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Cyanobacteria (A.K.A. blue-green algae): WANTED for causing serious damage to turf

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Bottom line: There are three widely shared misconceptions about the small, photosynthetic microbes that produce dark crusts and slime layers on putting green soils and foliage. The first is that all of these organisms are algae, when in fact many of them are cyanobacteria –microscopic organisms that are very different from true algae. The second misconception is that these organisms don't cause direct damage to turf, but are instead only secondary problems that result after turf has been stressed by disease, too much shade, poor drainage, or other factors. But in our diagnostic work we consistently find the opposite to be true. That is, cyanobacteria are frequently the direct cause of turf damage – resulting in mottled, yellowed and thinning turf on many cool season and warm season greens throughout the U.S. Thirdly, it is generally believed that algae or cyanobacteria are only problems in shady, wet areas. But we see many problems from sunny and relatively dry locations as well. From the standpoint of control, preliminary results indicate that although eradication is an unrealistic goal, several weekly treatments with chlorothalonil (Concorde, Daconil, Echo, Manicure, Thalonil) usually improves turfgrass quality by reducing cyanobacteria populations.

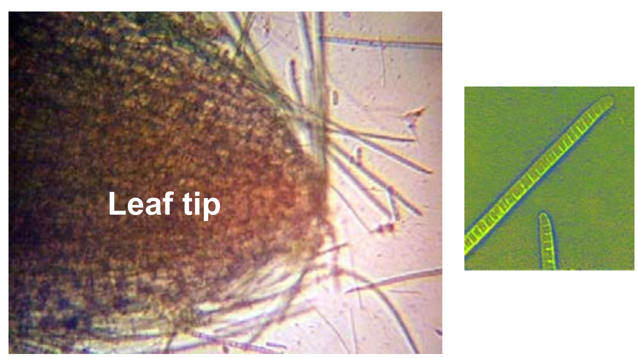
Figure 1. Typical symptoms caused by the cyanobacterium *Oscillatoria* on a bentgrass green.

The symptoms begin slowly, usually at the edges of greens. First, a few small, light green or yellow patches appear. The affected turf gradually begins to thin and decline further as the symptoms progress until large patches of turf are mottled and yellow. All types of greens are affected -- cool season or warm season, overseeded or not. And the lower the greens mowing height, the worse the problem seems to get. As a result, some of the newer bentgrass varieties that are typically mowed at 0.110 inches or less are particularly susceptible to this problem. Fertilizers fail to correct the problem, and applications of fungicides such as azoxystrobin (Heritage), propiconazole (Banner), myclobutanil (Eagle), thiophanate-methyl (Cleary's, Fungo) and others have no effect. When the turf is examined under the microscope (Figure 2), the only microorganism that can be found in any numbers are cyanobacteria – commonly (but incorrectly, as you will see below) known as blue-green algae.

From this description, wouldn't it be safe to conclude that cyanobacteria are the cause of the problem?. We believe that it would, but this is controversial. Because unlike other disease-causing microbes such as fungi, bacteria and viruses, cyanobacteria are not usually regarded as turf pathogens. As a result, very little is known about their interactions with turf.

But we need to know more, because the symptoms described here appear to be increasing in frequency at golf courses all around the country. For this reason, we have devoted this issue of *PACE Insights* to cyanobacteria – their biology, ecology and management on golf course greens.

Figure 2. Trichomes of the cyanobacteria *Oscillatoria*. A poa leaf tip has been colonized by hundreds of thin, hair-like filaments of *Oscillatoria* (left). The black slime layer seen on soils and on turf plants results when hundreds and even thousands of these trichomes aggregate. When two *Oscillatoria* trichomes are magnified (right), their fine structure becomes more apparent.



The odd world of cyanobacteria

Although the term "cyanobacteria" is not a familiar one, these small microbes are involved with many familiar phenomena – both beneficial and damaging – from the earthy odors commonly associated with greenhouses, to nitrogen fixation, to pond scum and black layer, to the color of the Red Sea, to the health food supplement known as spirulina. And that's just the tip of the iceberg for these tiny, but ubiquitous organisms.

Cyanobacteria are ancient, believed to have first appeared on earth almost 3 billion years ago (for comparative purposes, flowering plants first appeared on earth only 90 million years ago). As the first organisms on earth to produce oxygen, cyanobacteria were responsible for creating the oxygenated atmosphere that gave rise to most of the life forms that we know today. It is galling to have to admit that we owe our very existence on Earth to the same organisms that are capable of causing us so much trouble on turf!

Cyanobacteria are a very diverse group. They can range in shape from small, round cells to long, skinny filamentous trichomes (Figure 2), and are found in a vast number of environments -- including soil, fresh and marine water; some even grow on the surface of rocks. They vary in color too – all produce a bluish pigment known as phycocyanin, which along with chlorophyll enables them to capture energy from sunlight through the process of photosynthesis. Some cyanobacteria also contain the red pigment known as phycoerythrin which is responsible for the unusual color of the Red Sea; likewise, the pink color of African flamingos is due to their diet of a cyanobacterial species that produces red pigments.

What makes something a cyanobacterium?

Despite their diversity, cyanobacteria are grouped together because they share some very important characteristics, including:

Photosynthesis: All cyanobacteria are capable of photosynthesis – the ability to use sunlight, water and carbon dioxide to produce oxygen and the carbohydrates that serve as their source of food. Although a few cyanobacteria are known to grow in the dark, the large majority of species rely on light – an important characteristic that will come into play in our discussion of cyanobacterial turf damage below.

