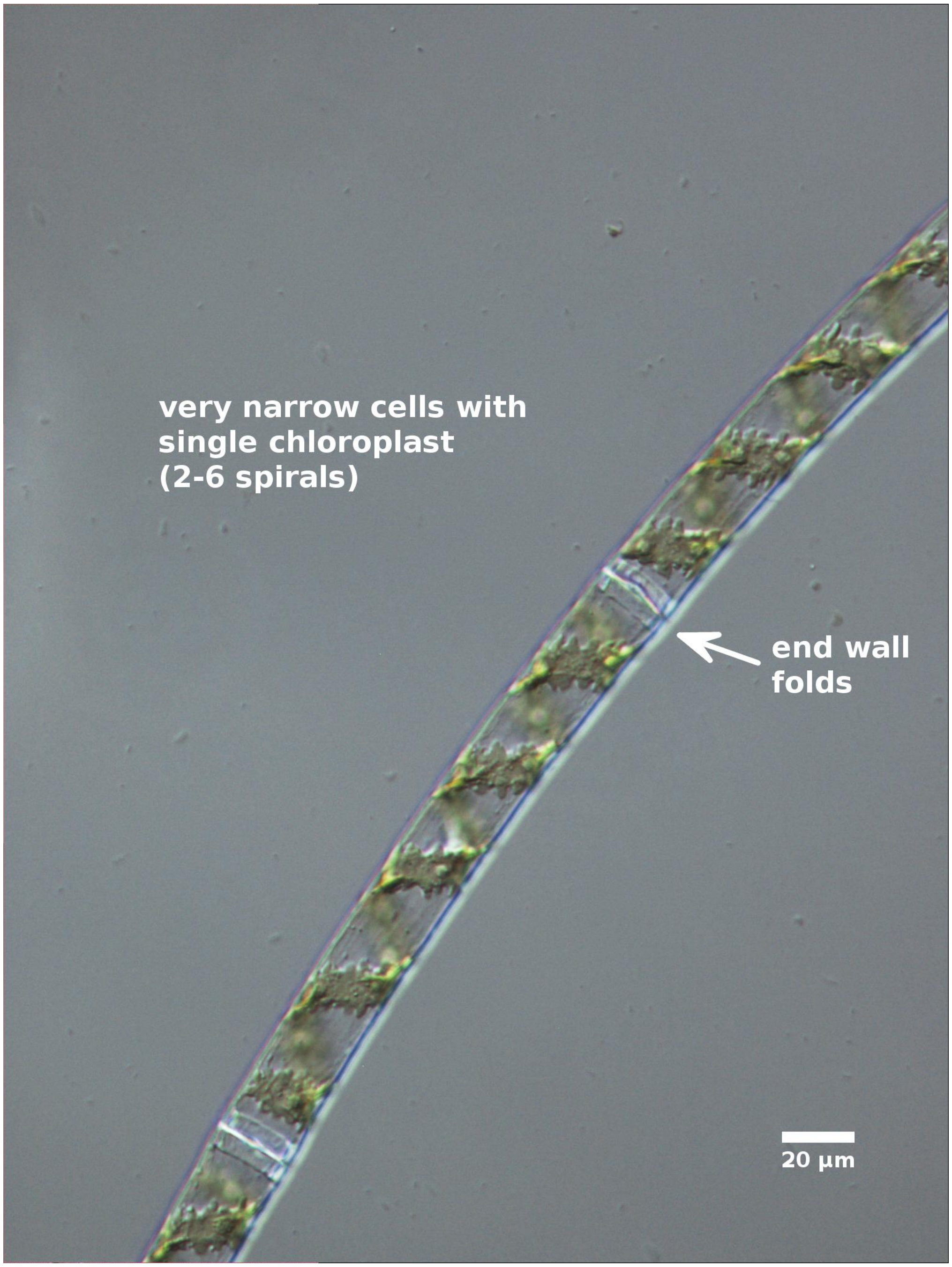


Figure 4.153: *Spirogyra* type 3 (200x DIC), Lake Ketchum, IWS water quality sampling site, Snohomish County, September 2, 2009.

Figure 4.154: *Spirogyra* type 3 (200x DIC), Devil's Lake, Snohomish County, October 7, 2009.

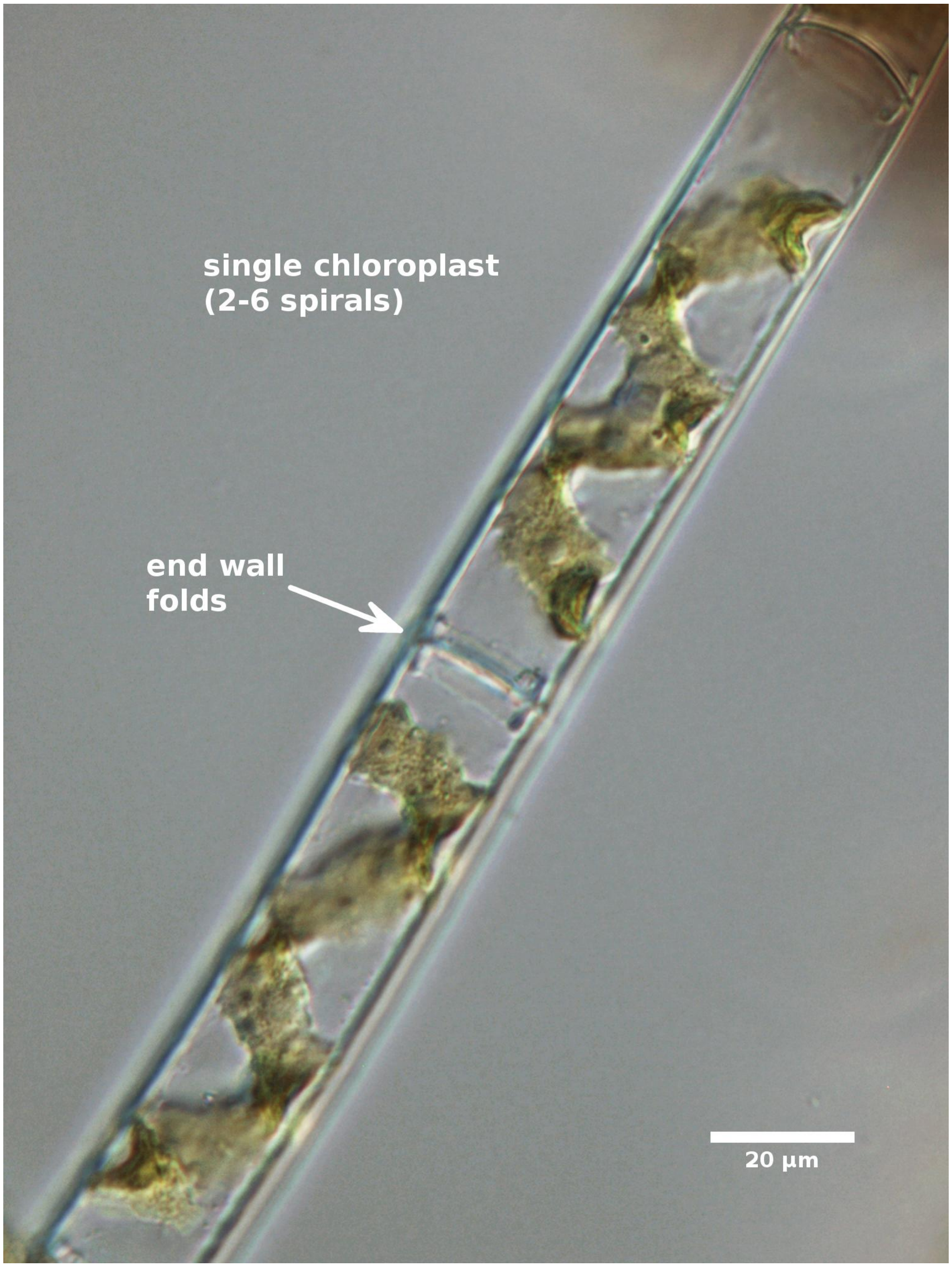


Figure 4.155: *Spirogyra* type 3 (400x DIC), Upper Bagley Lake, IWS water quality sampling site, Whatcom County, September 7, 2012.

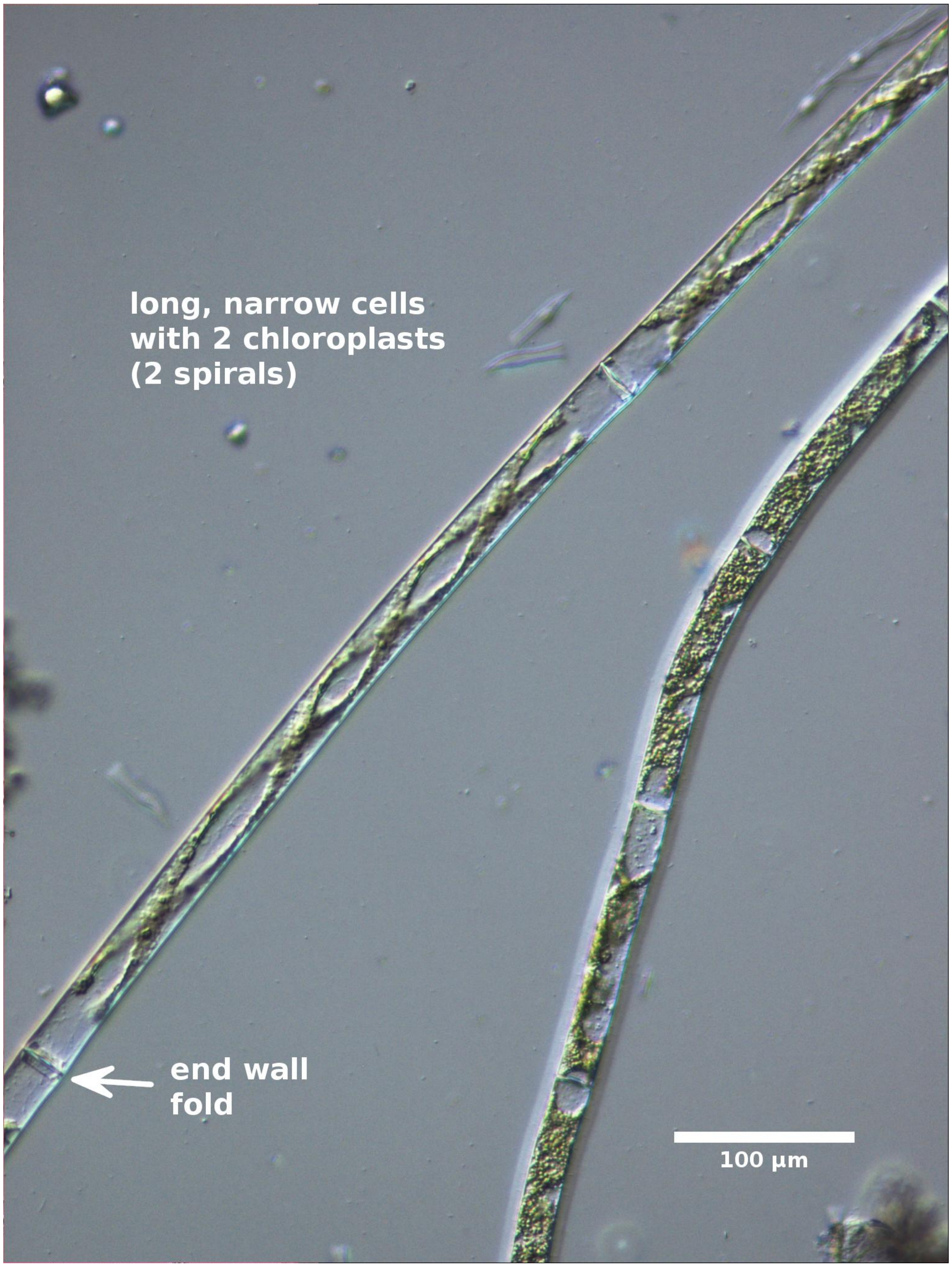


Figure 4.156: *Spirogyra* type 4 (100x DIC), Ross Lake, Ross Lake National Recreation Area, June 1, 2009.

Figure 4.157: *Spirogyra* type 4 (100x DIC), Ross Lake, Ross Lake National Recreation Area, September 27, 2010.

4.20 *Stigeoclonium* Kützing

Local taxa
Stigeoclonium tenue (C. Agardh) Kützing?;
Stigeoclonium sp.

Abundance
Infrequently collected in plankton samples; moderately common in flowing water and along shoreline; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Stigeoclonium tenue?	min	9.9 μm	11.4 μm	950 μm^3
axial cells (cylinder)	med	13.1 μm	18.3 μm	2,870 μm^3
	max	17.5 μm	28.5 μm	4,770 μm^3
Stigeoclonium tenue?	min	5.4 μm	7.0 μm	270 μm^3
branch cells (cylinder)	med	8.6 μm	11.8 μm	839 μm^3
	max	11.4 μm	24.4 μm	2,280 μm^3
Stigeoclonium sp.1	min	5.7 μm	19.1 μm	1,080 μm^3
branch/axial cells	med	9.6 μm	28.2 μm	1,810 μm^3
(cylinder)	max	13.8 μm	42.3 μm	4,740 μm^3

†Calculated using original measurements, not summary values.

Description
Stigeoclonium filaments range from sparsely to densely branched, and often have root-like rhizoids. The central (axial) portion of the filament contains large, untapered, cylindrical cells, while the secondary (branch) filaments contain narrower, more tapered cells (Figures 4.158–4.165). The axial cells may be constricted at the cross-wall, and contain a band-like chloroplast. The branch filaments are tapered, ending in either a bluntly pointed apex or an elongated cell. The filaments are often parasitized by a type of aquatic fungi (hyphochytrid), which causes the cells to become greatly enlarged and whitish at the infection site (Figure 4.162). *Stigeoclonium* is very polymorphic (John, et al., 2011). Recent studies suggest that many of the species descriptions represent natural variation caused by environmental conditions (Caisová, et al., 2011).

Stigeoclonium filaments resemble *Chaetophora* (Section 4.4, page 560) and *Draparnaldia* (Section 4.8, page 589). *Draparnaldia* has distinctive, differentiated axial and branch filaments, and usually appears dense and tufted. The axial filament is unmistakable, consisting of large, barrel-shaped cells with a deeply incised, band-shaped parietal chloroplast. *Chaetophora* is differentiated into axial filaments made up of parallel bundles of long, narrow cells, and tufted branch filaments containing short, rounded cells that often extend into long, multicellular hairs.

The specimens in Figures 4.158–4.162 were tentatively identified as *Stigeoclonium tenue* based on the presence of rhizoidal filaments, lack of hair-like terminal extensions, and the cell size.

The specimens in Figures 4.163–4.165 may be a different species, or may simply illustrate the morphological variation present in this genus. The cells in the branch filaments were about the same length as in the axial filaments (not shorter), and the branch cells terminated in either a blunt point (Figure 4.163) or a hair-like multicellular extension (Figure 4.164). None of the filaments appeared to be rhizoidal, even where attached to woody substrate (Figure 4.165).

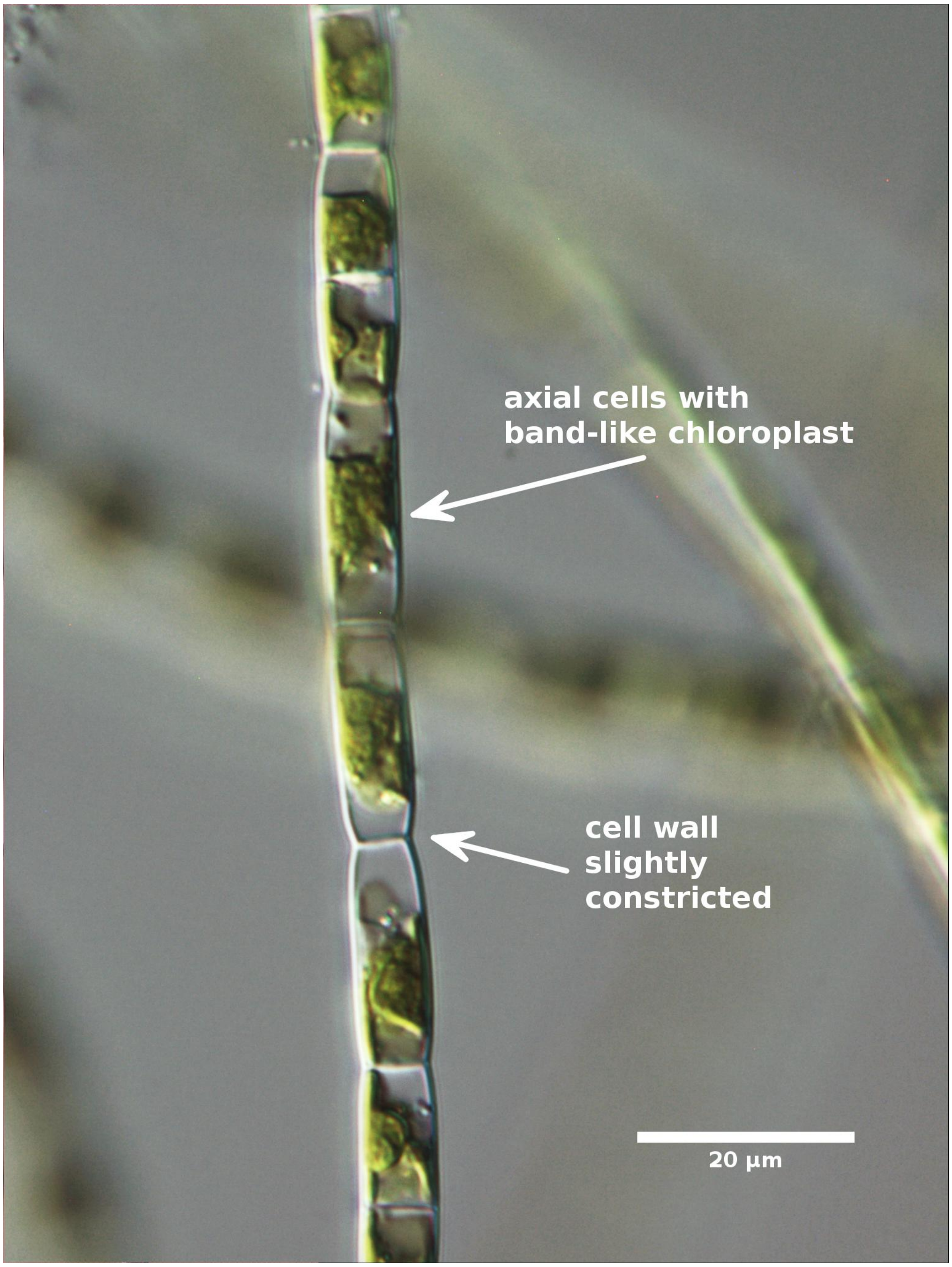


Figure 4.158: *Stigeoclonium* sp. (600x DIC), Wards Biological Supply Co., April 5, 2012.

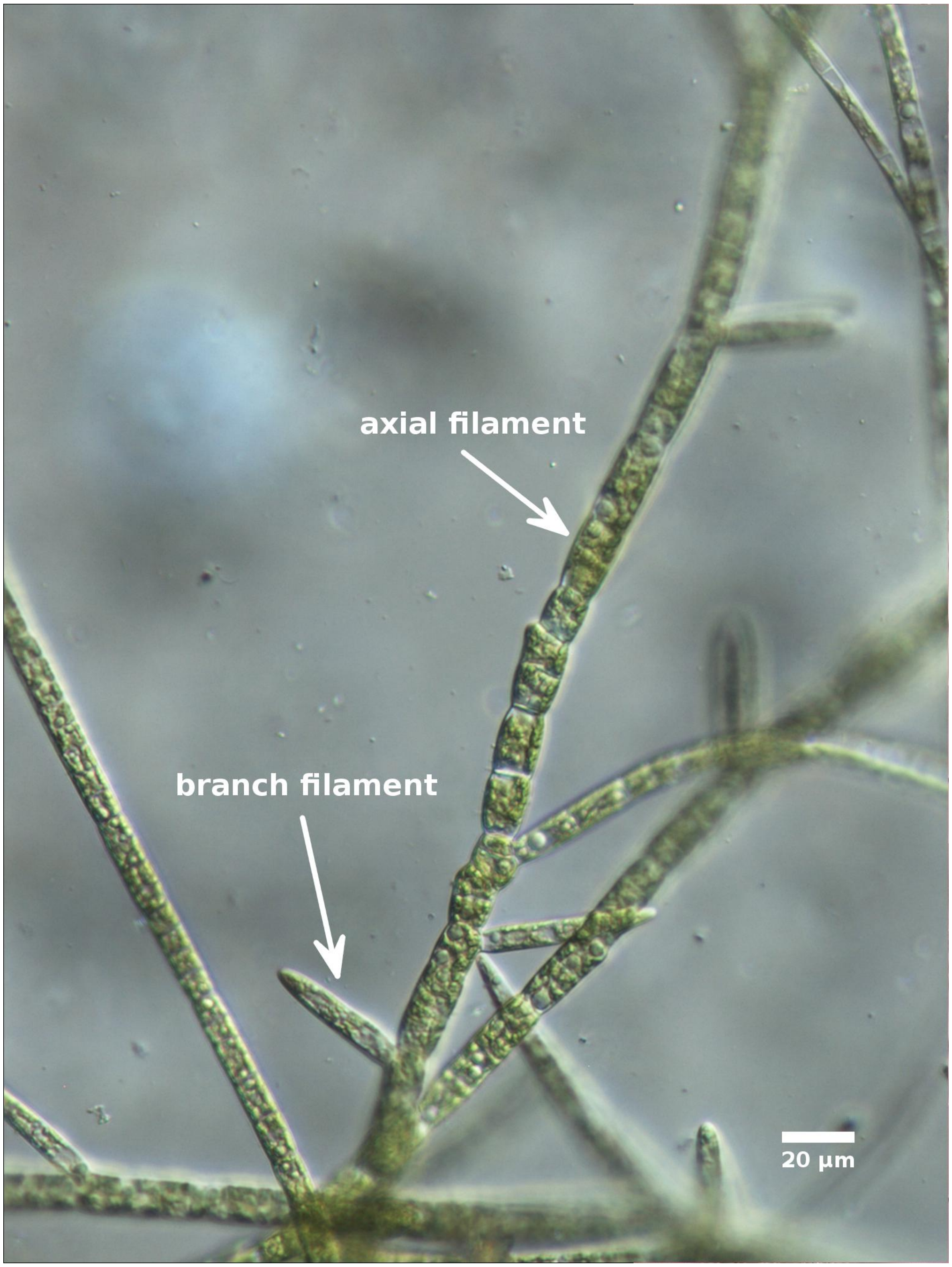


Figure 4.159: *Stigeoclonium tenue*? (200x DIC), small pond near Fairhaven College, May 2, 2011.

