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 emphasis 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 (John, et al., 2011; Komárek, 2013; Komárek & Anagnostidis, 1998; 2005; Prescott, 1962; Wehr, et al., 2015); and other taxonomic sources listed in Section 6 (page 481). Uncertain identifications were flagged using a “?” following the species name.\(^2\) Unknown taxa that could be separated using

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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.
morphological features were given a unique code (e.g., *Aphanocapsa* sp.1). The terms “sp” and “spp,” 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, *Aphanothece clathrata* West & G. S. West is currently named *Anathece clathrata* (West & G. S. West) Komárek, Kastovsky & Jezberová, but this species was included with other species of *Aphanothece* in Section 2.2 (page 39). More extensive revisions were addressed by including both genus names in the section heading. For example, all of the planktonic species of *Anabaena* have been moved to the genus *Dolichospermum*, so these species were included with the remaining species of *Anabaena* in a combined section containing both *Anabaena* and *Dolichospermum* (Section 3.1, page 198). 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](http://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 lack starch, so they will not stain dark brown or purple in Lugol’s iodine solution; the cells lack organelles like chloroplasts and pyrenoids; and the cells do not have flagella; any motility will be the result of twitching, spiraling, or gliding.

The preliminary key on page 9 separates algae based on 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.

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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 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 6 (page 481).

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 algal taxonomy: Motility is very common in freshwater algae. Some algae are motile by means of flagella and may have a red eyespot that detects light. The presence of these features usually indicates potential motility, even if the cells in your sample are stationary. But flagella and eyespots are not necessary for motility. Many types of Cyanobacteria move by means of gliding, spiraling, or twitching.

Although motility can be a distinctive taxonomic feature, the lack of motility is not as helpful. Motile algae often respond to stress by shedding flagella and becoming nonmotile. Conversely, algae that glide across surfaces may need to settle on the slide before they start moving, and algae that spiral or twitch may become increasingly active as the slide warms and dries under the hot microscope light. And, just to keep things interesting, there are a few common nonmotile algae that have residual eyespots or nonfunctional structures that resemble flagella.

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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 5.
Table 1.1: Summary of the Major Algal Divisions

<table>
<thead>
<tr>
<th>Volume I</th>
<th><strong>Cyanobacteria</strong> (blue-green algae): cells lack organelles like chloroplasts; no flagella (may move by gliding); starch absent.</th>
</tr>
</thead>
</table>
| 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 the Cyanobacteria

Cyanobacteria (blue-green “algae”) are prokaryotes (bacteria), so they lack cell organelles such as chloroplasts, pyrenoids, or a nucleus. They form a diverse group of organisms that are adapted to a wide variety of environments. At any particular time of the year you can probably find Cyanobacteria present in almost any freshwater location; however, they are usually much more diverse and abundant in lakes during late summer and early fall. Cyanobacteria may also be abundant on damp soil, in seeps along trails, on stony surfaces like cliffs surrounding waterfalls, and in hot springs.

Some types of Cyanobacteria can become so abundant in lakes that they form nuisance blooms. These blooms may result in a build-up of sticky scum along shorelines, making it unpleasant to swim or boat, or may otherwise affect the recreational use of the lake. The blooms may cause taste and odor problems if the lake is used as a source of drinking water, or may degrade aquatic habitat, making it difficult for other organisms to survive in the lake. Some Cyanobacteria produce toxins that can harm people, pets, and wildlife (WHO, 1999). In local lakes, Dolichospermum and Microcystis are the most common Cyanobacteria associated with toxic blooms, but many other types of Cyanobacteria have been known to produce toxins. It is important to note that not all blooms contain toxin-forming species, and toxin-forming species may bloom without producing toxins. But blooms that contain toxin-forming taxa are potentially harmful. The Washington State Department of Ecology maintains a web site that describes what to look for and how to report possible harmful Cyanobacteria blooms: [www.ecy.wa.gov/programs/wq/plants/algae/monitoring/index.html](http://www.ecy.wa.gov/programs/wq/plants/algae/monitoring/index.html).

Like most other freshwater algae, Cyanobacteria use chlorophyll $a$ as the primary light gathering pigment. The cells also contain a variety of auxiliary pigments such as phycocyanins (blue pigments) and phycoerythrins (red pigments) to help capture light energy at different wavelengths and low light intensities. Many Cyanobacteria can photosynthesize under aerobic or anaerobic conditions and under low light conditions. This allows the cells to grow in deep, low-oxygen regions of the water column that often have higher concentrations of nutrients compared to water near the surface.

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The energy storage product resulting from photosynthesis is not true starch, but rather a starch-like compound called cyanophycean starch (Van den Hoek et al., 1995). As a result, Cyanobacteria cells will not stain dark purple or brown in the Lugol’s iodine solution.

Slow, gliding motility is fairly common among Cyanobacteria, but active motility is best seen in Arthrosparis/Spirulina (Section 4.1, page 356), Oscillatoria (Section 4.6, page 394), Phormidium (Section 4.7, page 414), and a few other filamentous taxa. Cyanobacteria do not have true flagella, so you will not see rapid tumbling or spiraling movement that is present in flagellated green algae like Chlamydomonas.  

