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 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

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\(^1\)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](http://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 ([wwwcreativecommons.org](http://wwwcreativecommons.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 smell 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. 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.

3Dichotomous 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 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.

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4The 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

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

*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\textsubscript{2}) as a nitrogen source.\textsuperscript{5} Instead, Chlorophyta need dissolved inorganic nitrogen (DIN)\textsuperscript{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.

\textsuperscript{5}See Freshwater Algae in Northwest Washington, Volume I. Cyanobacteria.

\textsuperscript{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 alloxyanin (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).
# 1.3. INTRODUCTION TO CHLOROPHYTA AND RHODOPHYTA

## Table 1.2: Preliminary Key to the Chlorophyta and Rhodophyta

<table>
<thead>
<tr>
<th>A</th>
<th>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)</th>
<th>Motile Chlorophyta; Table 2.1 (page 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Vegetative cells nonmotile, lacking flagella; solitary or in colonies; ⇒ note that nonmotile cells may form motile reproductive cells (Figure 1.2, page 11)</td>
<td>Solitary/Colonial Chlorophyta; Table 3.1 (page 161)</td>
</tr>
<tr>
<td>C</td>
<td>Cells joined end-to-end in filaments or in pseudofilaments (cells not actually joined end-to-end, but filamentous structure is obvious)</td>
<td>Filamentous Chlorophyta; Table 4.1 (page 532)</td>
</tr>
<tr>
<td>C.1</td>
<td>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)</td>
<td>Filamentous Chlorophyta; Table 4.1 (page 532)</td>
</tr>
<tr>
<td>C.2</td>
<td>Filaments dark blue-green, olive green, purple, or reddish brown; cells stain ⇒ faintly in Lugol’s iodine solution (Figure 1.4, page 13)</td>
<td>Rhodophyta; Table 5.1 (page 755)</td>
</tr>
</tbody>
</table>
Figure 1.1: Typical motile Chlorophyta (*Chlamydomonas*).
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Figure 1.2: Typical nonmotile colonial Chlorophyta (*Pediastrum*).
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Figure 1.3: Typical filamentous Chlorophyta (*Ulothrix*).
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Figure 1.4: Typical filamentous Rhodophyta (*Batrachospermum*).