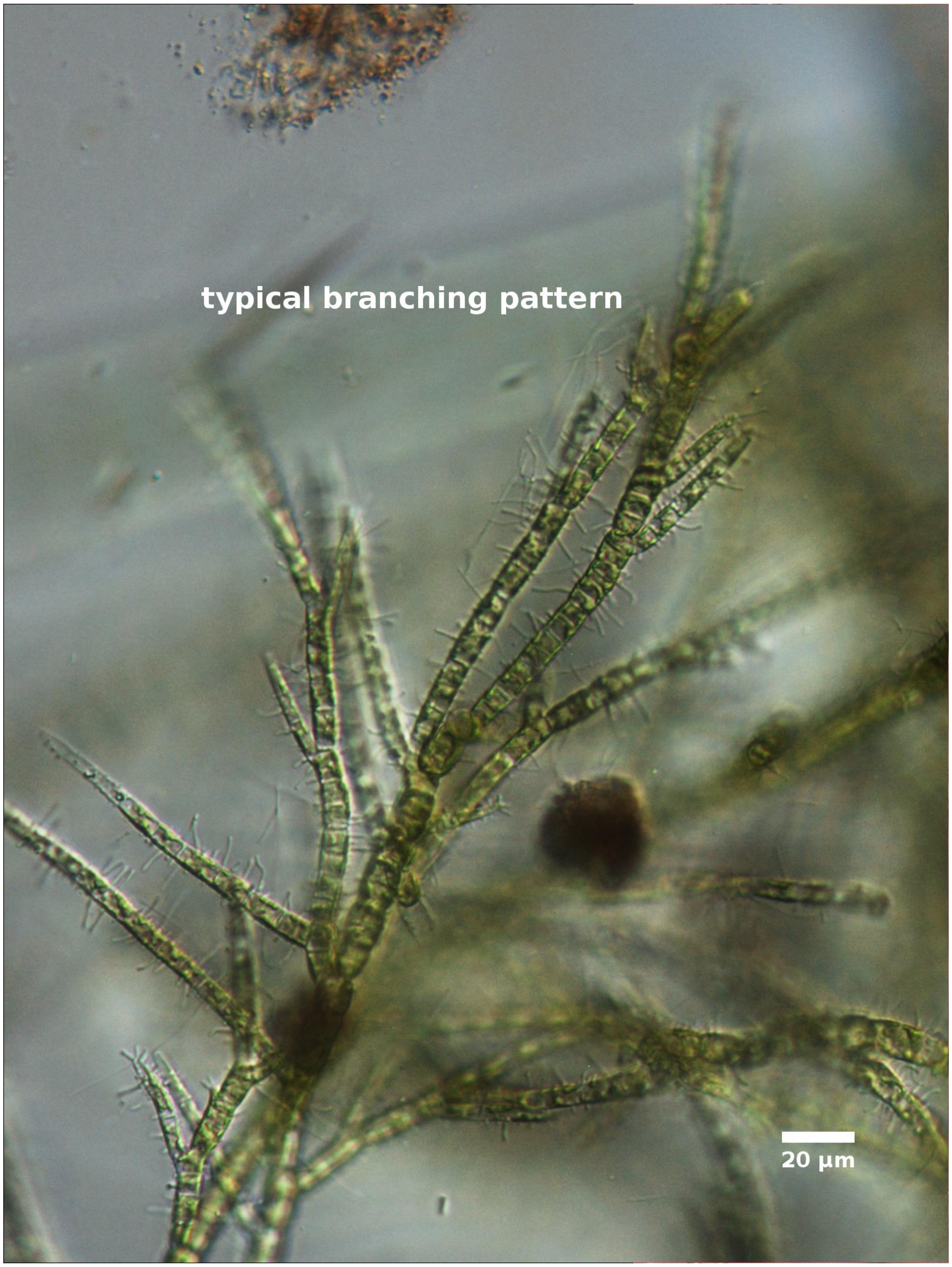


Figure 4.160: *Stigeoclonium tenue*? (200x DIC), Heart Lake, IWS water quality sampling site, Skagit County, September 21, 2010.

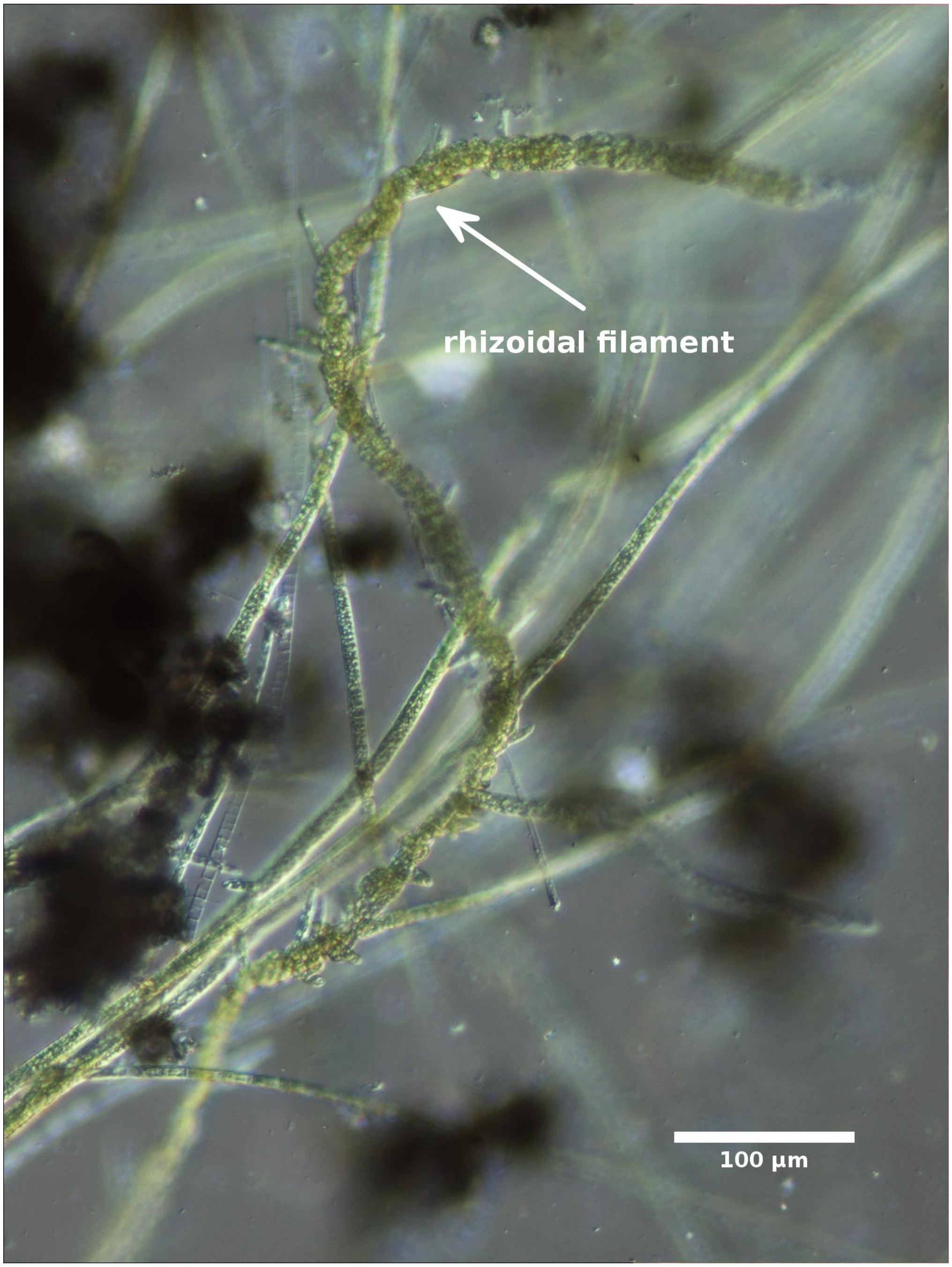


Figure 4.161: *Stigeoclonium tenue*? (100x DIC), small pond near Fairhaven College, May 2, 2011.

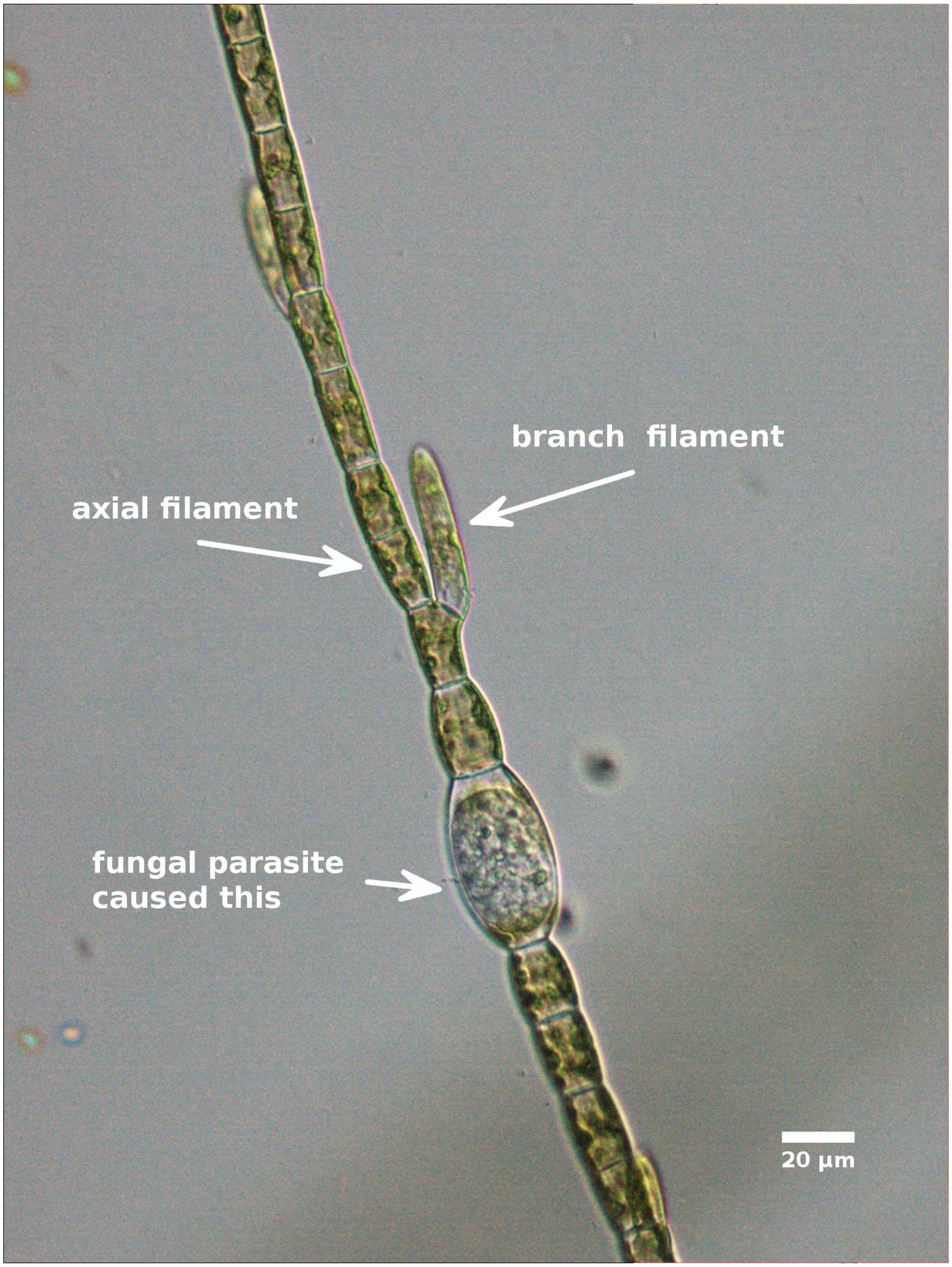


Figure 4.162: *Stigeoclonium tenue*? infected by hyphochytrid fungal parasite (200x DIC), Scudder's Pond (Lake Whatcom watershed), Whatcom County, April 12, 2011.

Figure 4.163: *Stigeoclonium* sp.1 (200x DIC), Lake Evan, IWS water quality sampling site, Snohomish County August 20, 2013.

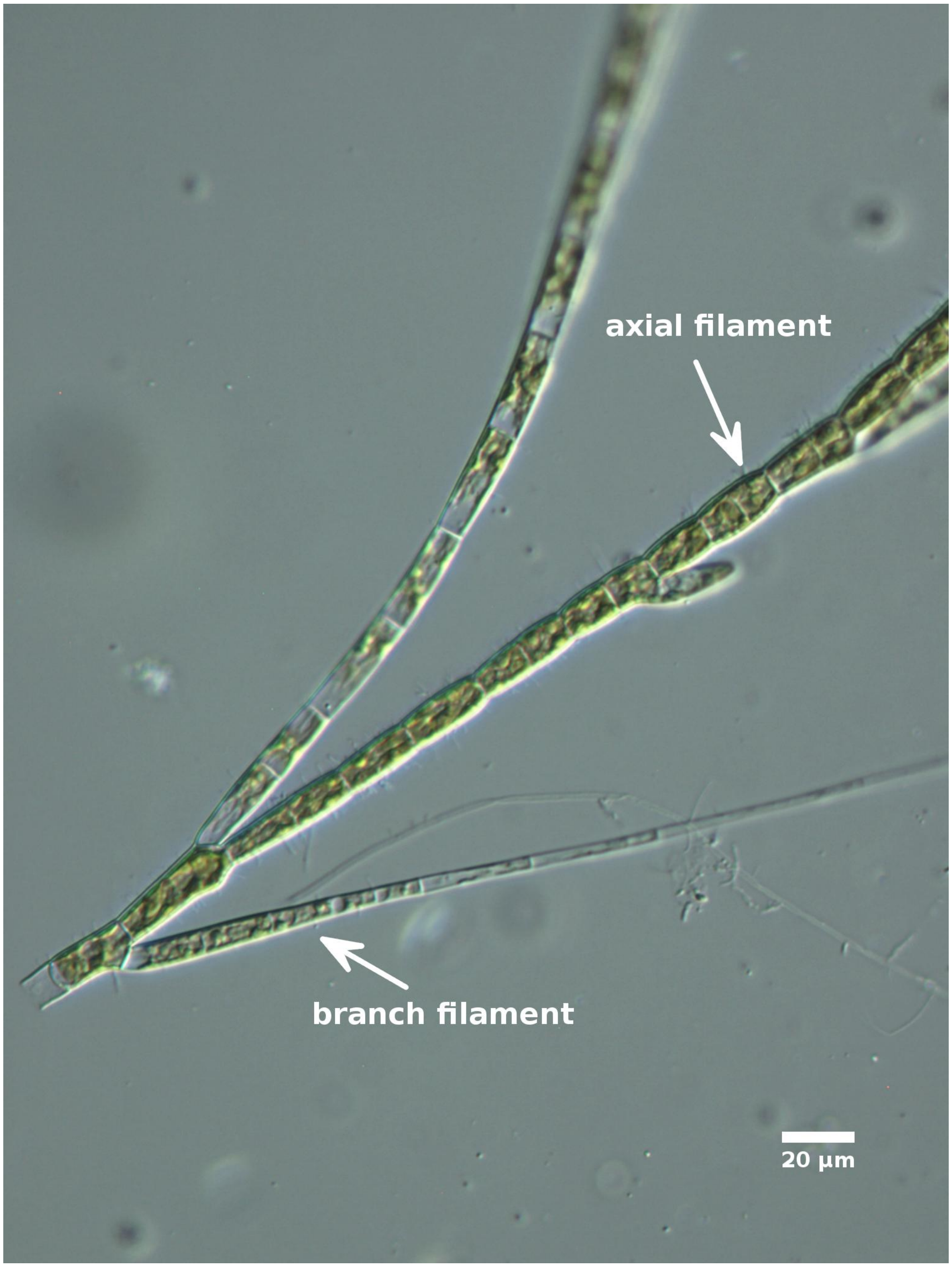


Figure 4.164: *Stigeoclonium* sp.1 (200x DIC), Lake Evan, IWS water quality sampling site, Snohomish County August 19, 2013.

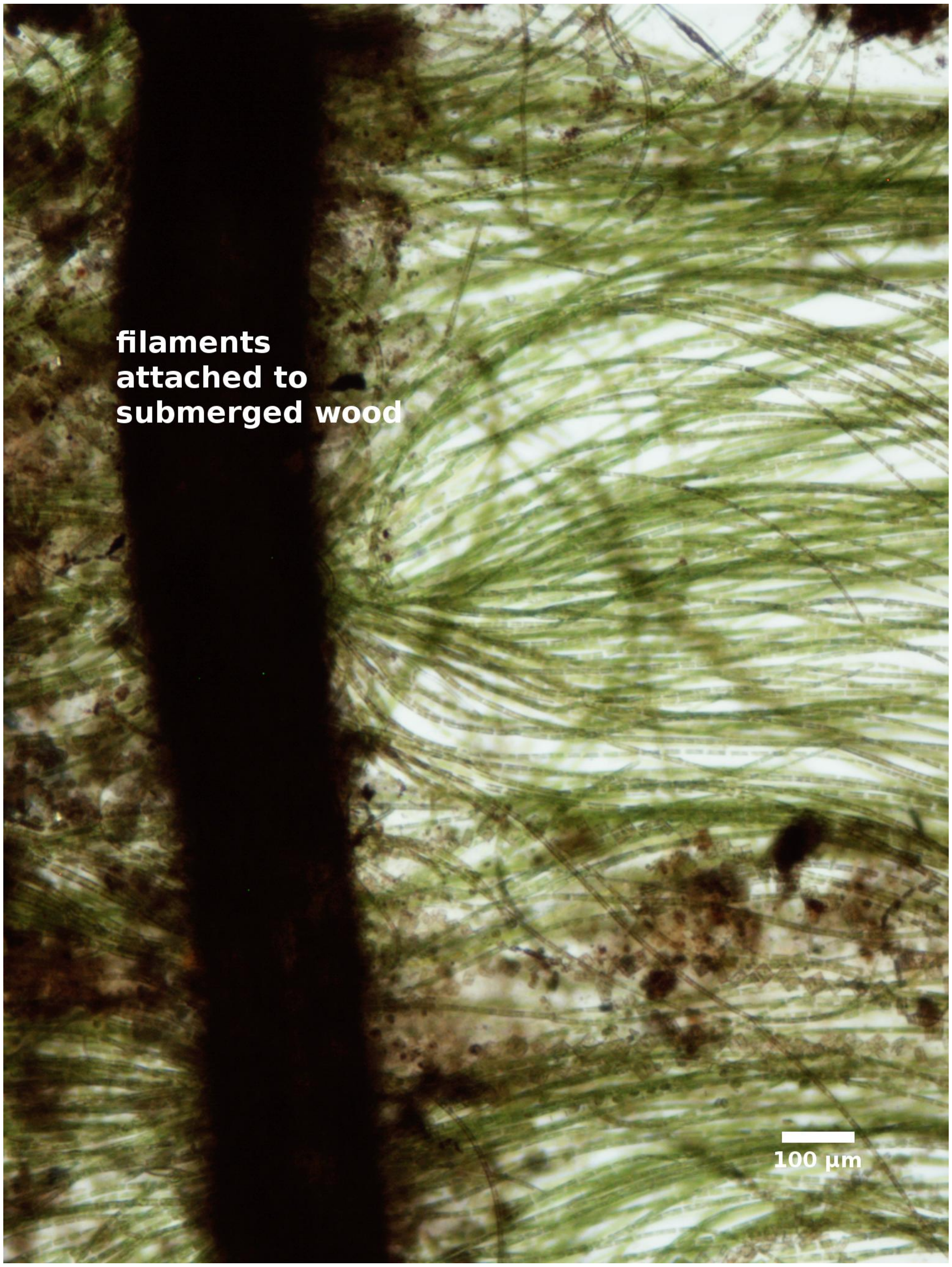


Figure 4.165: *Stigeoclonium* sp.1 (40x brightfield), Lake Evan, IWS water quality sampling site, Snohomish County, August 19, 2013.

4.21 *Trentepohlia* Martius

Local taxon

Trentepohlia aurea (Linnaeus) Martius

Abundance

Not planktonic; infrequently collected from wet seeps and damp rocks.

Local measurements		Width	Length	Biovolume†
Trentepohlia aurea	min	16.1 μm	51.6 μm	10,500 μm^3
cells (cylinder)	med	20.9 μm	58.5 μm	20,000 μm^3
	max	26.0 μm	75.6 μm	38,100 μm^3

†Calculated using original measurements, not summary values.

Description

Trentepohlia aurea is a branched filamentous species with large, thick-walled, cylindrical cells (Figures 4.166–4.169). The cells are initially green, with a parietal chloroplast, but quickly turn bright orange from accumulated carotenoids. This species is not planktonic, and is more likely to be found forming bright orange tufts on damp rocks, stone walls, or on cliffs in the spray zone of waterfalls. The specimens collected along Hwy. 20 were attached to damp rocks adjacent to a small waterfall. Many of the samples contained nonmotile dinoflagellates, presumably *Rufusiella insignis* (Hassal) Loeblich,[27] scattered throughout the bright orange *Trentepohlia* filaments.

[27] See **Freshwater Algae in Northwest Washington, Vol V. Cryptophyta, Dinophyta, and Euglenophyta**

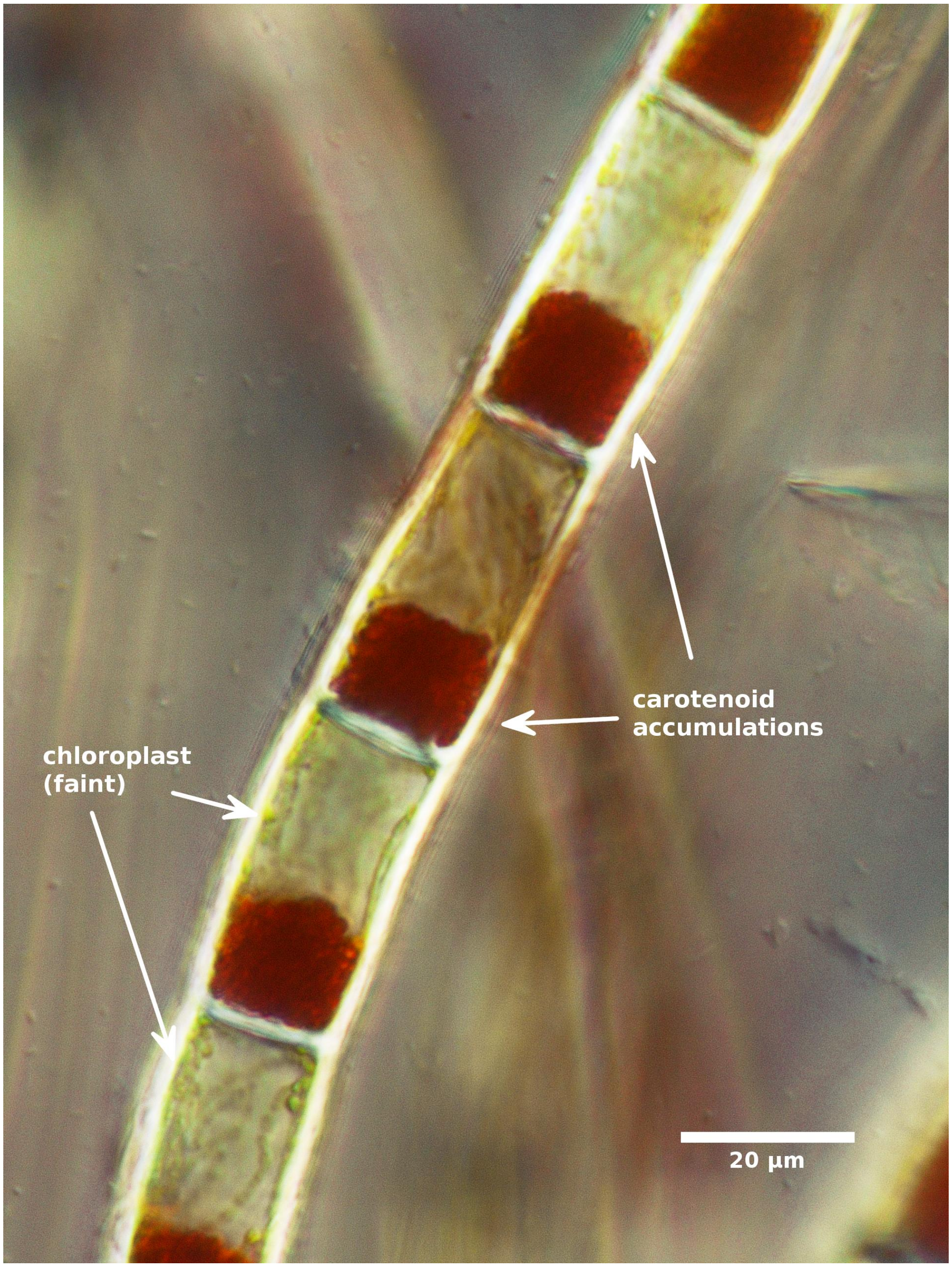


Figure 4.166: *Trentepohlia aurea* (600x DIC), damp rocks near waterfall along Hwy 20 near Maple Pass, August 19, 2014.