Some Cyanobacteria are solitary in the vegetative state, but most taxa form colonies or trichomes (Figures 1.1–1.8). Cyanobacteria colonies may be spherical or semi-spherical; flat, consisting of a single layer of cells; or amorphous, formed from aggregations of cells held together by mucilage (Figures 1.2–1.4). Filamentous Cyanobacteria may be unbranched or branched (Figures 1.5–1.7), with the branches originating from lateral division of the vegetative cells (true branching) or at a break in the trichome (false-branching). Some filamentous Cyanobacteria form spherical or hemispherical colonies comprised of trichomes radiating from a common center (Figure 1.8). A few types of Cyanobacteria form pseudofilaments in which the cells are arranged end-to-end, but are slightly separated from each other (Figures 1.9–1.10). The cells, colonies, pseudofilaments, and trichomes are often surrounded by mucilage, which can be thick or very thin, firm or soft, colored or clear, and is occasionally difficult to see except under phase contrast or when stained with methylene blue (Figure 1.4).

Some filamentous Cyanobacteria can fix dissolved nitrogen gas (N₂) into usable forms of inorganic nitrogen by converting vegetative cells into specialized cells called heterocysts (Figure 1.11). The enzymes that fix N₂ are inhibited by oxygen. The heterocyst creates a special low oxygen environment inside the cell that allows nitrogen fixation to occur despite high oxygen concentrations in adjacent

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6See Freshwater Algae in Northwest Washington, Volume II. Chlorophyta and Rhodophyta.
7Although solitary vegetative cells are somewhat uncommon, many Cyanobacteria form solitary resting cells near the end of their life cycle (e.g., Aphanizomenon, Section 3.3, page 250), and some Cyanobacteria release individual cells as a means of vegetative reproduction (e.g., Woronichinia; Section 2.18, page 181).
8The term “trichome” is used to describe chains of Cyanobacteria cells; the term “filament” is used to describe the trichome plus any associated mucilage layer or sheath that surrounds the trichome.
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cells and the surrounding water. The process is metabolically costly (it takes energy), so you rarely see heterocysts when dissolved inorganic nitrogen (DIN)\(^9\) concentrations are high. A few species of Cyanobacteria that lack heterocysts are able to fix nitrogen at night when photosynthetic oxygen is not generated, and one marine species has a different kind of specialized cell (diazocyte) that maintains a low oxygen microhabitat for nitrogen fixation (Lee, 2008).

Some heterocyst-forming filamentous Cyanobacteria can also form thick walled resting cells called akinetes that withstand desiccation, extreme temperatures, and other harsh environmental conditions (Figure 1.12). Akinetes are often formed late in the growing season when the Cyanobacteria bloom is beginning to die back (senescence phase). Species separation often requires being able to describe the size, shape, and position of the akinetes relative to heterocysts in the trichome.

As a group, Cyanobacteria are difficult to identify, even at the genus level. The following key will help you get started by separating the taxa using very basic structural features. The chapter keys will help you identify the individual taxa.

Table 1.2: Preliminary Key to the Cyanobacteria

<table>
<thead>
<tr>
<th>A</th>
<th>Vegetative cells solitary, in colonies, or forming pseudofilaments(^\dagger) (Figures 1.1–1.4 and 1.9–1.10)</th>
<th>Solitary and Colonial Cyanobacteria; Table 2.1 (page 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Vegetative cells joined end-to-end in trichomes; filamentous structure should be obvious (Figures 1.5–1.8)</td>
<td>Filamentous Cyanobacteria With Heterocysts; Table 3.1 (page 194)</td>
</tr>
<tr>
<td>B.1</td>
<td>Trichomes can produce heterocysts; akinetes may also be present (Figures 1.11–1.12)</td>
<td>Filamentous Cyanobacteria Without Heterocysts; Table 4.1 (page 354)</td>
</tr>
<tr>
<td>B.2</td>
<td>Trichomes are not capable of producing heterocysts or akinetes (Figure 1.5)</td>
<td></td>
</tr>
</tbody>
</table>

\(^\dagger\)Cells arranged end-to-end, but slightly separated from each other.

\(^9\)DIN = ammonium + nitrite + nitrate
Figure 1.1: Typical solitary Cyanobacteria (*Cyanothece*).
Figure 1.2: Typical colonial Cyanobacteria (*Gomphosphaeria* - spherical colony).
Figure 1.3: Typical colonial Cyanobacteria (*Merismopedia* - flat colony).
Figure 1.4: Typical colonial Cyanobacteria (*Aphanothece* - amorphous colony).
Figure 1.5: Typical filamentous Cyanobacteria (*Oscillatoria* - unbranched).
Figure 1.6: Typical filamentous Cyanobacteria (*Fischerella* - true branching).
Figure 1.7: Typical filamentous Cyanobacteria (*Tolypothrix* - false branching).
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Figure 1.8: Typical filamentous Cyanobacteria (*Gloeotrichia* - filaments joined to form spherical colony).
Figure 1.9: Typical pseudofilamentous Cyanobacteria (*Cyanodictyon*).
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Figure 1.10: Typical pseudofilamentous Cyanobacteria (*Stichosiphon*).
Figure 1.11: Typical heterocyst (*Dolichospermum*).
Figure 1.12: Typical akinete and heterocyst (*Dolichospermum*).