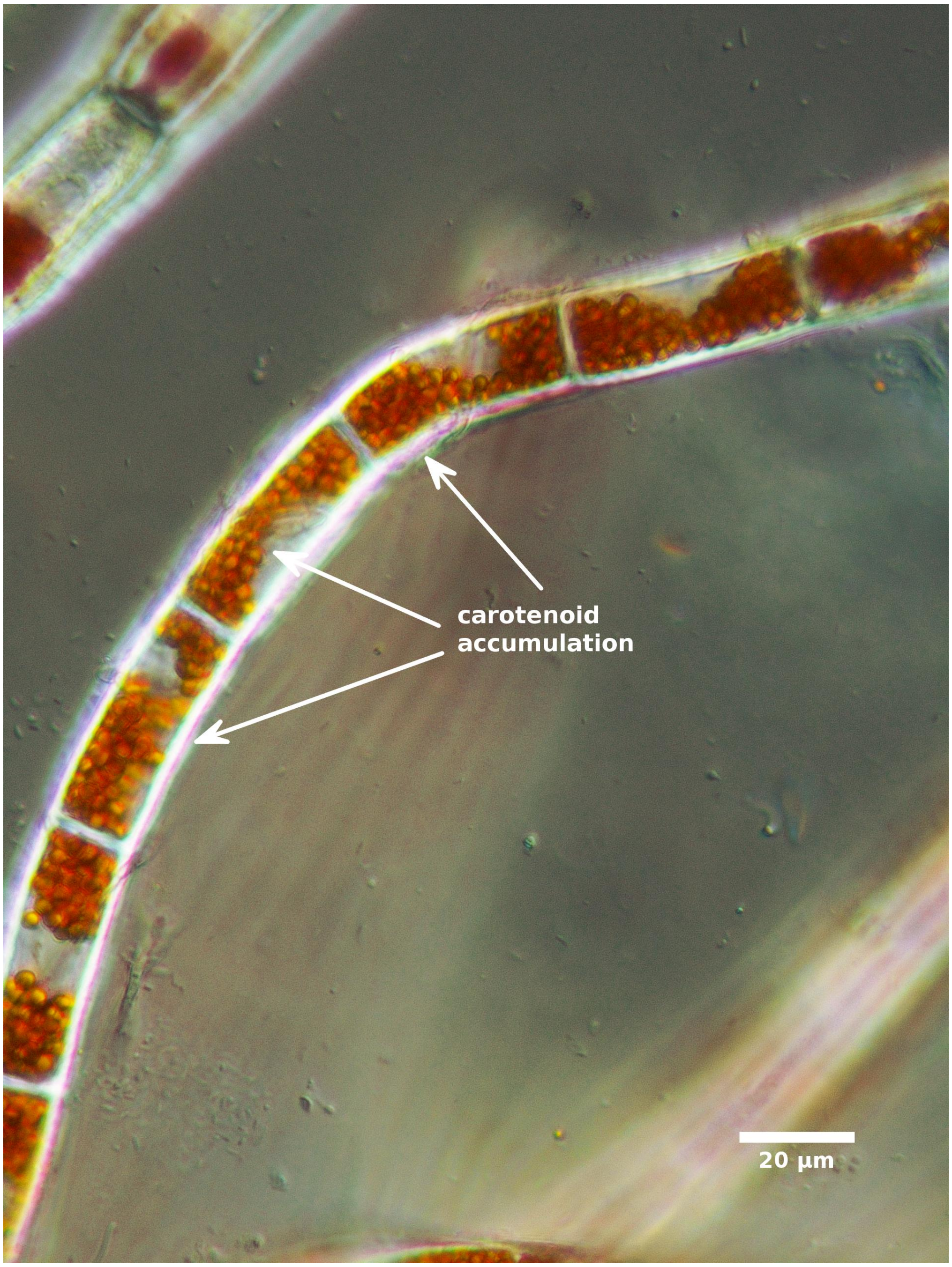


Figure 4.167: *Trentepohlia aurea* (400x DIC), damp rocks near waterfall along Hwy 20 near Maple Pass, August 19, 2014.

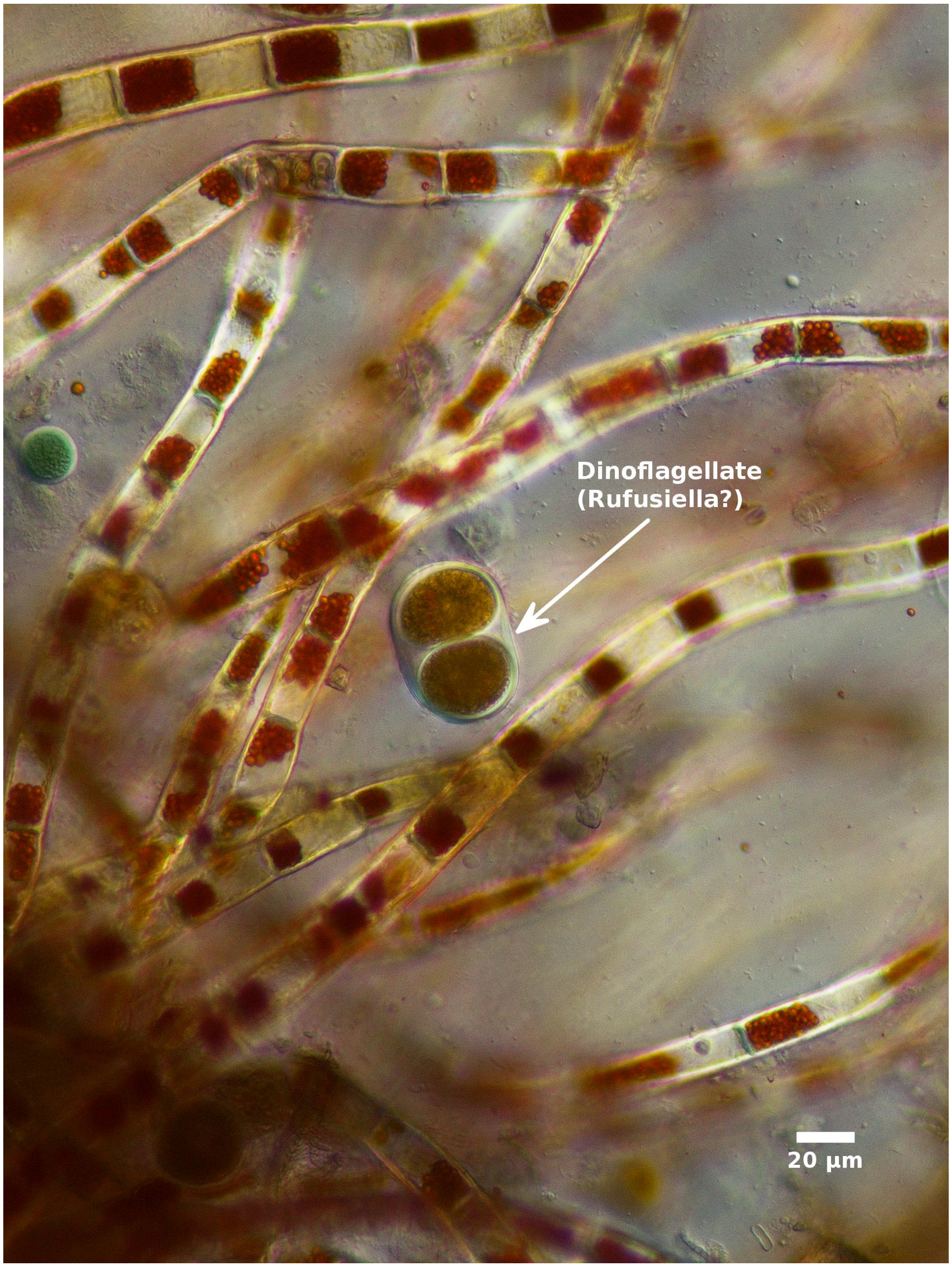


Figure 4.168: *Trentepohlia aurea* (200x DIC), damp rocks near waterfall along Hwy 20 near Maple Pass, August 19, 2014.

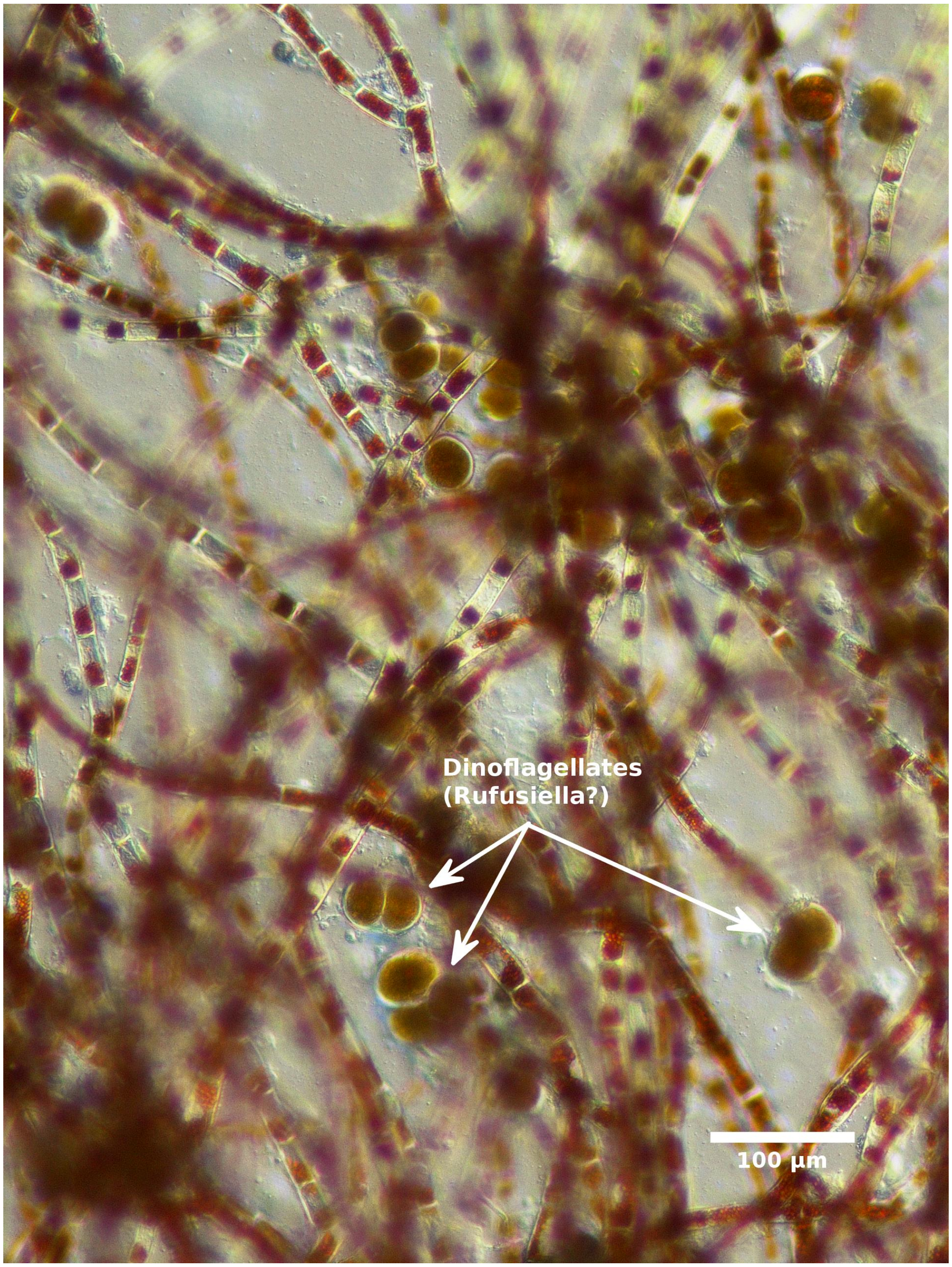


Figure 4.169: *Trentepohlia aurea* (100x DIC), damp rocks near waterfall along Hwy 20 near Maple Pass, August 19, 2014.

4.22 *Ulothrix* Kützing

Local taxa
Ulothrix aequalis Kützing;
Ulothrix tenerrima (Kützing) Kützing?;
Ulothrix zonata (Weber & Mohr) Kützing;
Ulothrix sp.1

Abundance
Moderately common in plankton samples, flowing water, and along shoreline; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Ulothrix aequalis	min	12.9 μm	15.4 μm	2,480 μm^3
cells (cylinder)	med	23.0 μm	29.3 μm	12,000 μm^3
	max	36.5 μm	38.5 μm	30,800 μm^3
Ulothrix tenerrima?	min	7.7 μm	12.1 μm	624 μm^3
cells (cylinder)	med	8.3 μm	20.7 μm	1,090 μm^3
	max	8.7 μm	31.1 μm	1,810 μm^3
Ulothrix zonata	min	17.6 μm	13.3 μm	3,500 μm^3
cells (cylinder)	med	29.9 μm	26.7 μm	23,400 μm^3
	max	53.0 μm	46.2 μm	80,700 μm^3
Ulothrix sp.1	min	4.5 μm	54.9 μm	912 μm^3
cells (cylinder)	med	4.6 μm	59.5 μm	962 μm^3
	max	5.0 μm	60.5 μm	1,170 μm^3

†Calculated using original measurements, not summary values.

Description
Although *Ulothrix* filaments are occasionally collected in plankton samples, this genus is more likely to be found around shorelines or in flowing water. The genus is characterized by unbranched filaments containing cells with a saddle-shaped or ring-shaped chloroplasts that may completely or partially circle the cell (Figures 4.170–4.179). The chloroplasts contain one or more distinct pyrenoids. *Ulothrix*

filaments commonly form motile reproductive cells, which may develop in freshly collected samples (Figures 4.172 and 4.177). The motile cells may have visible eyespots; live samples may exhibit movement while the reproductive cells are still contained within the wall of the filamentous (vegetative) cell.

Ulothrix cells and filaments closely resemble *Klebsormidium* (Section 4.12, page 630), some species of *Geminella* (Section 4.9, page 601), and *Microspora* (Section 4.13, page 636). *Geminella* filaments can be distinguished because the filaments are surrounded by a thick mucilaginous sheath. *Microspora* has a net-like (reticulated) chloroplast rather than an incomplete parietal band. *Ulothrix* can be difficult to distinguish from *Klebsormidium*, but the most common local species, *Ulothrix aequalis* and *Ulothrix zonata*, can be identified by their very large cells ($\gg$15 μm wide) and ring-shaped chloroplasts.

Ulothrix aequalis filaments are wide ($\geq$15 μm), with thick-walled, cylindrical cells that are usually slightly longer than their width (Figures 4.170–4.172). The ring-shaped chloroplast extends more than half way around the cell and contains one or more pyrenoids. The local specimens are probably *Ulothrix aequalis* var. *cataeniformis* (Kützing) Rabenhorst, which has constricted cross-walls and is more likely to be found along lake shorelines than *Ulothrix zonata*, which also has very wide filaments, but is typically collected in cold, clear, running water.

Ulothrix tenerrima filaments are narrow ($<$10 μm), with cells that may be shorter or longer than their width (Figures 4.173–4.174). The saddle-shaped chloroplast extends slightly more than half way around the cell and usually contains a single pyrenoid. This species is associated with lakes and stagnant water (John et al., 2011); only a few local specimens have been collected, so the species identification is tentative.

Ulothrix zonata filaments are wide ($\geq$15 μm), with short, cylindrical cells surrounded by a thick cell wall (Figures 4.175–4.177). The cross-walls may be flat or slightly constricted. The cells contain one or two band-shaped chloroplasts that completely circle the cell, sometimes expanding to fill the entire cell. The chloroplasts usually contain several pyrenoids.

Ulothrix sp.1 (Figures 4.178–4.179) is characterized by long, very narrow ($\leq$5 μm) cylindrical cells with slightly constricted cross-walls. The saddle-shaped chloroplast circles about half-way around the cell, and extends about half way up the length of the cell. The specimen could also be *Uronema elongatum* Hodgetts, which closely resembles *Ulothrix*, but has an inflated terminal cell.

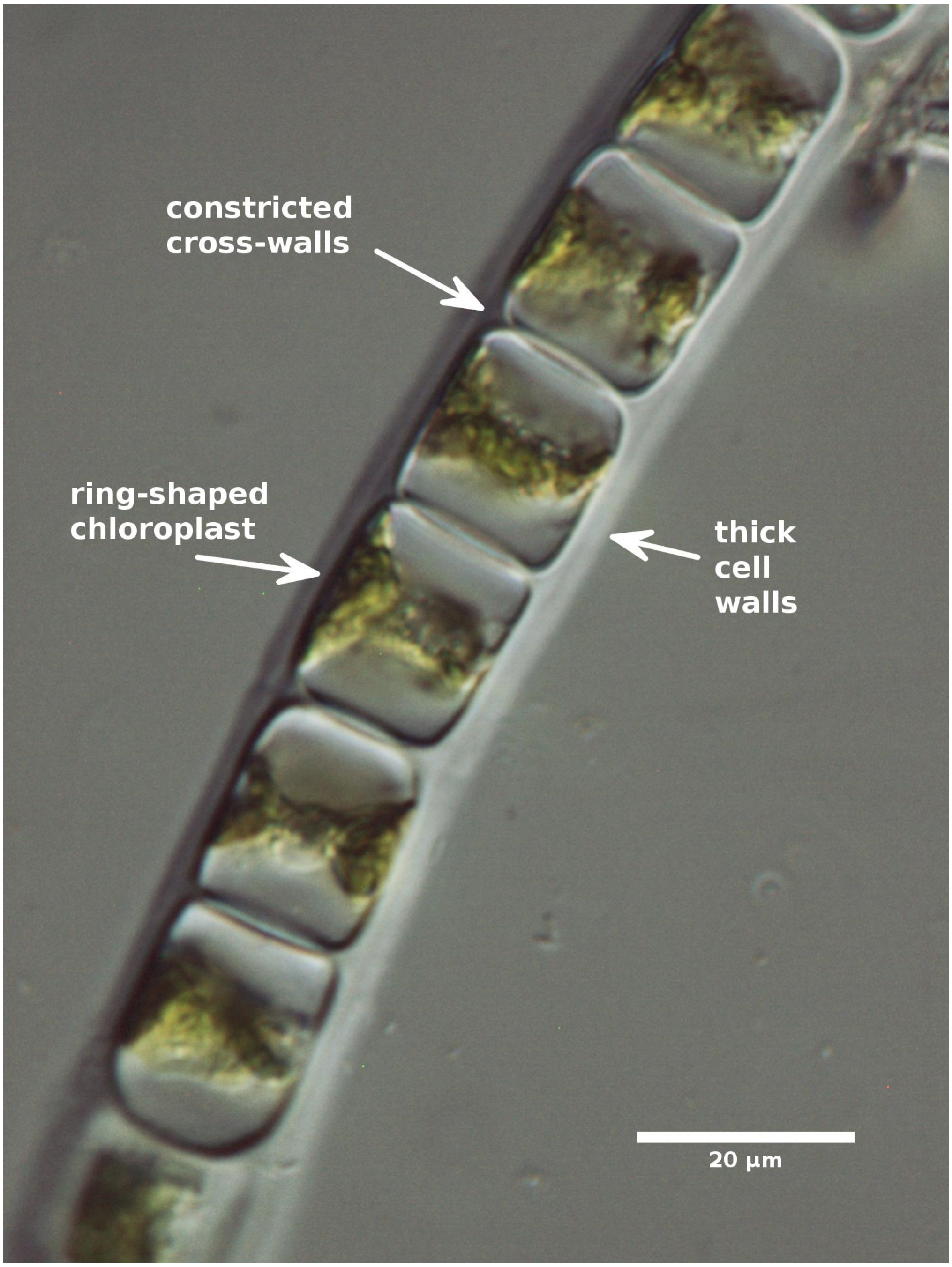


Figure 4.170: *Ulothrix aequalis* (600x DIC), Lake Padden shoreline, IWS water quality sampling site, Whatcom County, April 19, 2013.

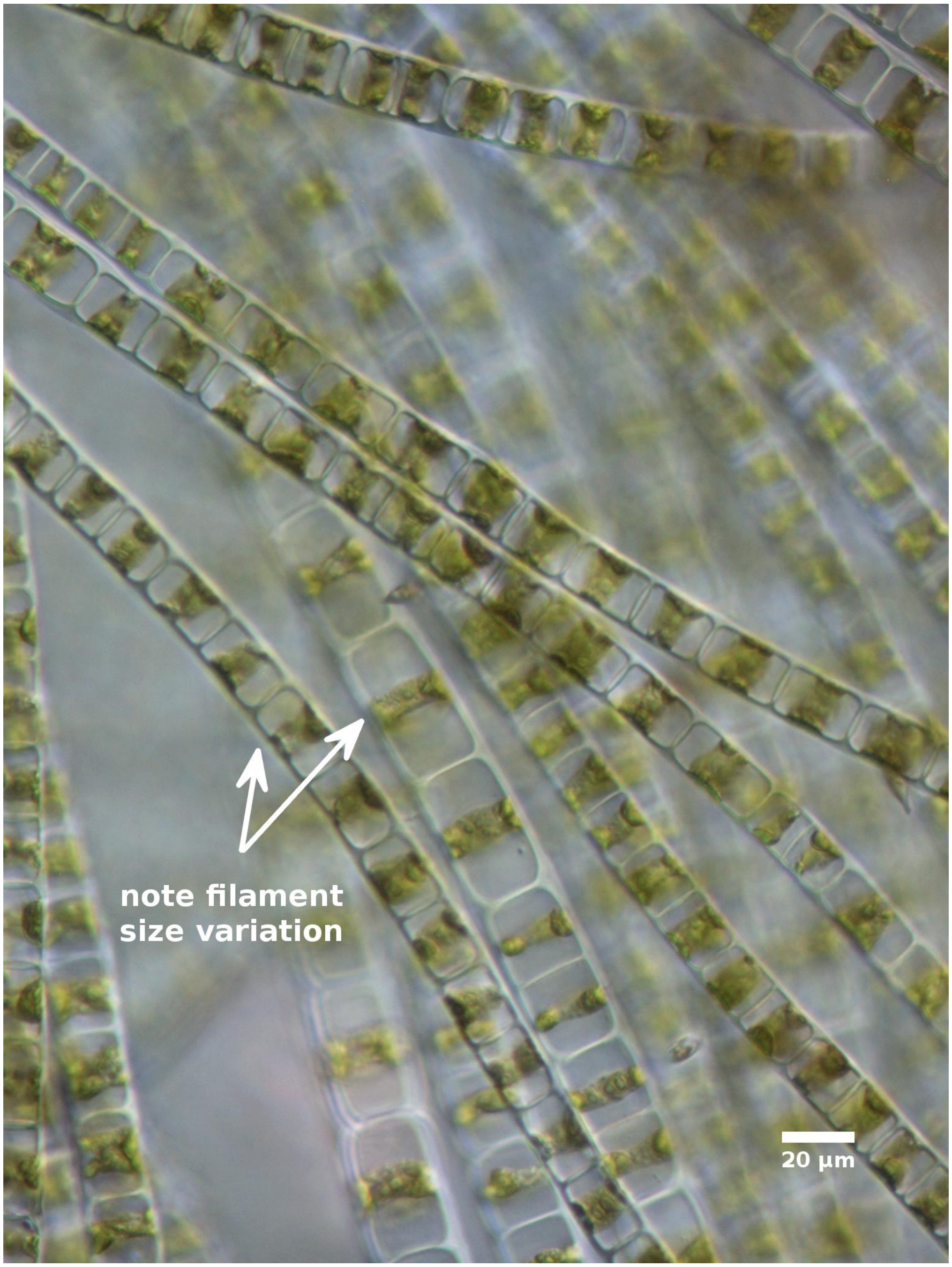


Figure 4.171: *Ulothrix aequalis* (200x DIC), Lake Padden shoreline, IWS water quality sampling site, Whatcom County, April 2, 2013.

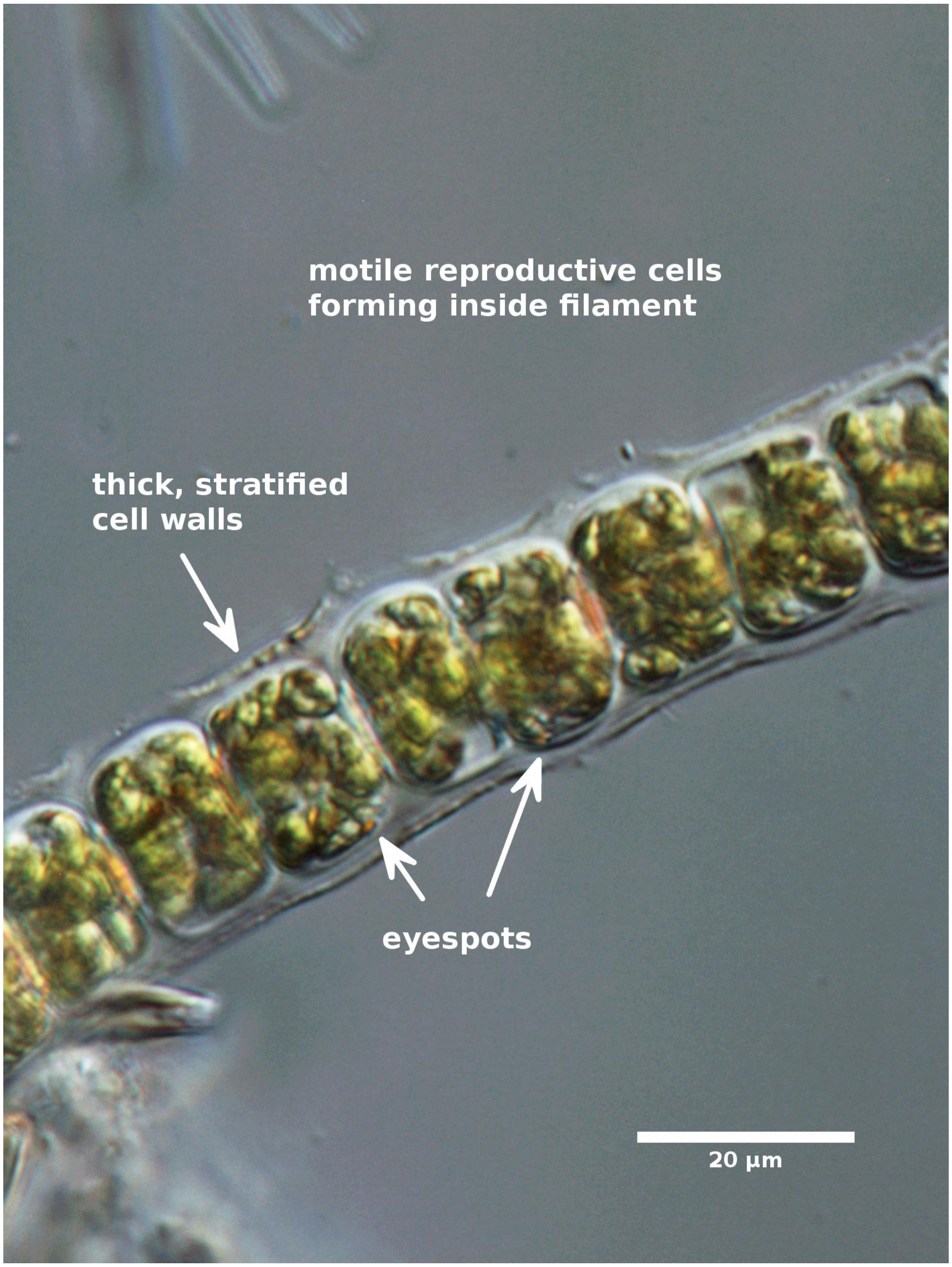


Figure 4.172: *Ulothrix aequalis* reproductive cells (600x DIC), Lake Padden shoreline, IWS water quality sampling site, Whatcom County, April 18, 2013.

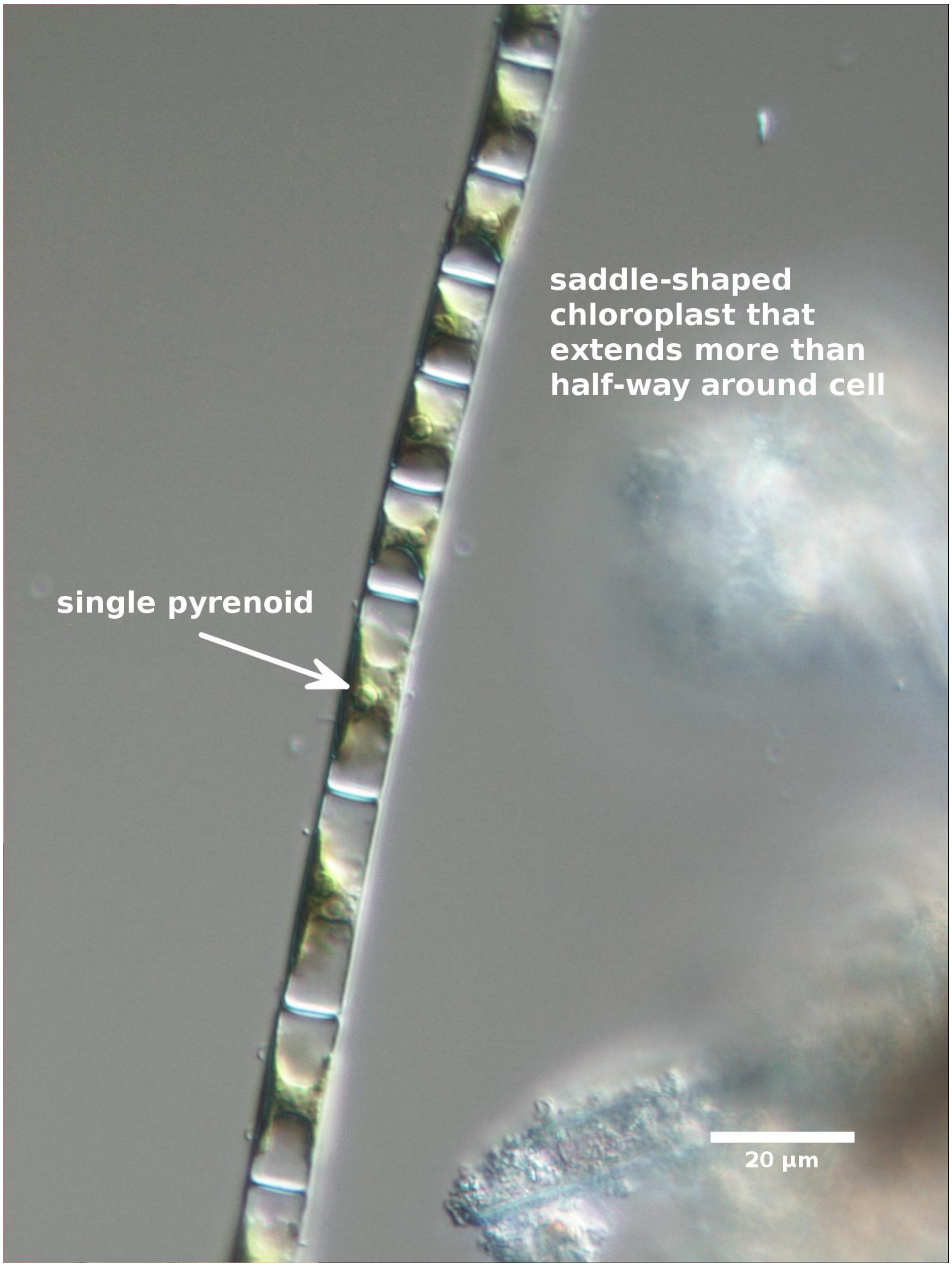


Figure 4.173: *Ulothrix tenerrima*? (400x DIC), Lake Louise, IWS water quality sampling site, Whatcom County, April 24, 2008.

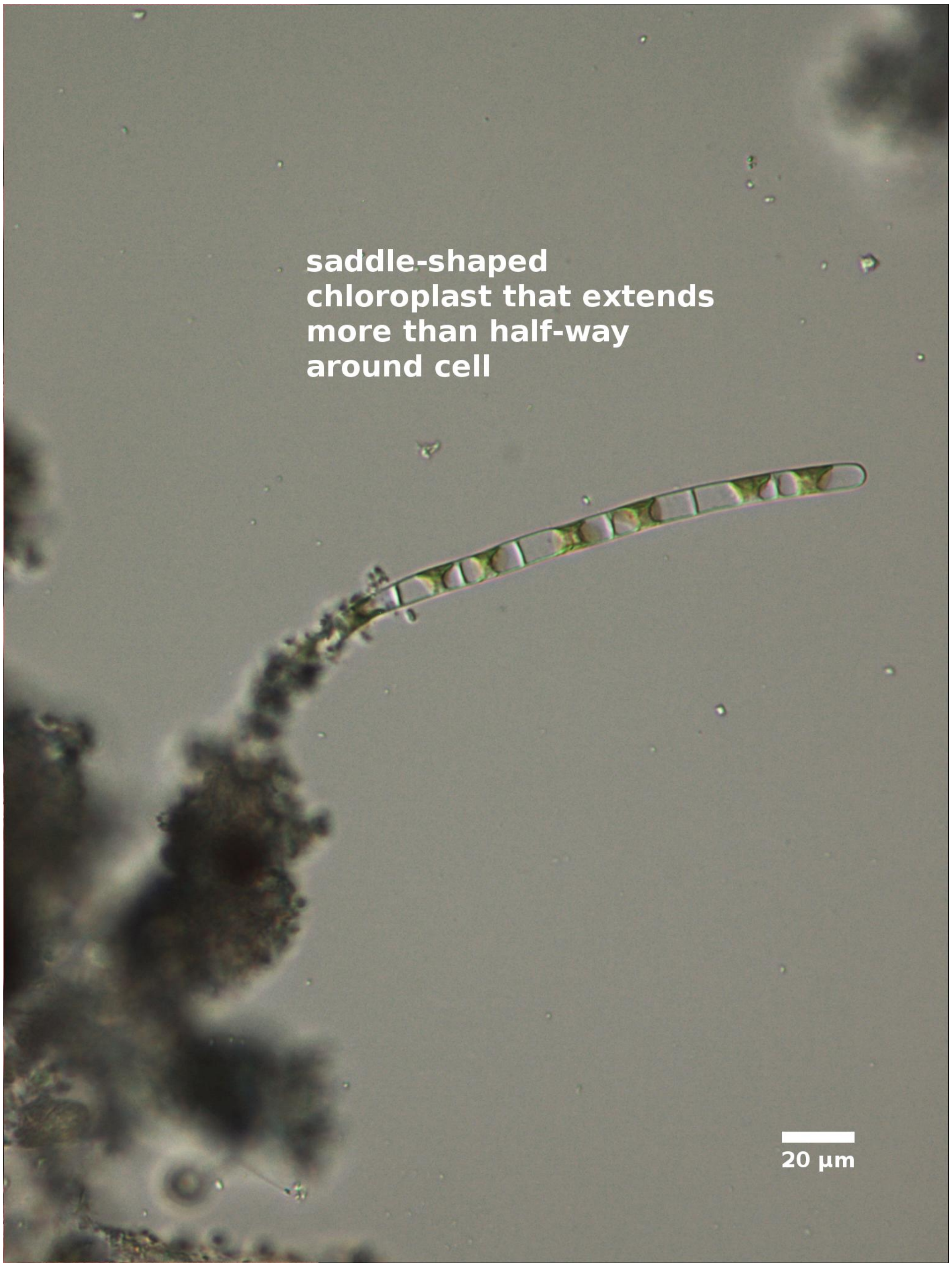


Figure 4.174: *Ulothrix tenerrima*? (400x DIC), Mirror Lake, IWS water quality sampling site, Whatcom County, July 12, 2011.

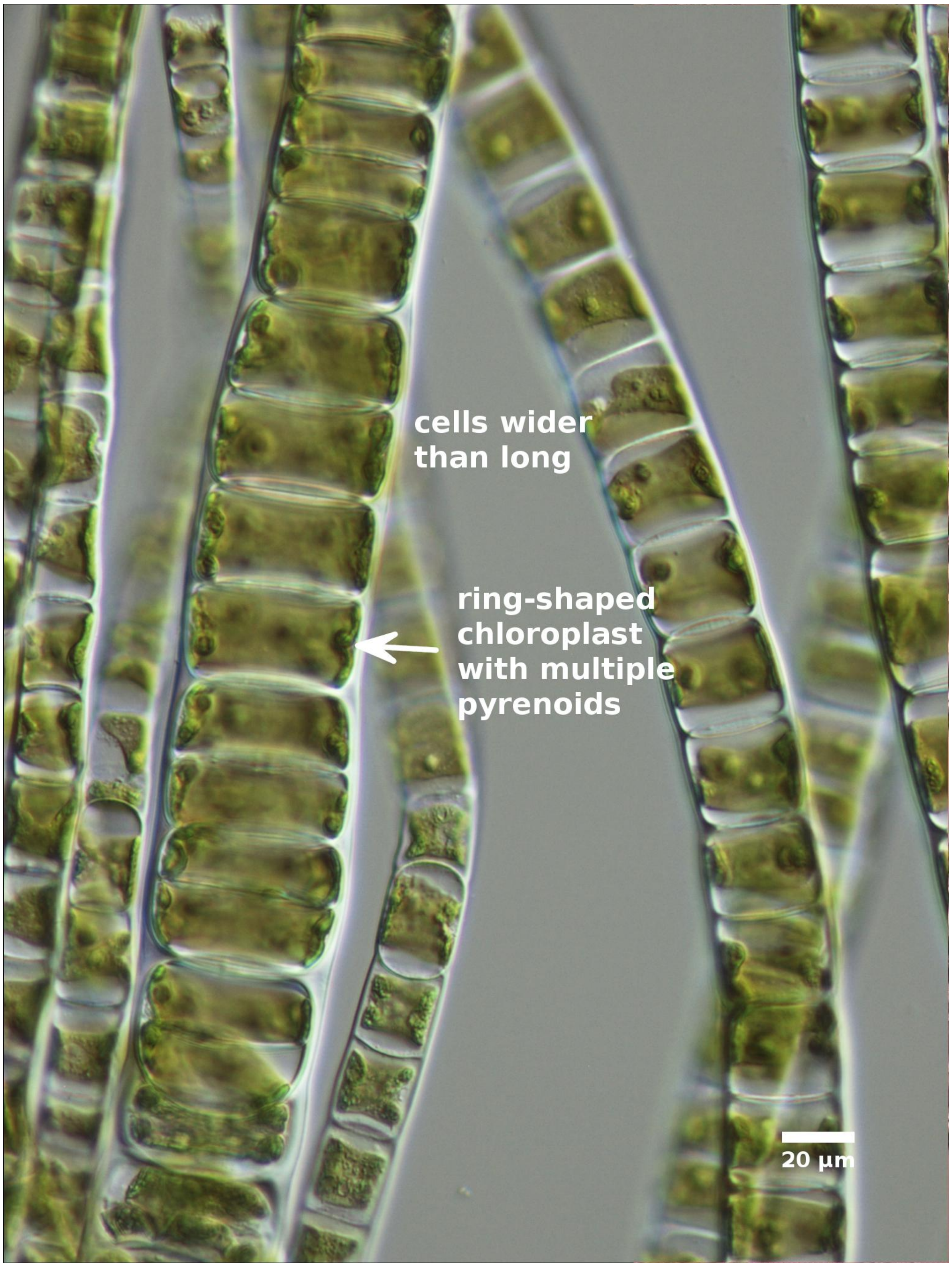


Figure 4.175: *Ulothrix zonata* (200x DIC), Big Four Ice Caves outlet stream, Mt. Loop Hwy, July 1, 2011.

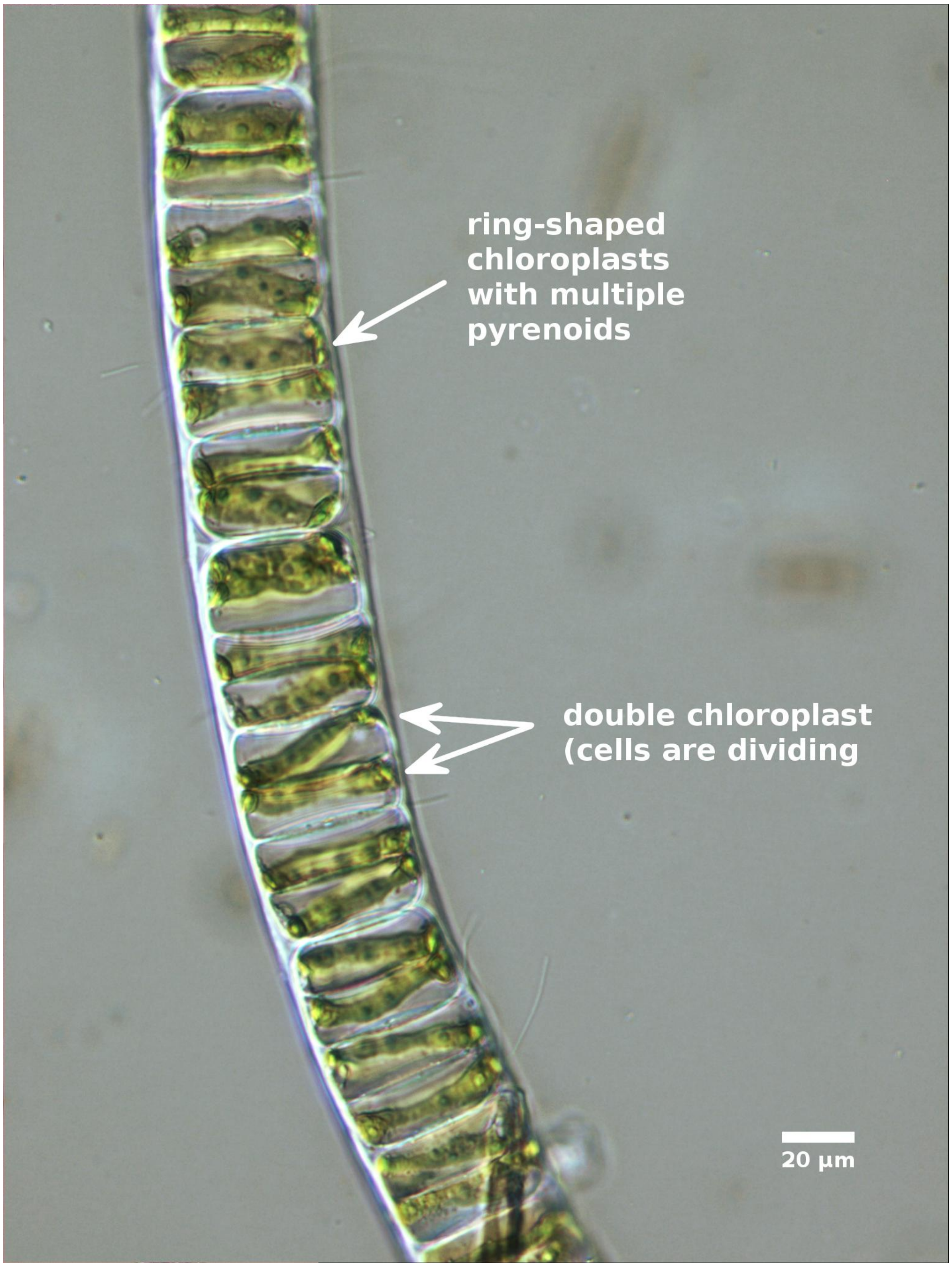


Figure 4.176: *Ulothrix zonata* (200x DIC), Whatcom Creek at fish hatchery, Whatcom County, May 16, 2011.

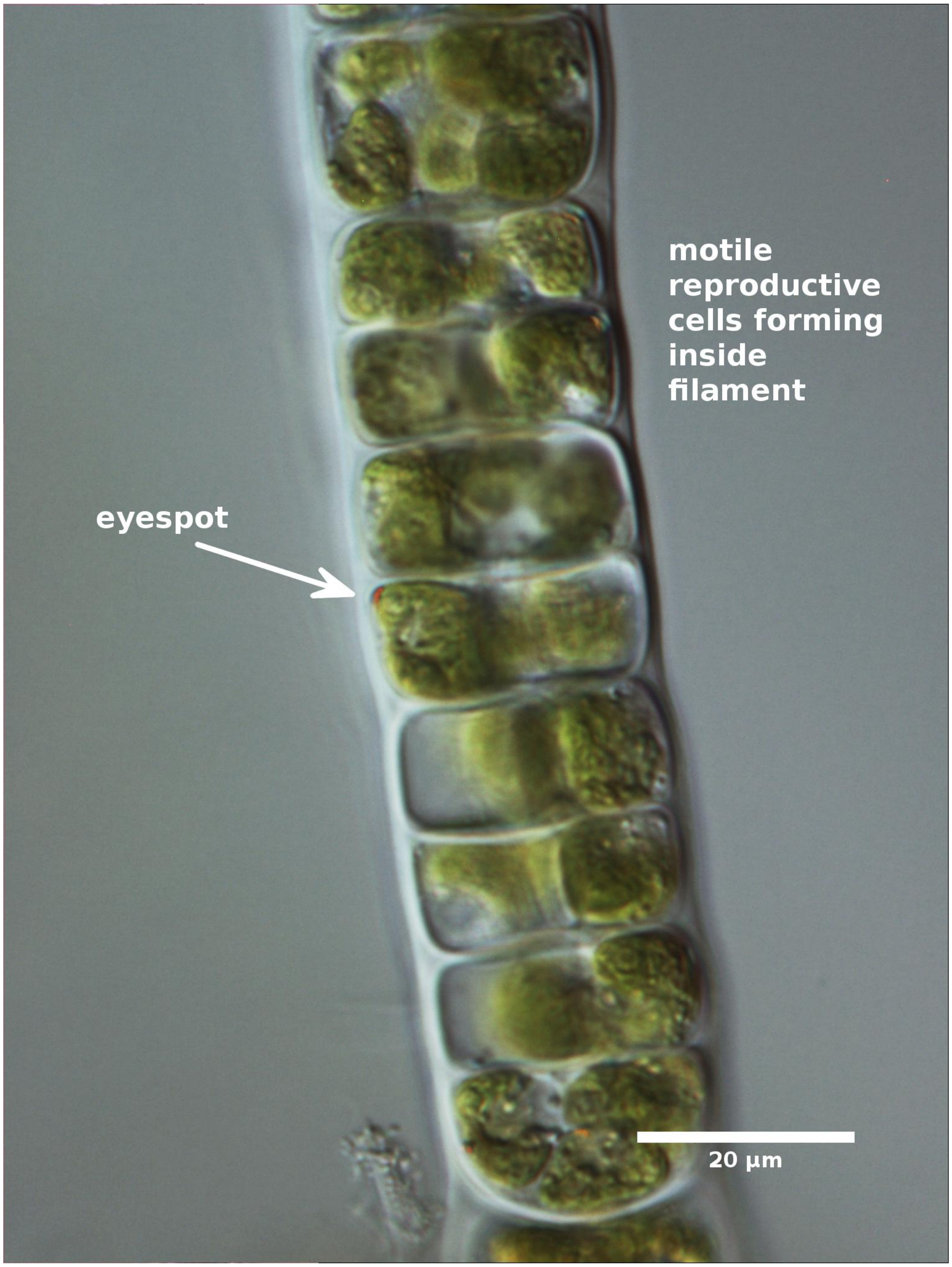


Figure 4.177: *Ulothrix zonata* reproductive cells (600x DIC), Whatcom Creek at fish hatchery, Whatcom County, May 16, 2011.

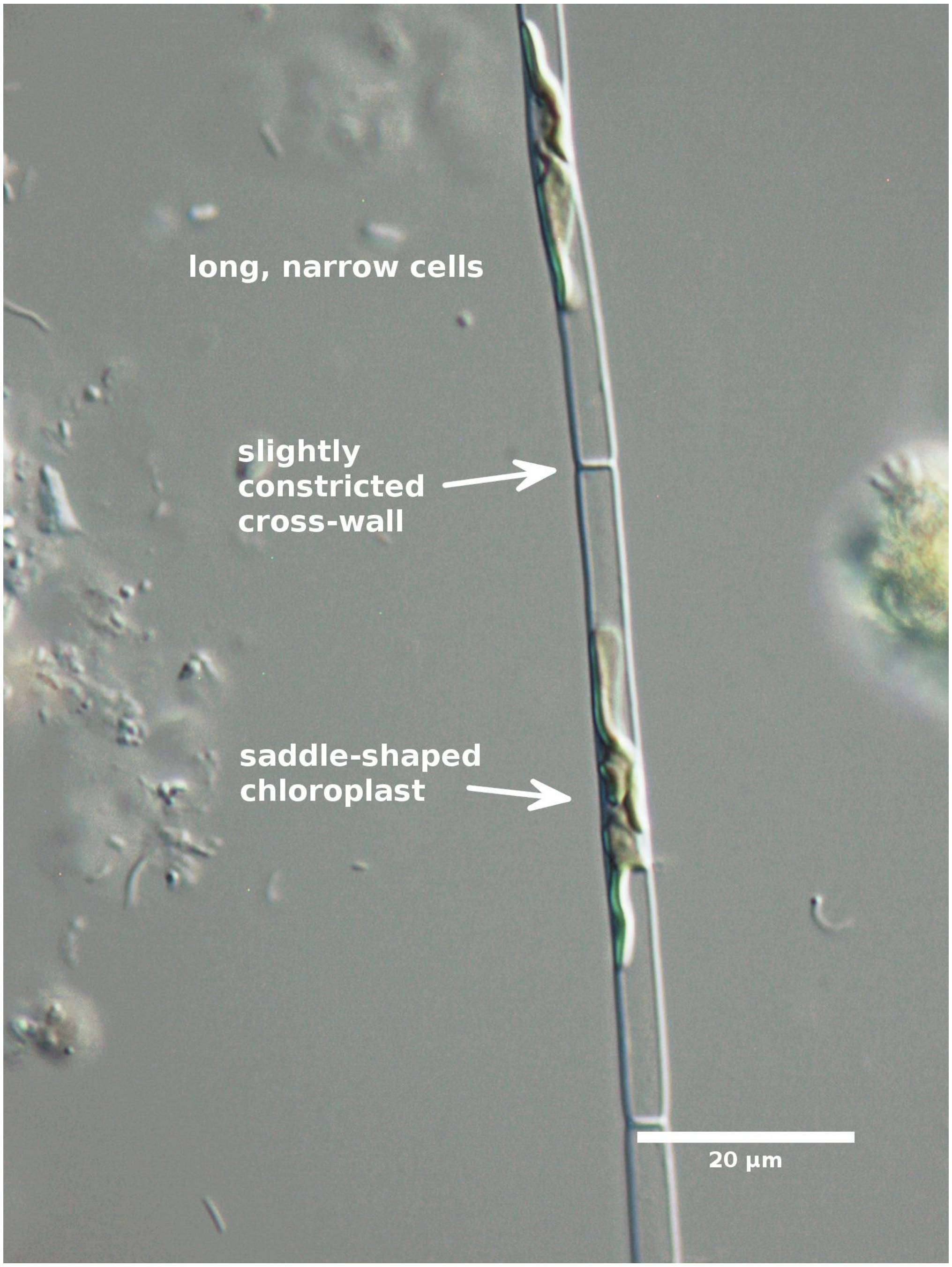


Figure 4.178: *Ulothrix* sp.1 or *Uronema*? (600x DIC), Bear Lake, IWS water quality sampling site, Snohomish County, August 16, 2013.

Figure 4.179: *Ulothrix* sp.1 or *Uronema*? (200x DIC), Bear Lake, IWS water quality sampling site, Snohomish County, August 16, 2013.

4.23 *Zygnema* C. Agardh

Local taxa
Zygnema spp.

Abundance
Moderately common in plankton samples, flowing water, and along shoreline; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Zygnema spp.‡	min	15.9 μm	29.8 μm	7,540 μm^3
cells (cylinder)	med	27.8 μm	48.1 μm	30,600 μm^3
	max	35.3 μm	81.1 μm	68,100 μm^3

†Calculated using original measurements, not summary values.
‡Cell dimensions represent multiple species.

Description
Zygnema, *Mougeotia* (Section 4.15, page 655), and *Spirogyra* (Section 4.19, page 691) are closely related. All three genera are members of the order **Zygnematales**, which also includes desmids.[28] Members of this order have a method of reproduction that includes the formation of conjugation bridges between filaments (Figure 4.133). The resulting zygote contains genetic information from both filaments.

Zygnema filaments are unbranched, with cylindrical cells containing paired, stellate chloroplasts (Figures 4.180–4.184). The filaments may be surrounded by a thin mucilage layer. Sexual reproduction occurs when filaments form conjugation bridges, producing zygotes (Figure 4.184). *Zygnema* can also reproduce vegetatively through cell division and filament fragmentation. Compare *Zygnema* to *Cylindrocystis*, a common desmid with stellate chloroplasts.

Species identification is difficult, requiring the presence of healthy vegetative filaments, conjugating filaments, and mature zygotes, which are rarely present in the same sample. As a result, *Zygnema* species identification beyond the scope of this guide.

[28] See **Freshwater Algae in Northwest Washington, Volume III. Desmids**.

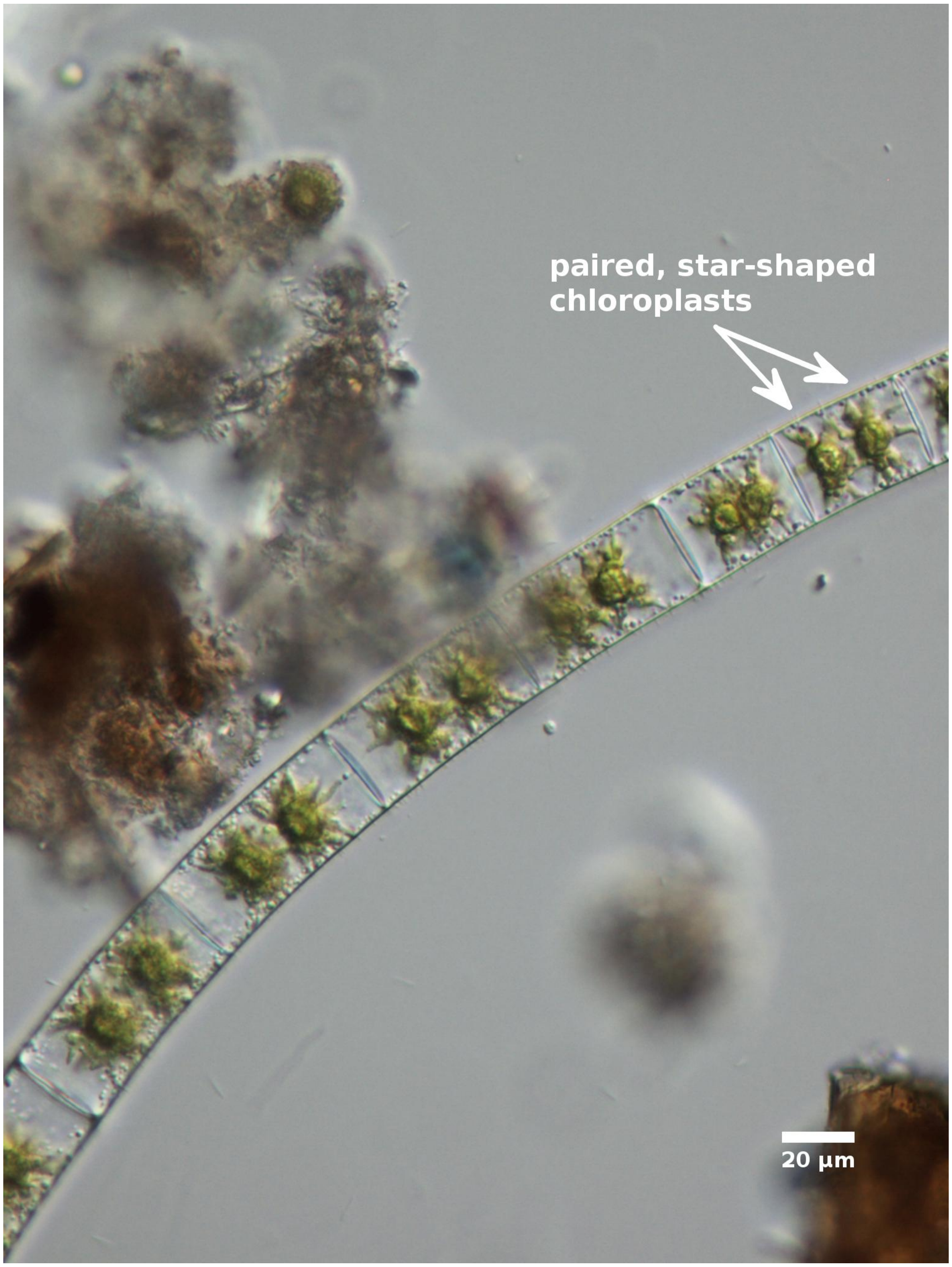


Figure 4.180: *Zygnema* (200x DIC), Diablo Lake, Ross Lake National Recreation Area, September 20, 2012.

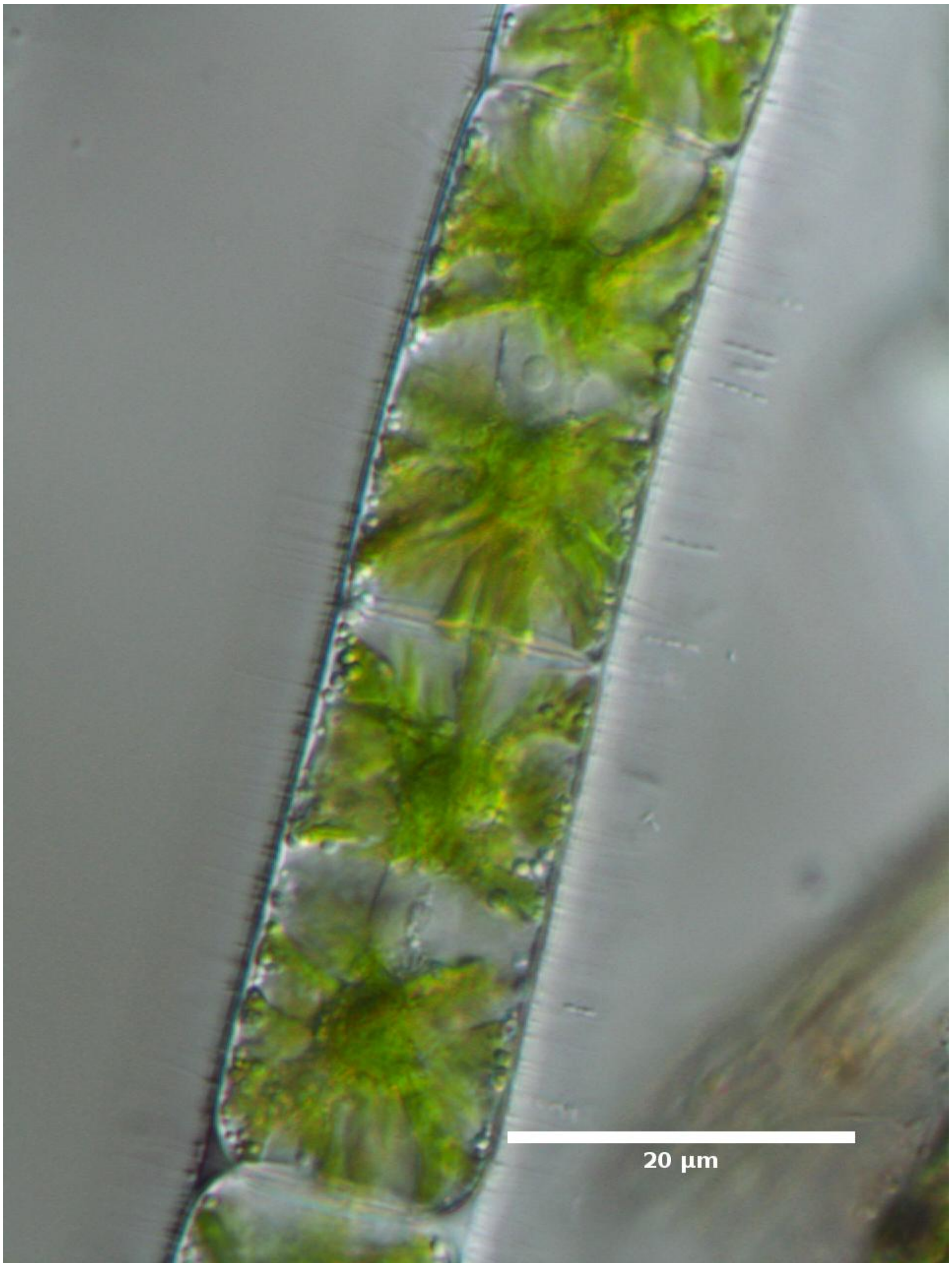


Figure 4.181: *Zygnema* (600x DIC), Blue Lake on Dock Butte trail, North Cascades along Hwy 20, July 2, 2015.

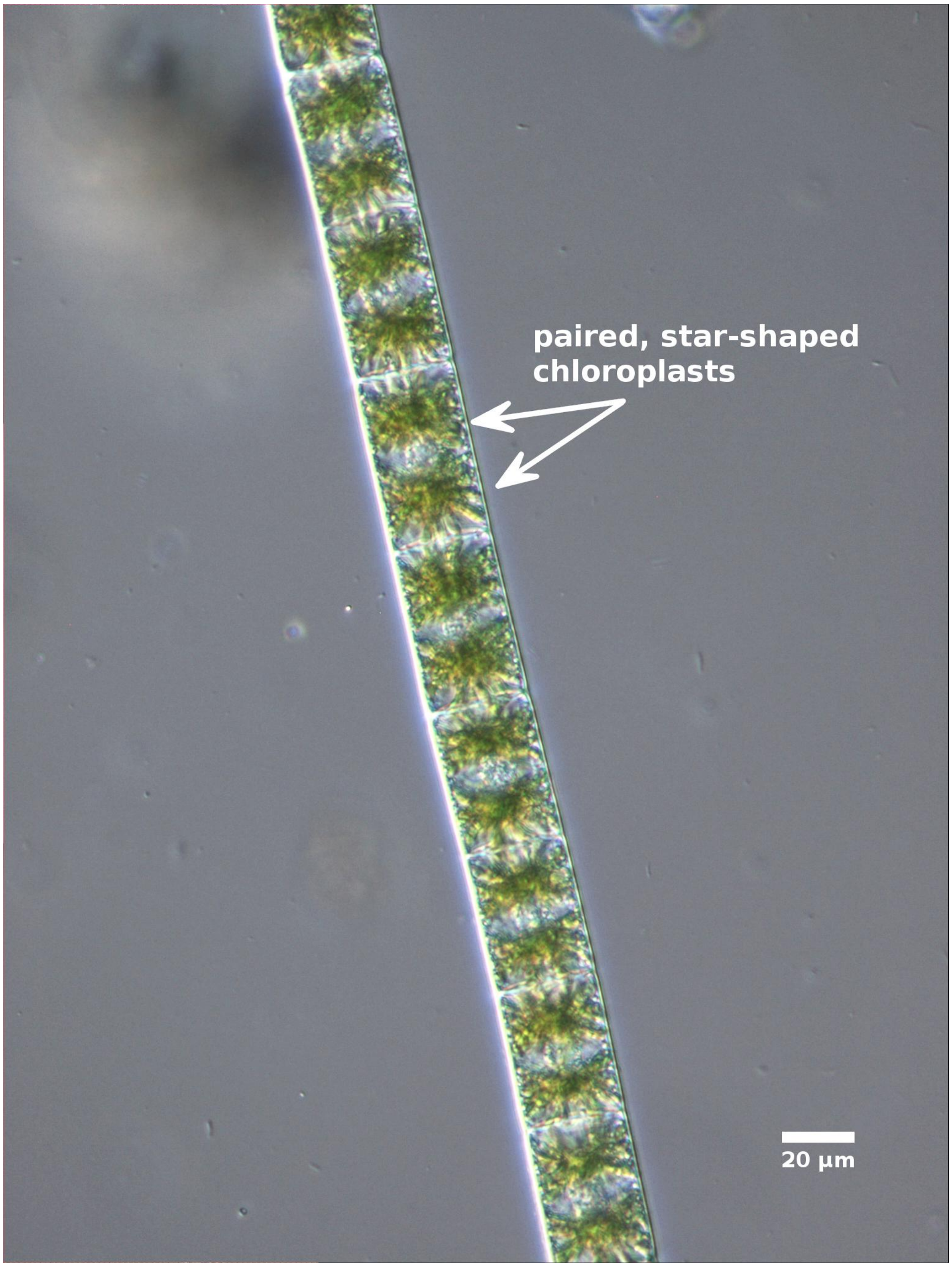


Figure 4.182: *Zygnema* (200x DIC), Tennant Lake, IWS water quality sampling site, Whatcom County, June 1, 2009.

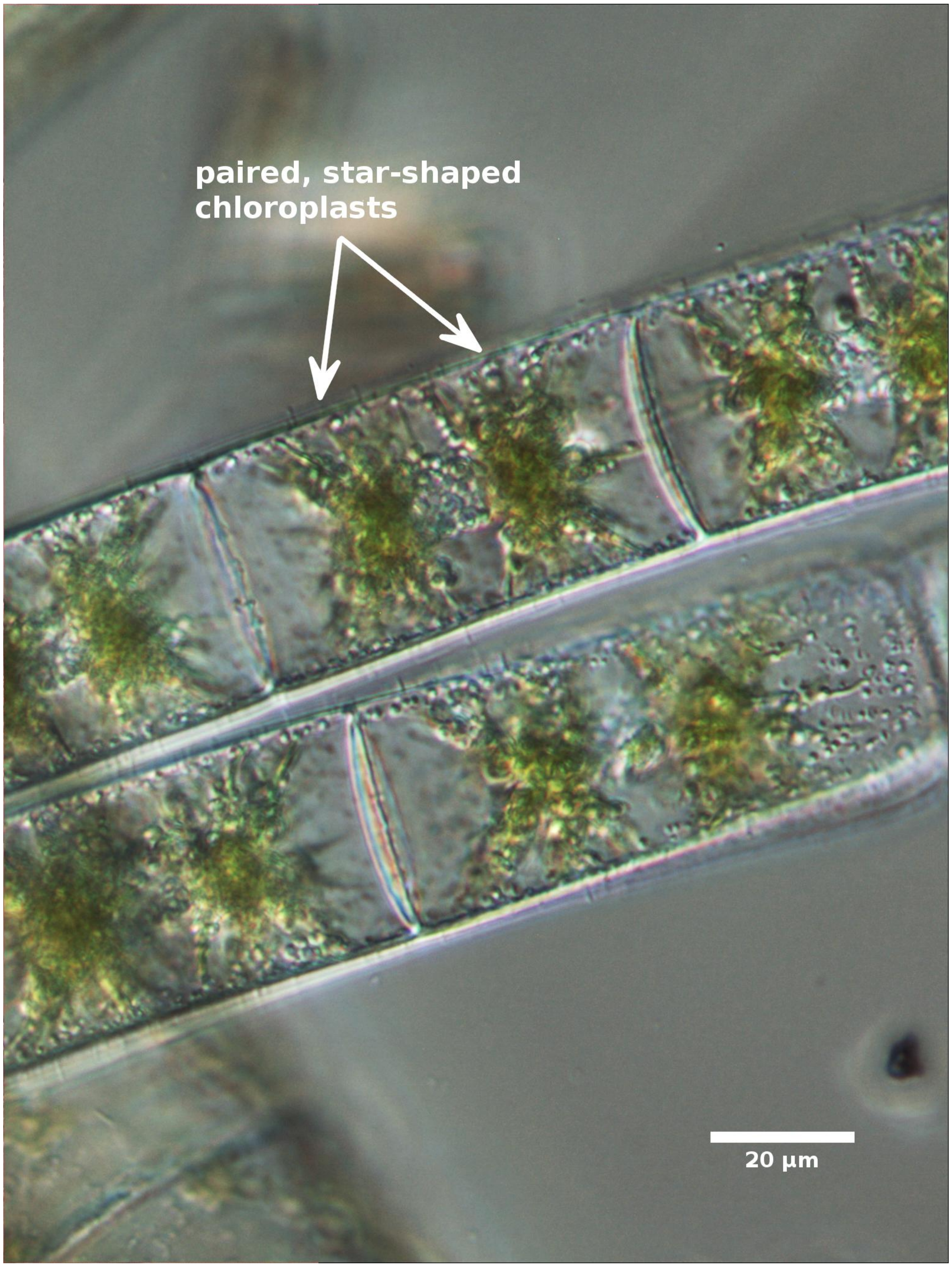


Figure 4.183: *Zygnema* (400x DIC), Sunday Lake, IWS water quality sampling site, Snohomish County, September 2, 2009.

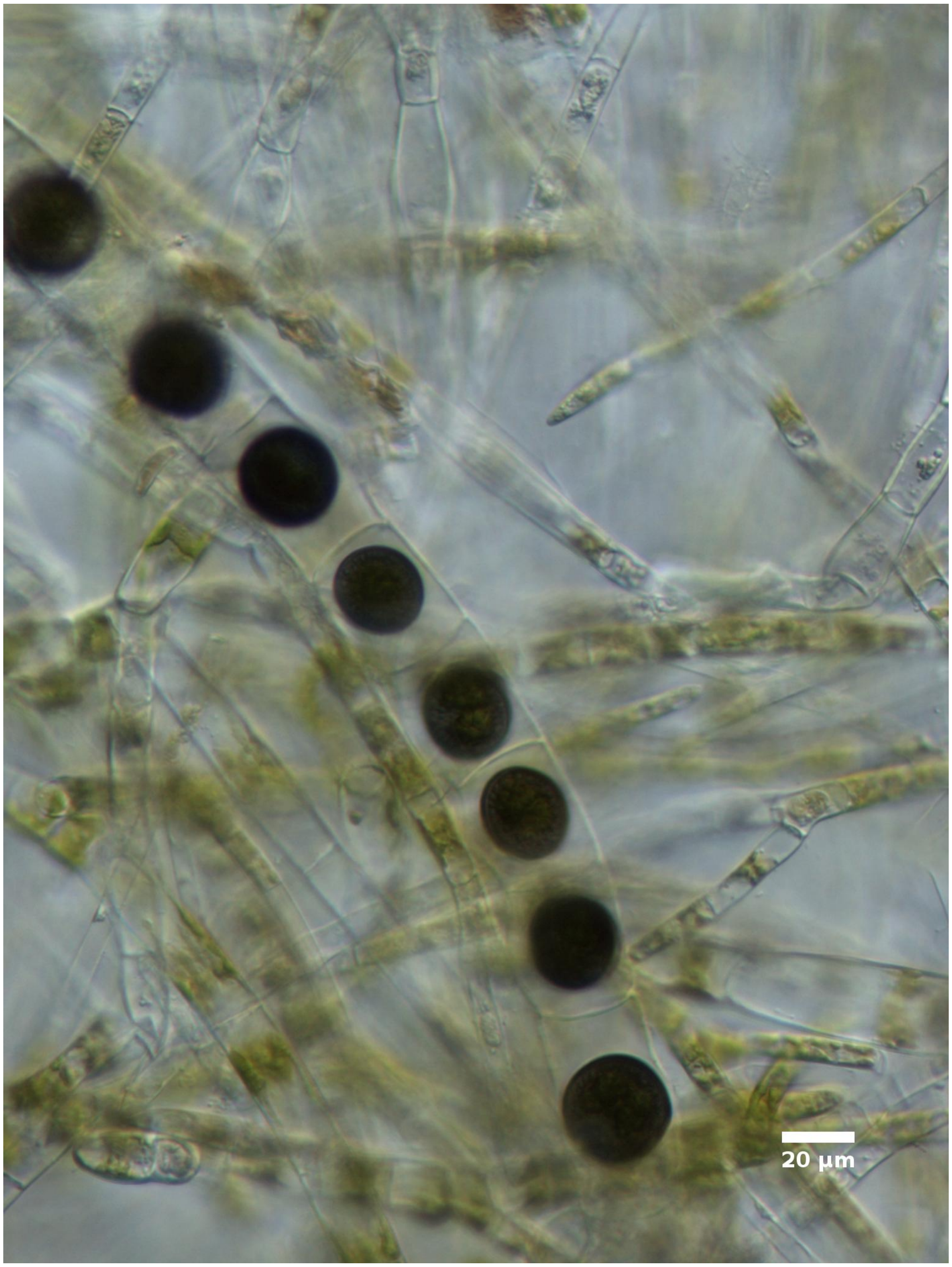


Figure 4.184: *Zygnema* zygotes (400x DIC), Barclay Lake outlet stream, North Cascades along Hwy 2, July 22, 2013.

Chapter 5

Rhodophyta

The key below will help identify the local freshwater Rhodophyta. For motile Chlorophyta, go to page 16; for solitary and colonial nonmotile Chlorophyta, go to page 161; and for filamentous[29] Chlorophyta go to page 532.

Rhodophyta are always nonmotile, and the local taxa are all filamentous. But they have complex life histories and produce a variety of morphologically dissimilar reproductive cells, which makes identification challenging. Rhodophyta contain red and blue pigments, so the cells and filaments will appear reddish brown, blue-green, or purple. Rhodophyta store floridean starch and will stain slightly in Lugols iodine solution.

Table 5.1: Key to the Rhodophyta

A	Simple, sparsely branched filaments; vegetative cells cylindrical	*Audouinella* (page 756)
B	Densely branched filaments; plants often macroscopic; vegetative cells bead-like	*Batrachospermum* (page 765)

[29]The filamentous Chlorophyta key includes pseudofilaments (cells not actually joined end-to-end) as long as the filamentous structure is obvious.

5.1 *Audouinella* Bory

Local taxa
Audouinella spp.

Abundance
Infrequently collected in plankton samples; occasionally collected in flowing water and along shoreline; may form dense mats attached to substrates.

Local measurements		Width	Length	Biovolume†
Audouinella sp.1	min	3.9 μm	10.0 μm	120 μm^3
cells (cylinder)	med	5.2 μm	17.7 μm	348 μm^3
	max	8.5 μm	24.2 μm	1,370 μm^3
Audouinella sp.1	min	8.2 μm	8.1 μm	285 μm^3
sporangia (spheroid)	med	10.0 μm	10.9 μm	560 μm^3
	max	10.4 μm	13.0 μm	708 μm^3
Audouinella sp.2	min	8.7 μm	32.4 μm	2,110 μm^3
cells (cylinder)	med	10.1 μm	37.1 μm	2,850 μm^3
	max	12.1 μm	42.1 μm	4,740 μm^3
Audouinella sp.2	min	6.7 μm	9.7 μm	247 μm^3
sporangia (spheroid)	med	8.4 μm	12.1 μm	445 μm^3
	max	8.9 μm	13.7 μm	568 μm^3

†Calculated using original measurements, not summary values.

Description
Audouinella filaments are sparsely branched, with long, cylindrical vegetative cells. The filaments are usually epiphytic or attached to solid substrates, where they may form dense reddish purple or bluegreen mats. The cells contain one or more ribbon or disk-shaped chloroplasts; pyrenoids are absent from all Rhodophyta taxa. *Audouinella* cells store a type of starch, so the cells will stain slightly in Lugols iodine solution. The filaments often contain specialized reproductive cells, especially monosporangia, which can be solitary or in grape-like clusters. As with most Rhodophyta, the species have complex life histories.

Audouinella sp.1 and sp.2 filaments are reddish-purple, with long, cylindrical cells and ribbon-like chloroplasts (Figures 5.1–5.7). Both taxa match the descriptions provided by John, et al. (2011) for *Audouinella hermannii* (Roth) Duby, but there are morphological differences that suggest they may not be the same species. The *Audouinella* sp.1 specimens came from a rocky, low elevation waterfall (Figures 5.1–5.2). The vegetative cells are small compared to the other local *Audouinella* specimens. The filaments contained short lateral branches, many of which terminated in a solitary sporangium or pair of sporangia. Planes of cleavage were visible in some of the sporangia (Figure 5.2), suggesting that the sporangia will produce four spores (tetrasporangium) rather than one spore (monosporangium).

Audouinella sp.2 specimens were collected from the shoreline of an oligotrophic lake (Figures 5.3–5.7). The sparsely branching filaments were superficially similar to *Audouinella* sp.1, consisting of long, reddish purple, cylindrical cells. But the vegetative cells were larger and reproductive cells were dissimilar. The sporangia were oval or broadly elliptical (not spherical) and formed grape-like clusters on short lateral branches (Figures 5.4–5.5). Some of the sporangia appeared to contained a single spore (monosporangium) and others appeared to be dividing to form multiple spores (tetrasporangium). In addition to the asexual sporangia, the filaments contained long, narrow trichogynes on short lateral branched (Figures 5.6–5.7).

Figure 5.1: *Audouinella* sp.1 (200x DIC), Chuckanut Falls, Whatcom County, May 2, 2013.

Figure 5.2: *Audouinella* sp.1 (400x DIC), Chuckanut Falls, Whatcom County, May 2, 2013.

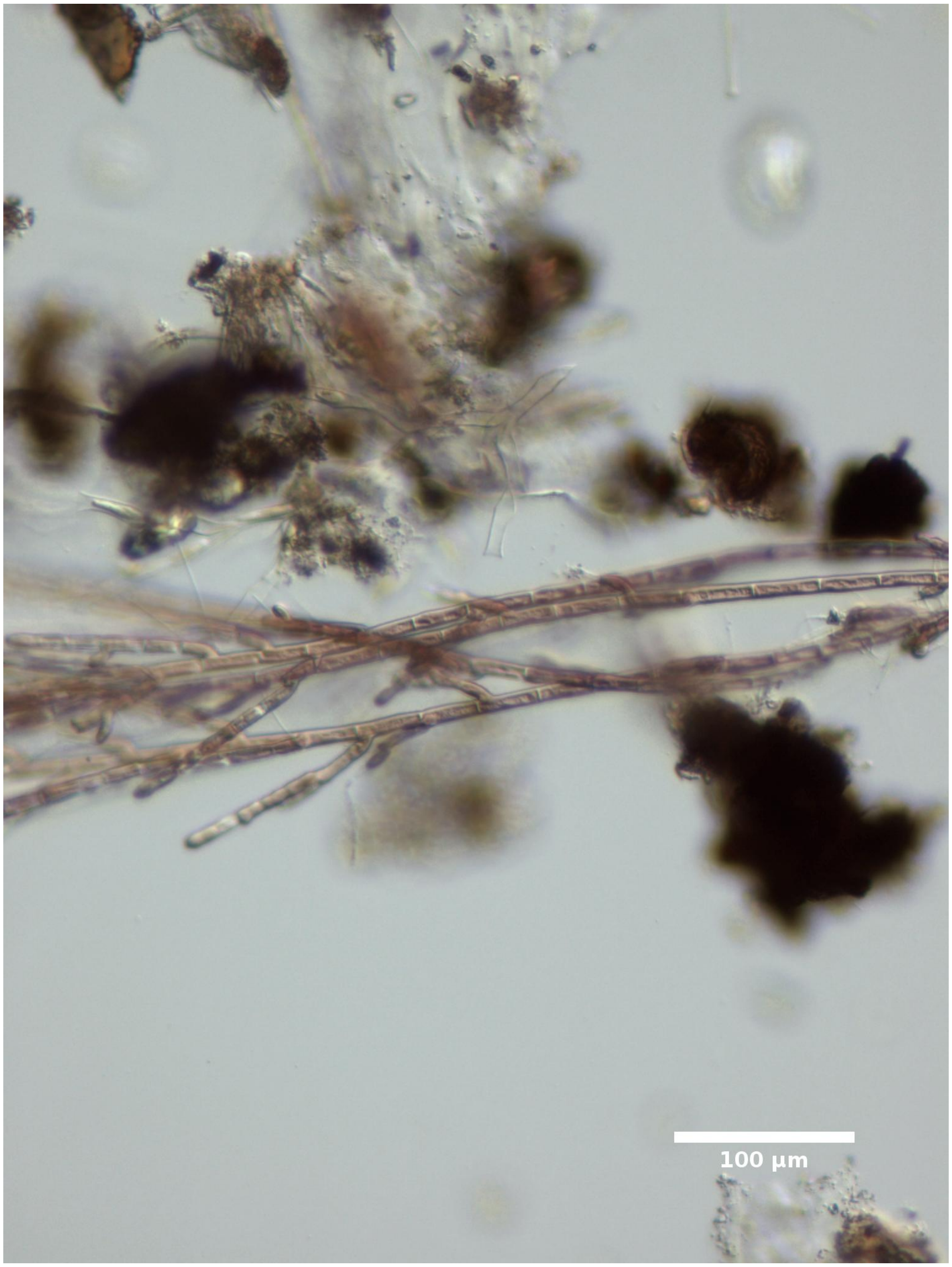


Figure 5.3: *Audouinella* sp.2 (100x DIC), Diablo Lake, Ross Lake National Recreation Area, September 20, 2012.

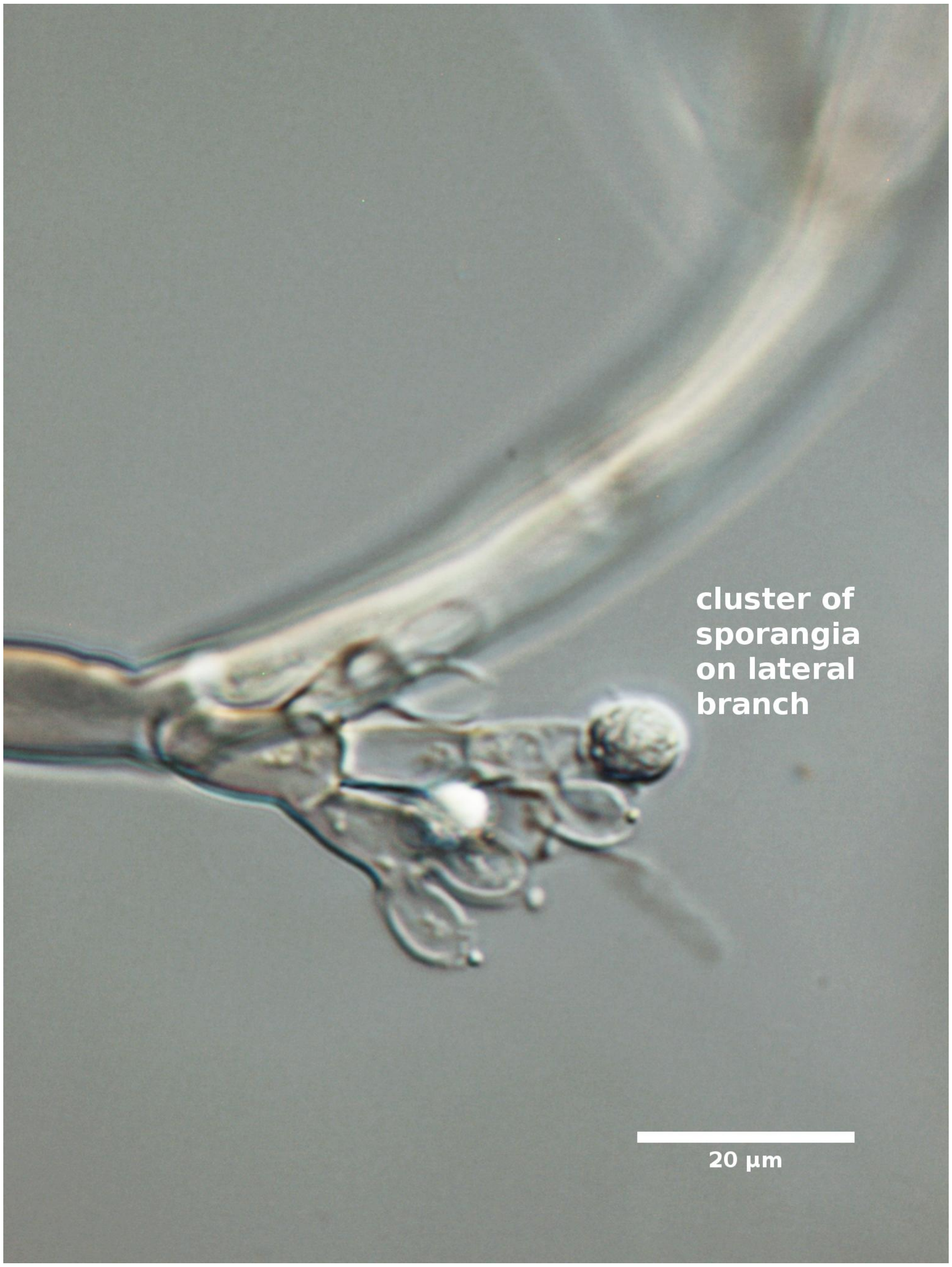


Figure 5.4: *Audouinella* sp.2 (600x DIC), Diablo Lake, Ross Lake National Recreation Area, September 20, 2012.

Figure 5.5: *Audouinella* sp.2 (600x DIC), Diablo Lake, Ross Lake National Recreation Area, September 20, 2012.

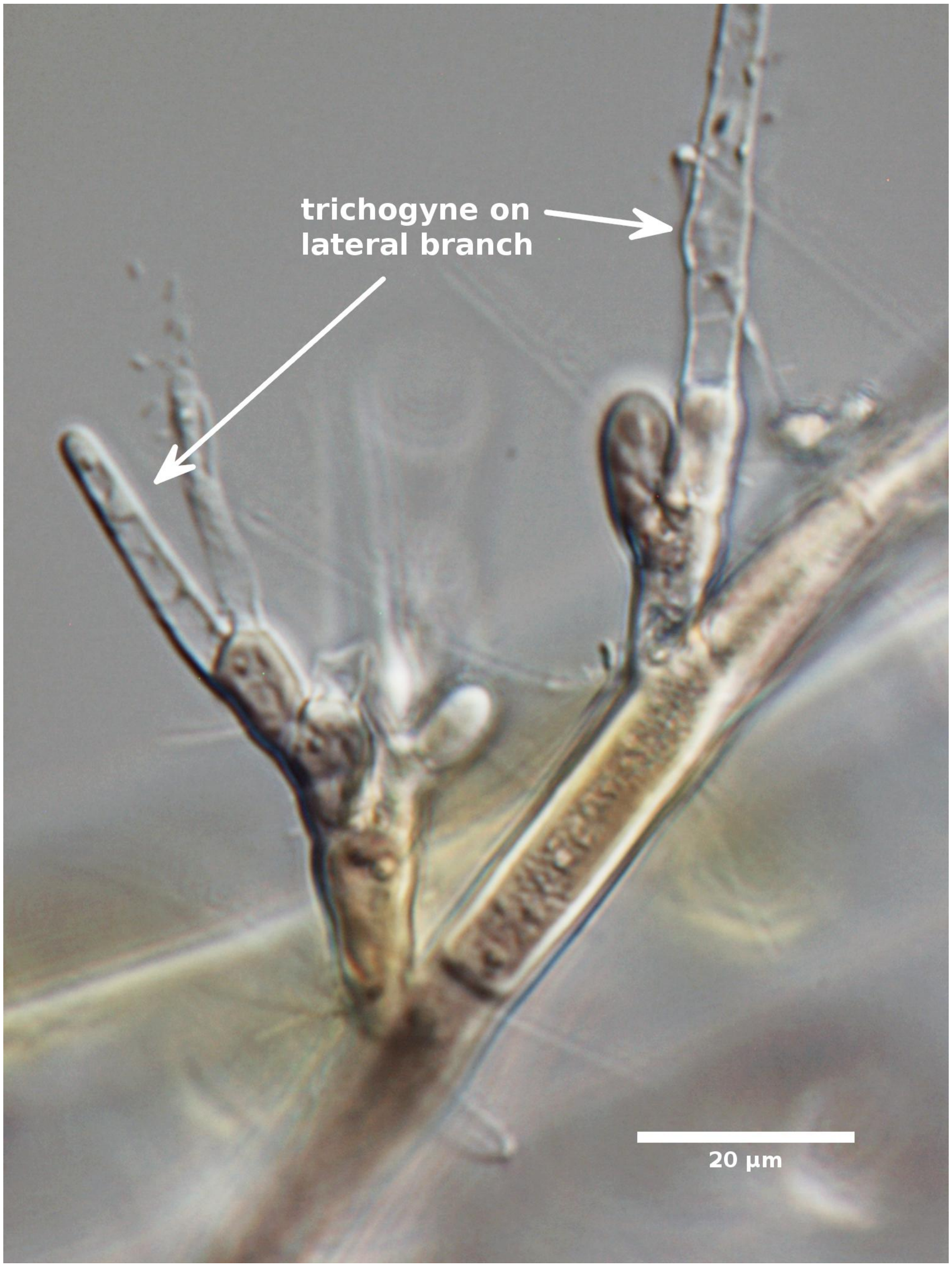


Figure 5.6: *Audouinella* sp.2 (600x DIC), Diablo Lake, Ross Lake National Recreation Area, September 20, 2012.

Figure 5.7: *Audouinella* sp.2 (200x DIC), Diablo Lake, Ross Lake National Recreation Area, September 20, 2012.

5.2 *Batrachospermum* Roth

Local taxa

Batrachospermum gelatinosum (Linnaeus) De Candolle?;
Batrachospermum turfosum Bory?

Abundance

Infrequently collected in plankton samples; moderately common in cold, flowing water.

Local measurements		Width	Length	Biovolume†
Batrachospermum gelatinosum?	min	7.1 μm	12.1 μm	361 μm^3
lateral branch cells	med	8.4 μm	16.6 μm	623 μm^3
(spheroid)	max	11.5 μm	45.7 μm	1,560 μm^3
Batrachospermum gelatinosum?	min	59.2 μm	68.8 μm	128,000 μm^3
carposporangia	med	74.2 μm	77.3 μm	223,000 μm^3
	max	84.4 μm	87.8 μm	327,000 μm^3
Batrachospermum gelatinosum?	min	415.2 μm	282.3 μm	–
whorls‡	med	527.0 μm	377.7 μm	–
	max	630.5 μm	444.5 μm	–
Batrachospermum turfosum?	min	8.2 μm	14.8 μm	709 μm^3
lateral branch cells	med	11.2 μm	21.9 μm	1,600 μm^3
(spheroid)	max	16.2 μm	35.1 μm	3,520 μm^3
Batrachospermum turfosum?	min	432.4 μm	99.0 μm	–
whorls‡	med	497.9 μm	141.3 μm	–
	max	697.8 μm	152.4 μm	–

†Calculated using original measurements, not summary values.
‡Whorl biovolume can be estimated using a cylindrical or spheroid shape.

Description

Batrachospermum filaments form dense, slimy brown or reddish black mats along stream banks (Figures 5.8–5.15). The filament structure is complex, consisting of a central axis of colorless, cylindrical axial cells that are partly or completely covered by creeping cortical cells. Fascicles of lateral branches extend outward to form whorls around the central axis. The lateral branch cells are bead-like, with several parietal chloroplasts. In addition to the vegetative cells, the filaments produce a variety of reproductive structures. The morphological complexity of this genus makes it difficult to identify species, so all of the species identifications are tentative.

The specimens tentatively identified as *Batrachospermum gelatinosum* are characterized by large, regularly spaced, spherical or barrel-shaped lateral whorls, cylindrical cortical cells, and many scattered carposporophytes[30] (Figures 5.8–5.11). These specimens were collected from the outlet streams draining boggy high elevation lakes.

The specimens tentatively identified as *Batrachospermum turfosum* have closely spaced lateral branch whorls that often do not appear separated under low magnification (Figures 5.12–5.15). The cortical cells are cylindrical, and in older filaments may form multiple layers. The specimens were collected in shoreline samples from several small high elevation mountain lakes.

[30]Carposporophytes contain carposporangia, which produce spores that germinate into sparsely branching filaments (chantransia stage) that resemble *Audouinella* rather than the parent form of *Batrachospermum* (Wehr, et al., 2015).

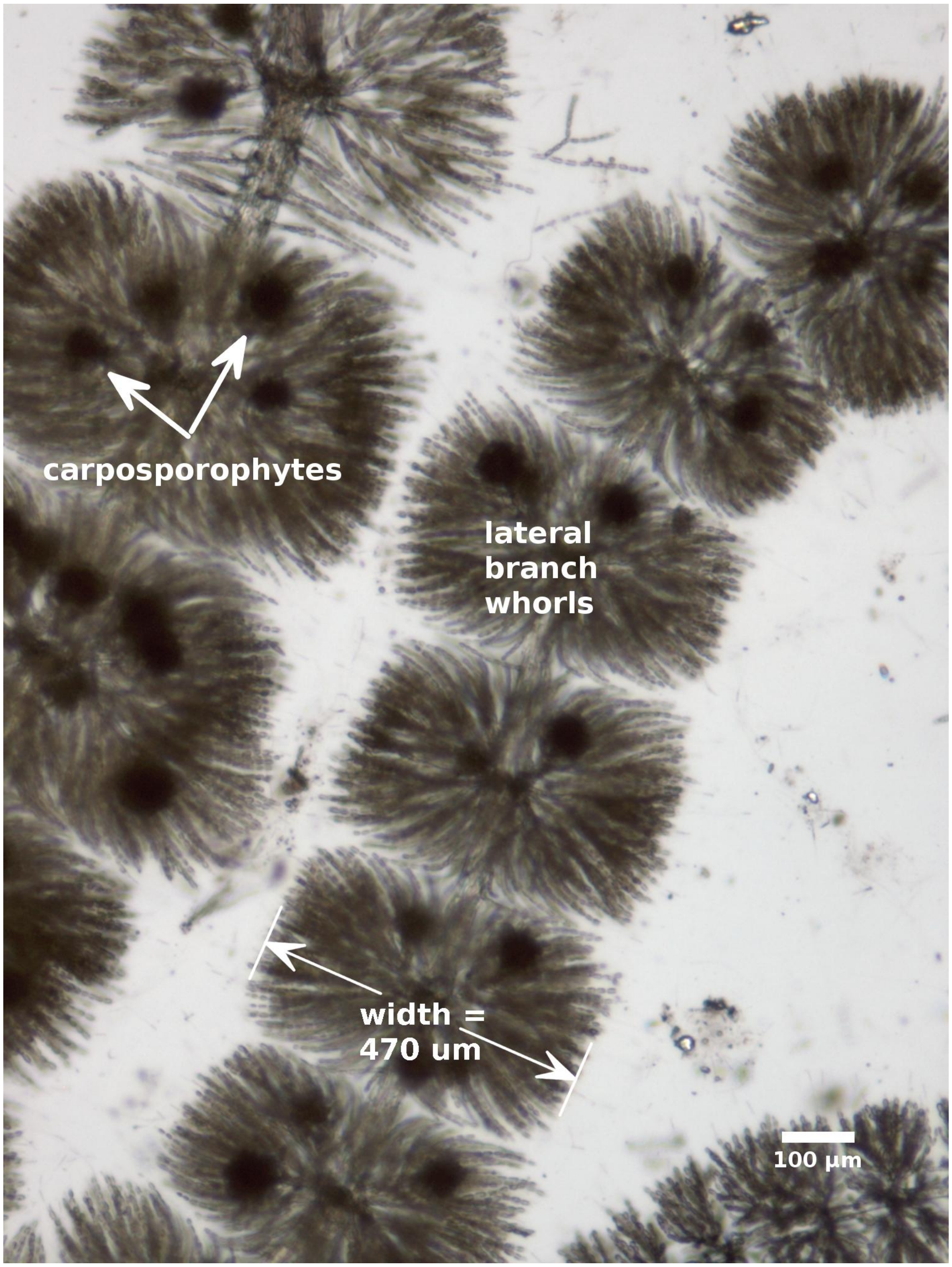


Figure 5.8: *Batrachospermum gelatinosum*? (40x brightfield), Beaver Plant Lake outlet stream, Mt. Loop Hwy, August 16, 2012.

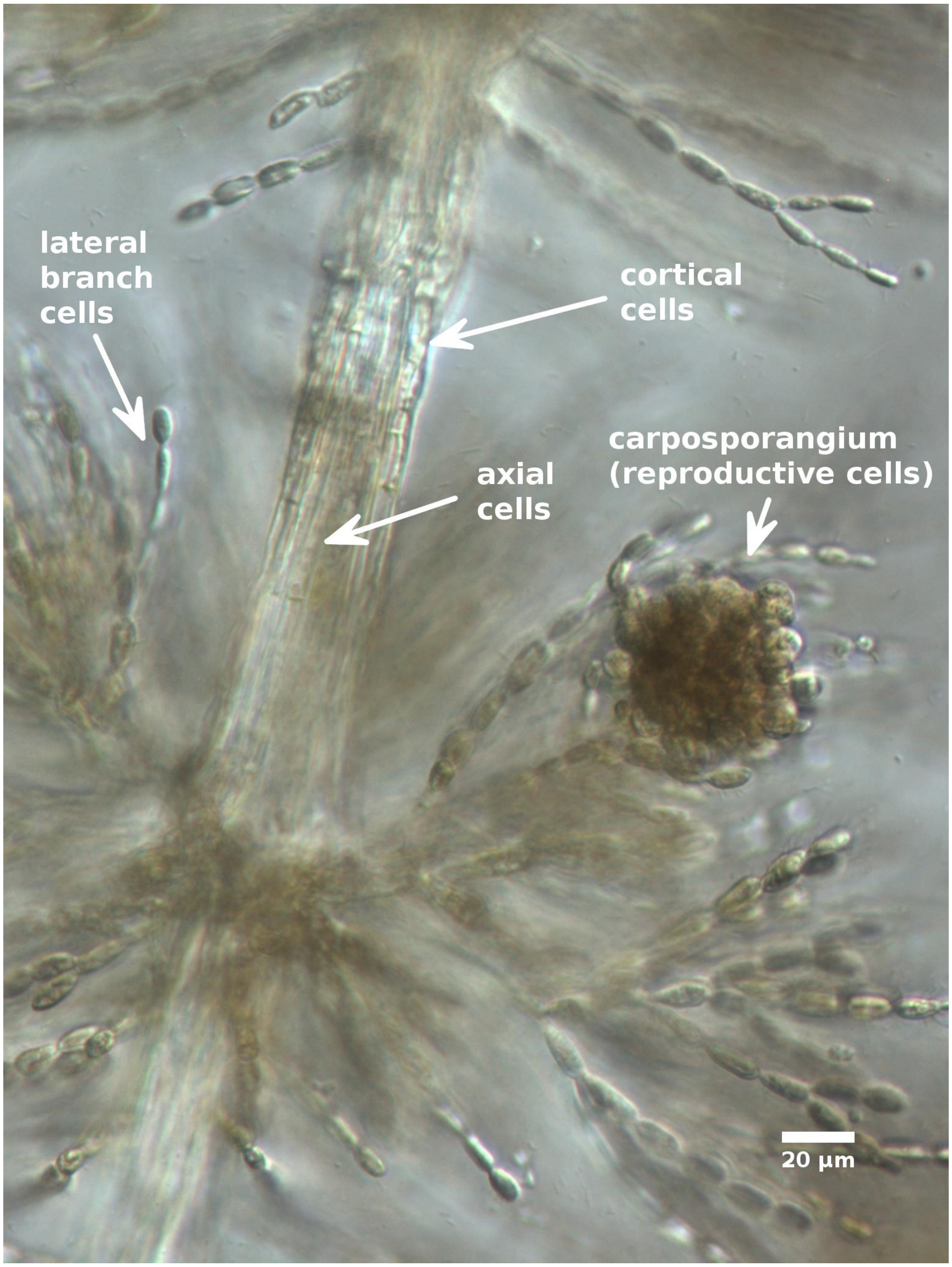


Figure 5.9: *Batrachospermum gelatinosum*? (200x DIC), Beaver Plant Lake outlet stream, Mt. Loop Hwy, August 16, 2012.

Figure 5.10: *Batrachospermum gelatinosum*? (400x DIC), Beaver Plant Lake outlet stream, Mt. Loop Hwy, August 16, 2012.

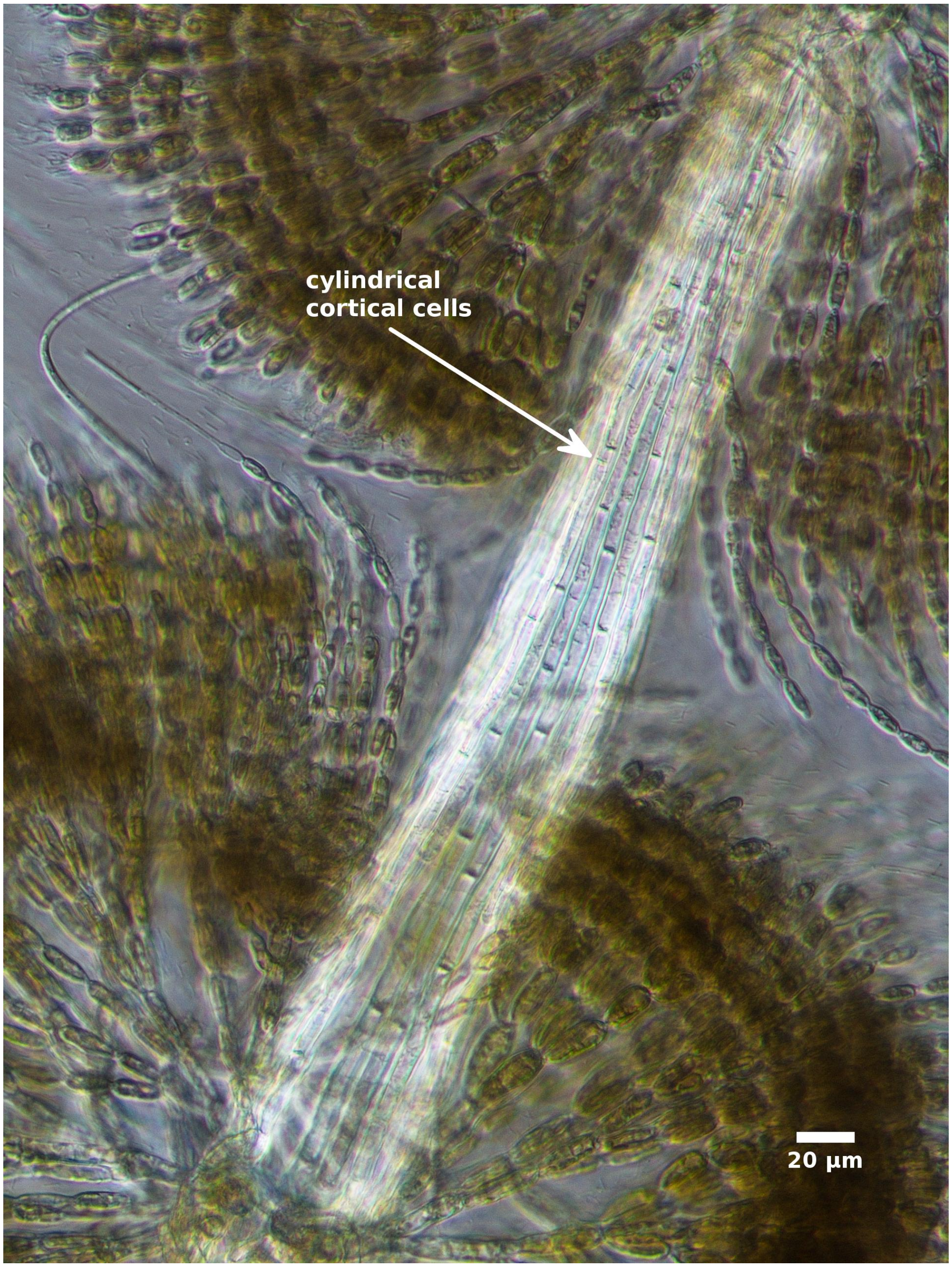


Figure 5.11: *Batrachospermum gelatinosum*? (200x DIC), Independence Lake outlet stream, Mt. Loop Hwy, August 1, 2014.

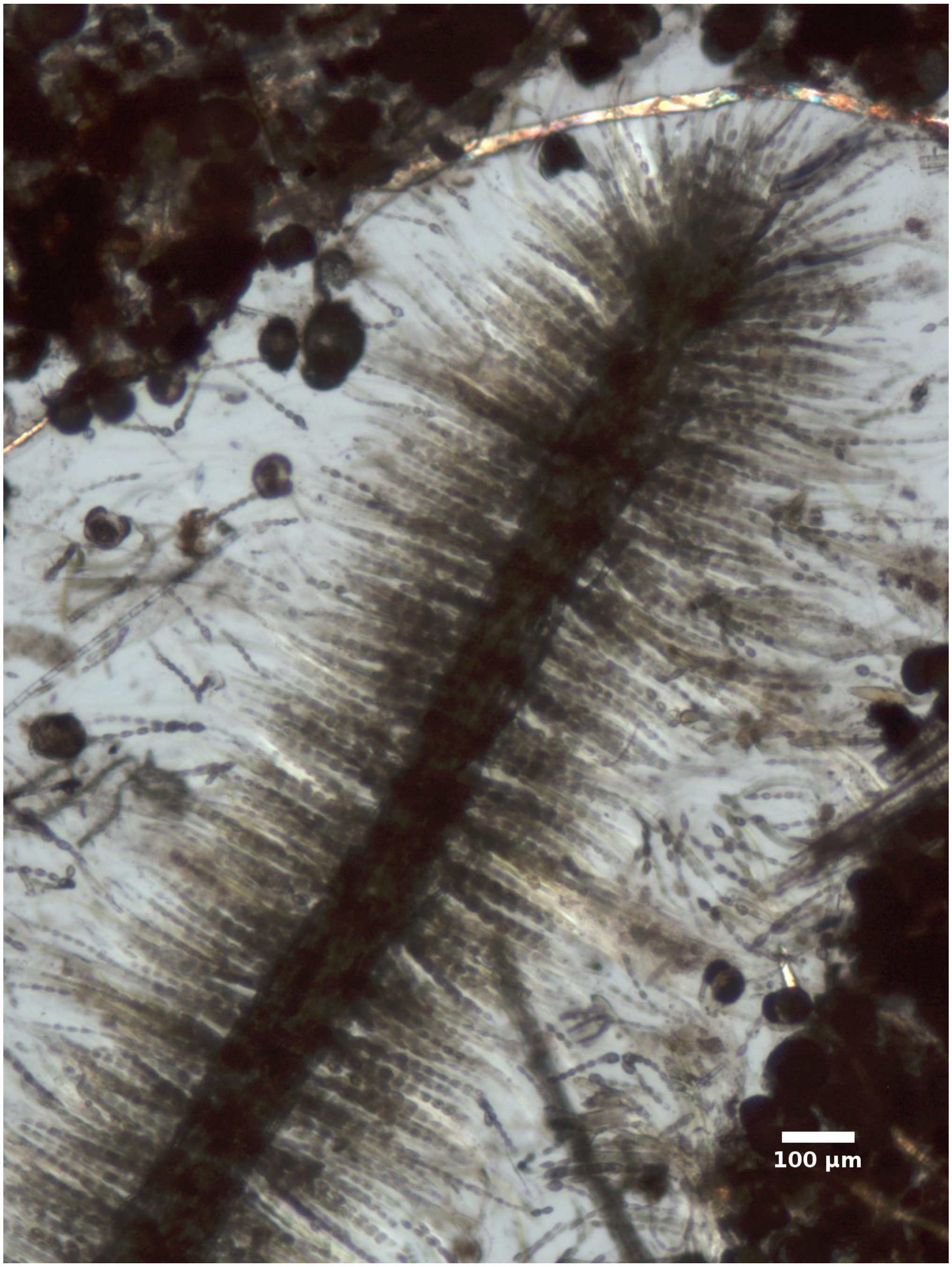


Figure 5.12: *Batrachospermum turfosum*? (40x brightfield), Deer Lake, Alpine Lakes Wilderness Area, July 11, 2013.

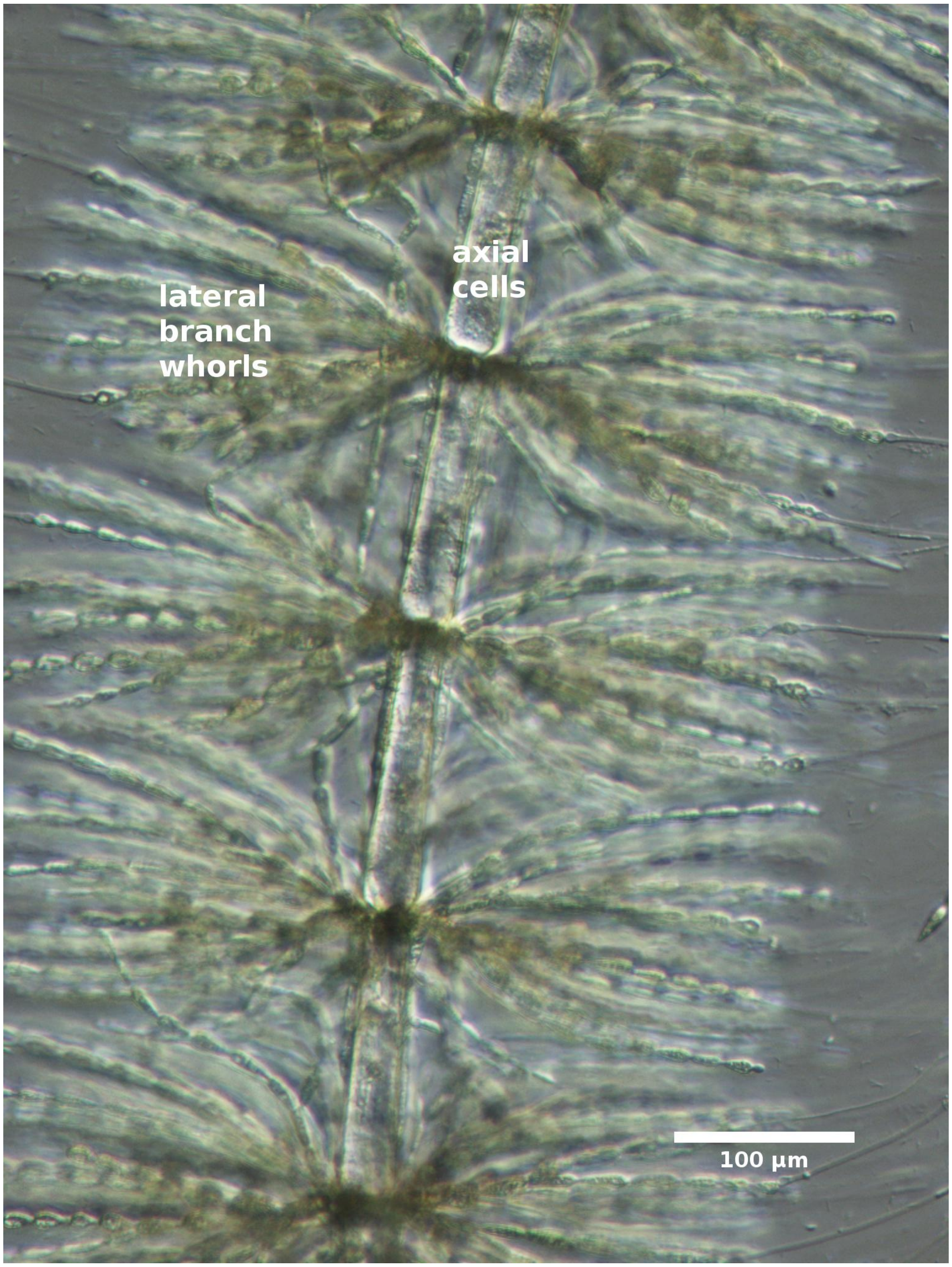


Figure 5.13: *Batrachospermum turfosum*? (100x DIC), Deer Lake, Alpine Lakes Wilderness Area, July 11, 2013.

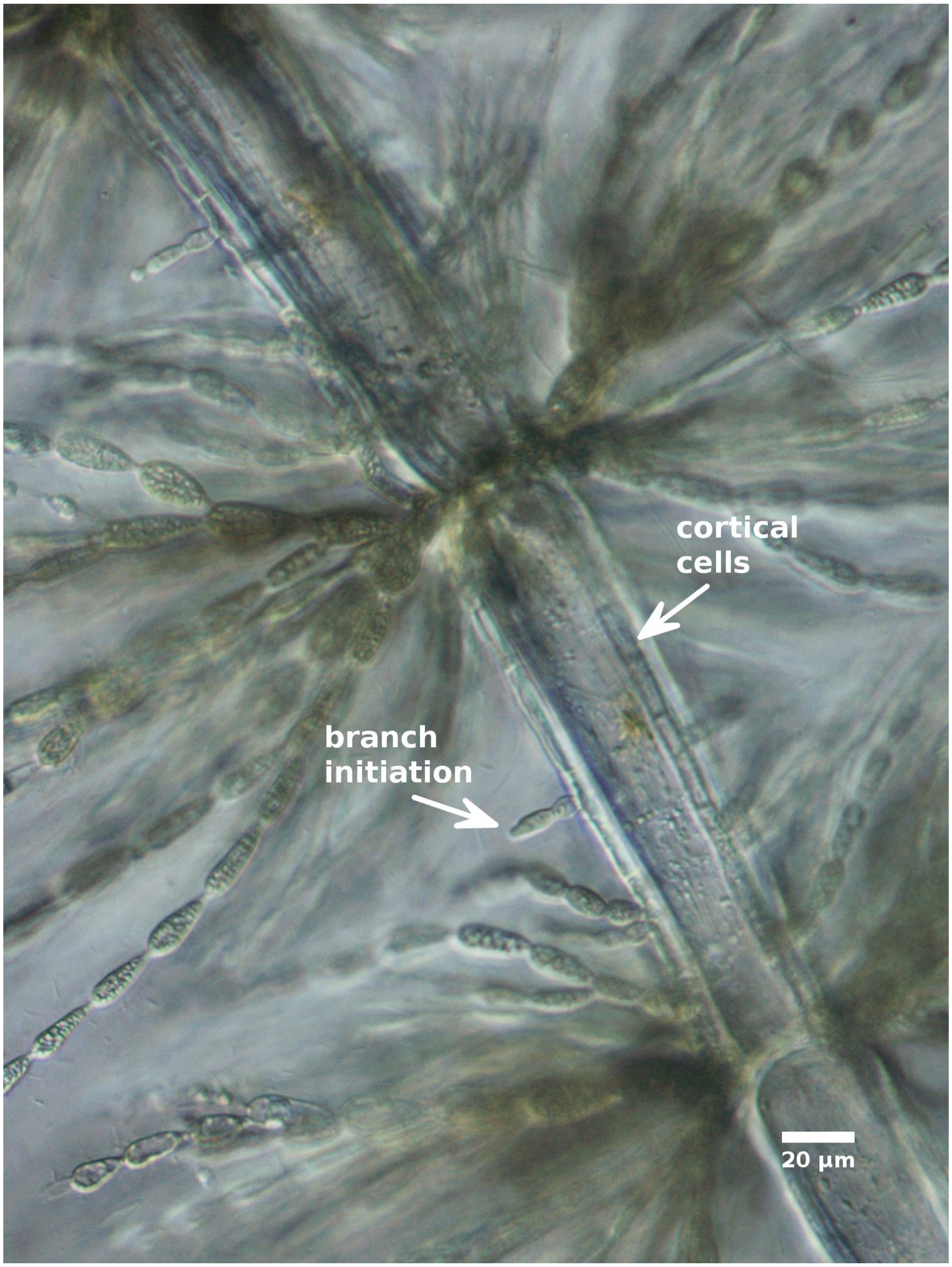


Figure 5.14: *Batrachospermum turfosum*? (200x DIC), Deer Lake, Alpine Lakes Wilderness Area, July 11, 2013.

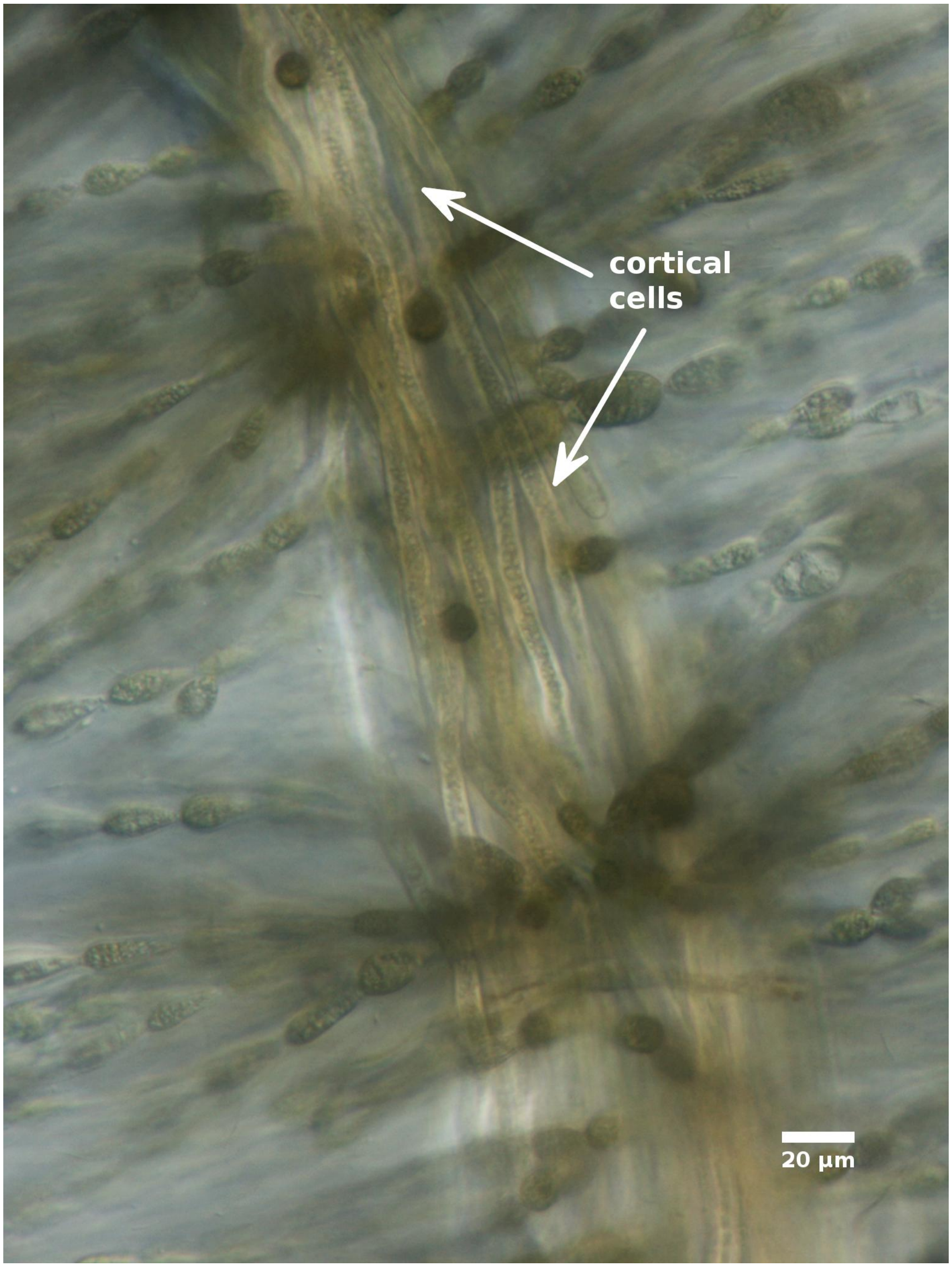


Figure 5.15: *Batrachospermum turfosum*? (200x DIC), Deer Lake, Alpine Lakes Wilderness Area, July 11, 2013.

Chapter 6

Biovolume Calculations

Algal counts can be misleading because the cells vary in size from very tiny (<2 μm diameter) to nearly macroscopic (>1 mm diameter). In addition, some cells are too tiny or indistinct to count accurately, so the algae are counted as colonies. Algal biovolume is often used to adjust for variations in size by estimating the total volume occupied by each type of algae.

Algal biovolume is estimated by collecting cell or colony measurements from a representative number of algae, then the biovolume is estimated using a similar geometric shape. Cell biovolume estimates are included for many of the species in this volume using the equations listed in Table 6.1 (page 776). Examples of each shape and solved biovolume calculations are illustrated in Figures 6.1–6.9.

The biovolume approach used in this manual is based on personal observations and recommendations by EPA (2010), Hillebrand, et al., (1999), Olenina, et al., (2006), and Sun & Liu (2003); all equations in Table 6.1 are from Hillebrand, et al. (1999) or EPA (2010). My approach was to use the simplest geometric approximation because the accuracy that is saved by using a "better" geometric shape is rarely worth the extra time required to make complex measurements.

Where possible, the biovolume summary statistics were based on at least 5–10 cells collected from different sites. Estimates based on fewer than 5 cells were flagged. The biovolume summary statistics (min., med., max.) were generated from original cell measurements, not averages, and were rounded to three significant figures. Colony biovolume estimates were not usually not included because they are too variable.

Shape	**Measurements**†	**Equation**
Sphere: spherical cells; circular in cross-section (Figure 6.1)	width (W)	$\frac{\pi}{6} \times \mathrm{W}^3$
Spheroid: oval or bluntly elliptical cells; circular in cross-section (Figure 6.2)	width (W); length (L)	$\frac{\pi}{6} \times \mathrm{W}^2 \times \mathrm{L}$
Ellipsoid: oval or bluntly elliptical cells; flattened in cross-section (Figure 6.3)	width (W); length (L); depth (D)	$\frac{\pi}{6} \times \mathrm{W} \times \mathrm{L} \times \mathrm{D}$
Cone+half-sphere: club-shaped cells; circular in cross-section (Figure 6.4)	cone width (W); cone length (L)	$\frac{\pi}{12} \times \mathrm{W}^2 \times (\mathrm{L} + \mathrm{W})$
Cylinder: cylindrical cells with flat ends; circular in cross-section (Figure 6.5)	width (W); length (L)	$\frac{\pi}{4} \times \mathrm{W}^2 \times \mathrm{L}$
Cylinder+2 half-spheres: bluntly rounded cylindrical cells; circular in cross-section (Figure 6.6)	cylinder width (W); cylinder length (L)	$\pi \times \mathrm{W}^2 \times \left(\frac{\mathrm{L}}{4} - \frac{\mathrm{W}}{6}\right)$
Fusiform: narrow, acutely pointed cells (may be curved); circular in cross-section (Figure 6.7)	cone width (W); cone length (L)	$\frac{\pi}{6} \times \mathrm{W}^2 \times \frac{\mathrm{L}}{2}$
Elliptical prism: circular or oval cells/colonies; rectangular in cross-section (Figure 6.8)	width (W); length (L); depth (D)	$\frac{\pi}{4} \times \mathrm{W} \times \mathrm{L} \times \mathrm{D}$
Rectangular box: rectangular cells/colonies; rectangular in cross-section (Figure 6.9)	width (W); length (L); depth (D)	$\mathrm{W} \times \mathrm{L} \times \mathrm{D}$

†Width is equivalent to diameter; length is equivalent to height.

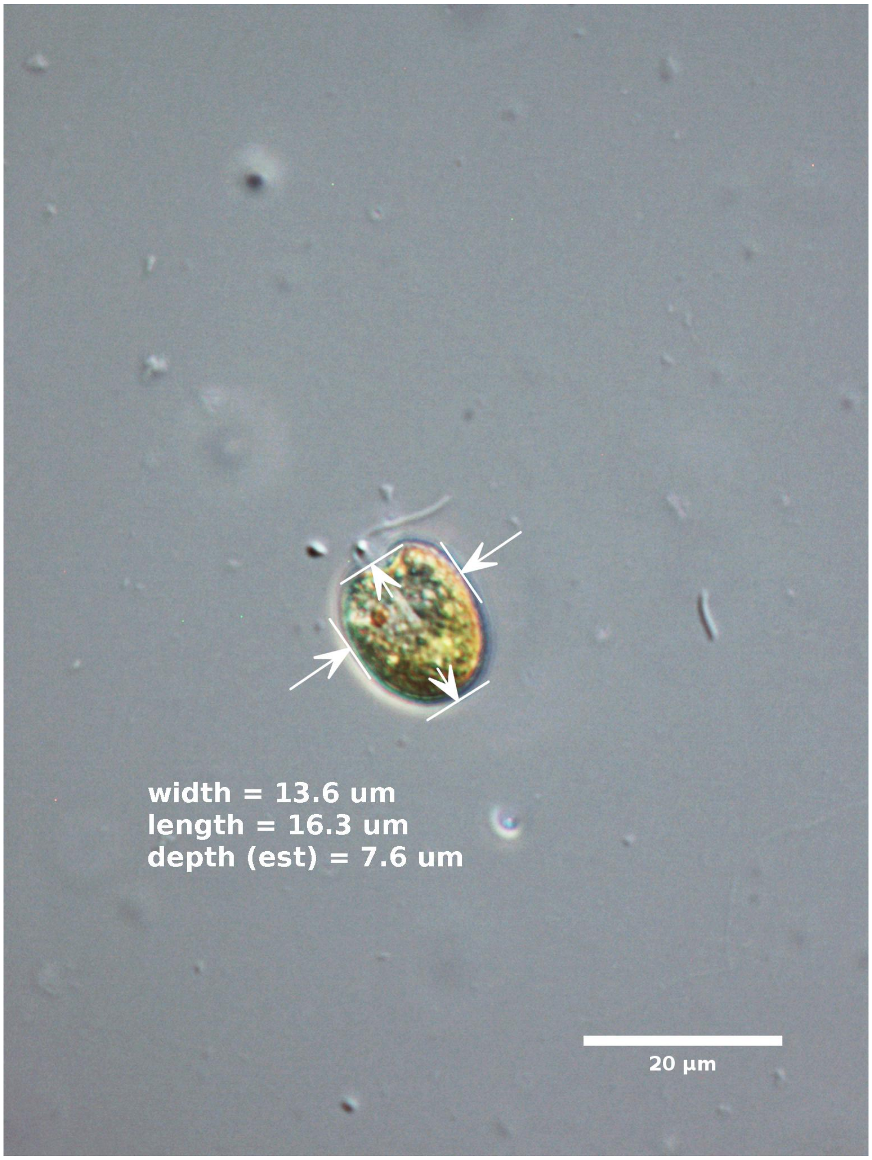
Table 6.1: Biovolume equations (adapted from EPA, 2010; Hillebrand, et al., 1999; Olenina, et al., 2006; Sun & Liu, 2003).

$$
\begin{aligned}
\text{Sphere} &= \frac{\pi}{6} \times \mathrm{W}^3 \\
&= \frac{\pi}{6} \times 150.9^3 = 1,799,146\,\mu\mathrm{m}^3 \\
&= 1,800,000\,\mu\mathrm{m}^3\,(3\,\text{sig. figs})
\end{aligned}
$$

Figure 6.1: Biovolume example - sphere (*Eremosphaera*).

$$\begin{aligned} \text{Spheroid} &= \frac{\pi}{6} \times \mathrm{W}^2 \times \mathrm{L} \\ &= \frac{\pi}{6} \times 13.6^2 \times 19.5 = 1,888\,\mu\mathrm{m}^3 \\ &= 1,890\,\mu\mathrm{m}^3\,(3\,\text{sig. figs}) \end{aligned}$$

Figure 6.2: Biovolume example - spheroid (*Oocystis*).

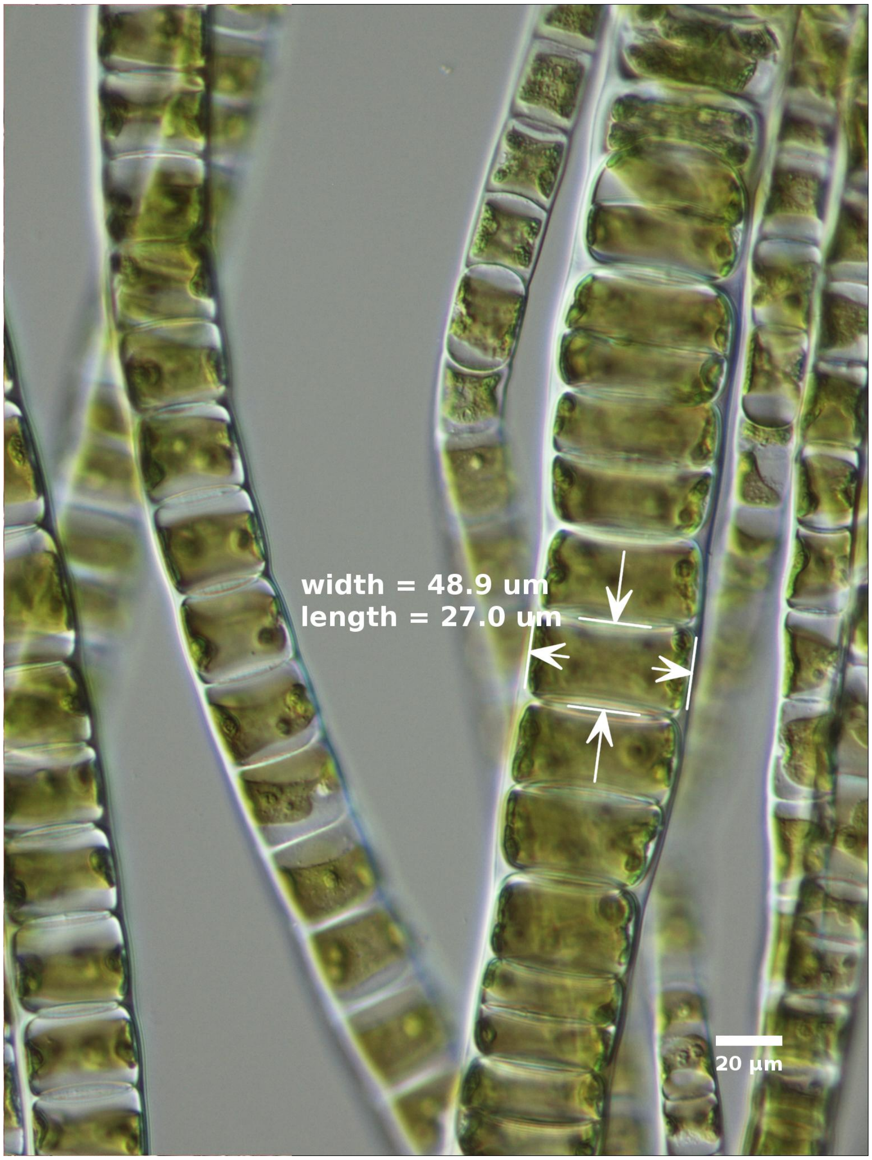


$$\begin{aligned}\text{Ellipsoid} &= \frac{\pi}{6} \times \mathrm{W} \times \mathrm{L} \times \mathrm{D} \\ &= \frac{\pi}{6} \times 13.6 \times 16.3 \times 7.6 = 882\,\mu\mathrm{m}^3\end{aligned}$$

Figure 6.3: Biovolume example - ellipsoid (*Tetraselmis*).

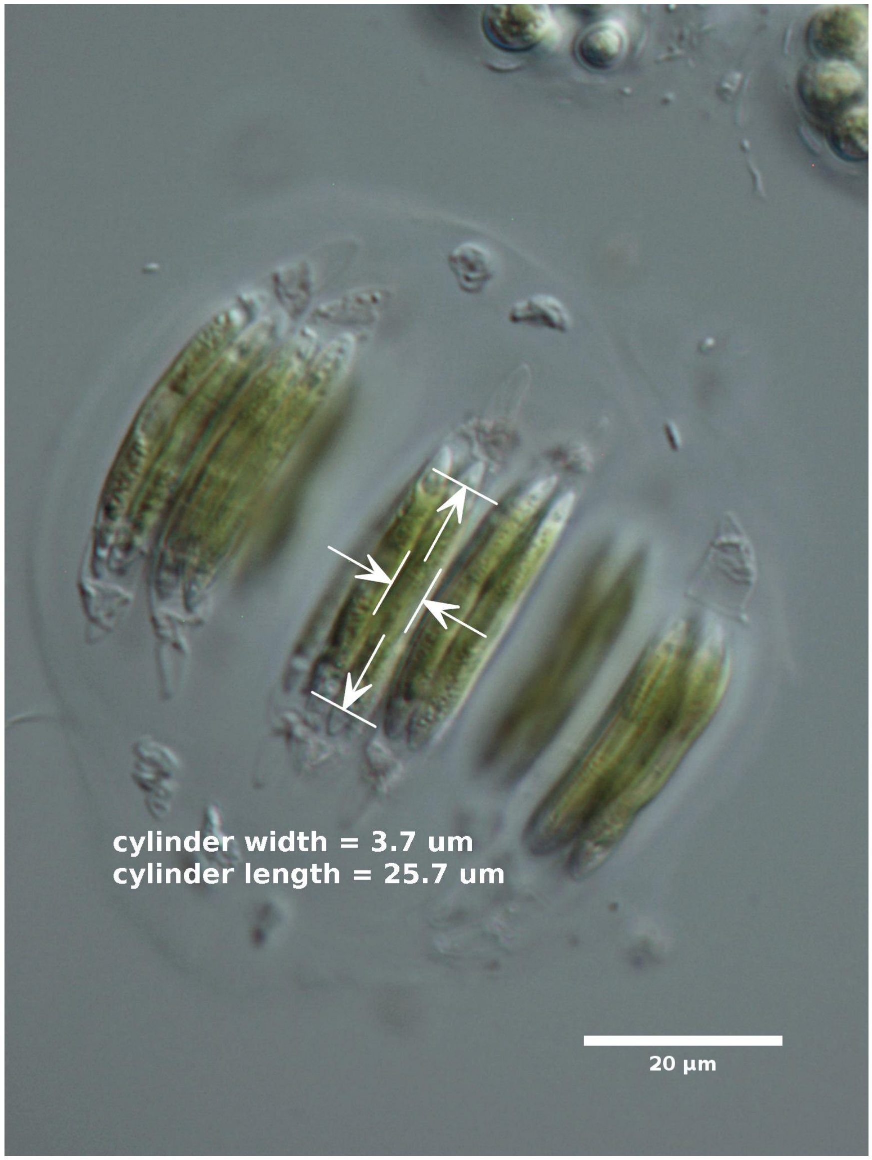
$$\text{cone + half sphere} = \frac{\pi}{12} \times \mathrm{W}^2 \times (\mathrm{L} + \mathrm{W})$$
$$= \frac{\pi}{12} \times 6.3^2 \times 26.4 = 274\,\mu\mathrm{m}^3$$

Figure 6.4: Biovolume example - cone + half sphere (*Paradoxia*).



$$\begin{aligned}\text{Cylinder} &= \frac{\pi}{4} \times \mathrm{W}^2 \times \mathrm{L} \\ &= \frac{\pi}{4} \times 48.9^2 \times 27.0 = 50,707\,\mu\mathrm{m}^3 \\ &= 50,700\,\mu\mathrm{m}^3\,(3\,\text{sig. figs})\end{aligned}$$

Figure 6.5: Biovolume example - cylinder (*Ulothrix*).

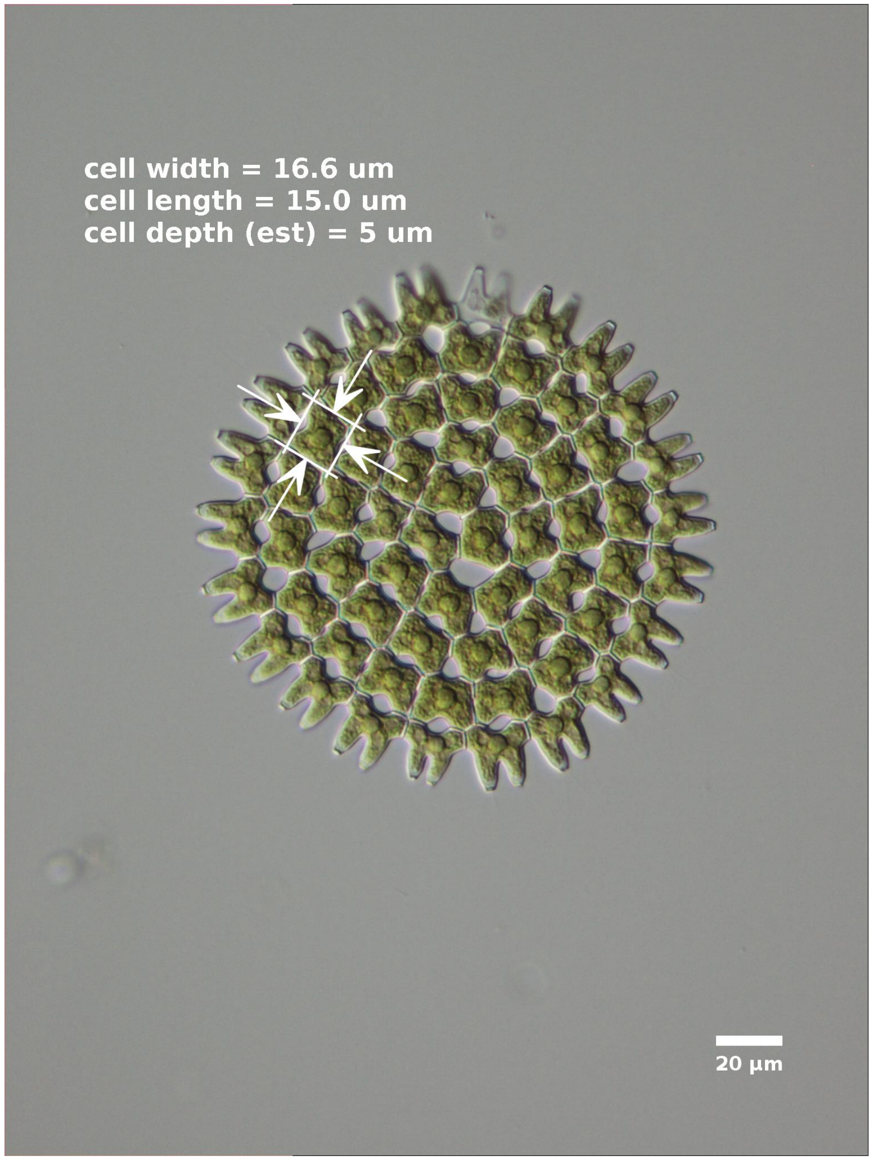


$$\begin{aligned}\text{Cylinder} + 2\,\text{half spheres} &= \pi \times \mathrm{W}^2 \times \left(\frac{\mathrm{L}}{4} - \frac{\mathrm{W}}{6}\right) \\ &= \pi \times 3.7^2 \times \left(\frac{25.7}{4} - \frac{3.7}{6}\right) = 250\,\mu\mathrm{m}^3\end{aligned}$$

Figure 6.6: Biovolume example - cylinder + 2 half-spheres (*Quadrigula*).

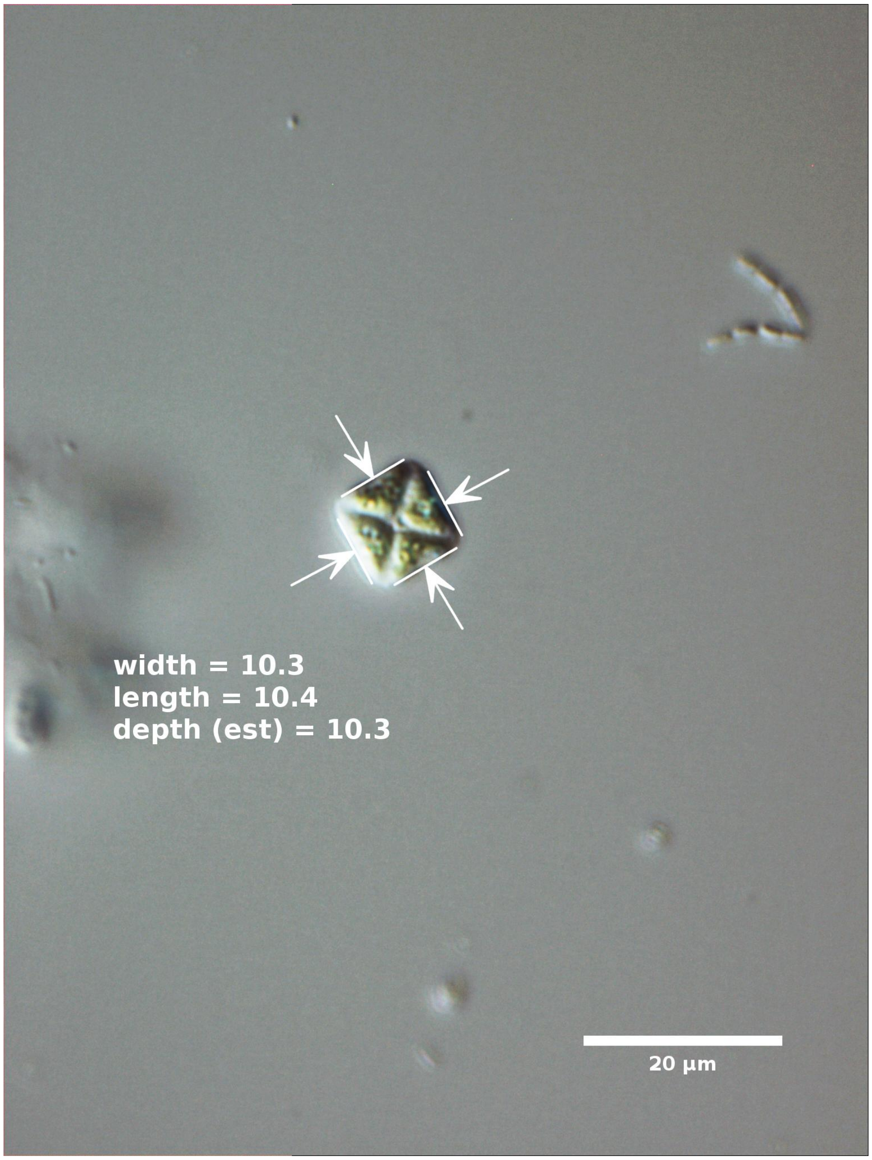
$$\begin{aligned} \text{Fusiform} &= \frac{\pi}{6} \times \mathrm{W}^2 \times \frac{\mathrm{L}}{2} \\ &= \frac{\pi}{6} \times 6.0^2 \times 38.6 = 728\,\mu\mathrm{m}^3 \end{aligned}$$

Figure 6.7: Biovolume example - fusiform (*Ankyra*).



$$
\begin{aligned}
\text{Elliptical prism} &= \frac{\pi}{4} \times \mathrm{W} \times \mathrm{L} \times \mathrm{D} \\
&= \frac{\pi}{4} \times 16.6 \times 15.0 \times 5.0 = 978\,\mu\mathrm{m}^3
\end{aligned}
$$

Figure 6.8: Biovolume example - elliptical prism (*Pediastrum*).



$$
\begin{aligned}
\text{Rectangular box (colony)} &= \mathrm{W} \times \mathrm{L} \times \mathrm{D} \\
&= 10.3 \times 10.4 \times 10.3 = 1,103\,\mu\mathrm{m}^3 \\
&= 1,100\,\mu\mathrm{m}^3\ (\text{three sig. figs})
\end{aligned}
$$

Figure 6.9: Biovolume example - rectangular colony (*Crucigenia*).

Chapter 7

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