Survival in harsh environments: Cyanobacteria flourish under a wide range of temperatures and humidities. Some live in hot springs where temperatures frequently reach 125°F, while others colonize frigid Antarctic lakes. Although some cyanobacteria are found in aquatic environments, many live under relatively dry conditions – on rocks, sand and plant roots, for example.

Structure: All cyanobacteria are small (cells are 0.5 – 50 micrometers [2/100,000 – 2/1,000 inch] wide) microorganisms with a relatively simple structure. Unlike the complex cells of plants and animals, cyanobacterial cells are known as prokaryotic – that is, they have no nuclei, mitochondria or chloroplasts. Although individual cyanobacteria are much too small to see without a high power microscope, they can aggregate together to form layers of dark, slimy material that are clearly visible with the naked eye (Figure 3).

Figure 3. The search for light drives the cyanobacterium, *Oscillatoria*, to the tips of turf leaves after they are kept in the dark. The dark, slimy cyanobacterial coating seen at the tip of the turf plant below is not visible during the day because cyanobacteria reside at the base of the plant during daylight hours. However, if the turf is kept in the dark for 12 or more hours (as this sample was), the cyanobacteria will slowly move to the top of the plant in search of light.

Movement: Many cyanobacteria are able to move by "gliding", even though there are no obvious organs responsible for movement. It is believed that this movement is aided by the secretion of mucilaginous (slimy) materials that reduce friction. *Oscillatoria*, a cyanobacterium that is frequently associated with turf, has been clocked at speeds of 11 micrometers per second, which is equivalent to 1.6 inches per hour (Staley, 1986). An *Oscillatoria* strain that we have isolated from bentgrass in California is not quite as speedy, but slithers along at a respectable 1.7 micrometers per second (1/4 inch per hour).

Symbiotic relationships: Cyanobacteria frequently occur in nature in association with other, unrelated organisms such as algae, mosses (Figure 4), ferns, cycads, flowering plants, fungi, sponges, shrimps and even mammals. These associations, which benefit both of the organisms involved, are termed "symbiotic". Lichens are the result of symbiosis between cyanobacteria and certain fungi, while nitrogen fixation occurs when cyanobacteria live as symbionts within the roots of plants.

Cyanobacteria and algae: worlds apart

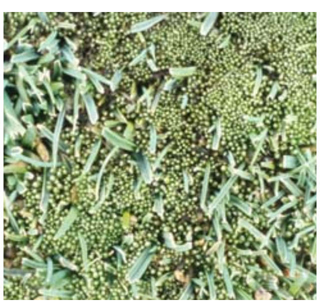
Cyanobacteria are frequently (sometimes even in older PACE publications!) called "algae", a term that persists from the days before we understood just how different these two groups of organisms really are.

But the organisms that cause us problems on golf courses, such as *Oscillatoria, Nostoc* and *Anacystis*, are identified by scientists as cyanobacteria, and not as algae. When these organisms were first studied over 200 years ago, the superficial similarities between cyanobacteria and "true" algae – primarily the ability of both to photosynthesize – led scientists to classify them together. It wasn't until the 1970s, when biologists began using the electron microscope (which can magnify objects 10,000 fold and higher), that the differences became clear. For while algae are very complex cells that contain nuclei, mitochondria, chloroplasts, endoplasmic reticulum and many other organelles, cyanobacteria are comparatively simple – with none of these sub-cellular organelles, and with very different chemical and biochemical pathways. While true algae such as *Chlamydomonas* are closely related to green plants, cyanobacteria are more closely related to other bacteria such as *E. coli* and *Xanthomonas*.

Why is the distinction between algae and cyanobacteria so important? In addition to the benefits of calling things by their correct names, the answer is that the more we know about the behavior, biology and survival needs of cyanobacteria – or of any pest for that matter -- the better we will be able to develop management strategies for them. If we continue to call these organisms "algae", it will help to bolster the mistaken belief that they can be managed the way other true algae are managed, when this may in fact not be the case – as we will discuss below.

Despite all of this, use of the term "blue-green algae" to refer to organisms that are actually cyanobacteria still persists – on pesticide labels, in trade journals, and even in some technical publications. Old habits die hard, and we have been calling these organisms algae for a long time now. This type of transition period can be confusing, though, so if you have any doubts about what type of organism a publication is referring to, please give us a call.

Figure 4. Bent/poa green heavily infested with silvery thread moss (*Bryum argenteum*) (left). In the right-hand photo, the same area is shown, following incubation in the dark for 12 hours. The dark material is a filamentous cyanobacterium that occurs in association with this moss.




Cyanobacteria: are they "true" turf pathogens?

Most plant pathology textbooks ignore algae and/or cyanobacteria in their discussion of turfgrass diseases. If they are mentioned at all, it is in the context of black layer or surface sealing of greens – phenomena in which cyanobacteria are also involved (see May, 2000 *PACE Insights*).

In contrast to these widely held assumptions, we believe that cyanobacteria are true turf pathogens, and should be viewed in the same way as other diseases such as brown patch, Pythium or summer patch. The evidence below, much of it related to *Oscillatoria* (the cyanobacterium most commonly associated with turf damage) provides some support for this conclusion:

Cyanobacteria are frequently associated with damaged turf: When a cup cutter sample is taken from greens that suffer from the symptoms illustrated in Figure 1, fungal pathogens of turfgrass are typically not present. However, when the sample is incubated in the lab overnight, the damaged turf is covered with a dark, slimy coating the next morning (Figure 3) that is visible to the naked eye. When examined under the microscope, the black slime is found to be made up of **trichomes** (long chains of cells; see Figure 2) of the cyanobacterium *Oscillatoria*. When healthy turf is incubated under similar conditions, the cyanobacterial black slime coating does not form.

Cyanobacteria produce toxins that damage plants: In addition to the high "yuchh factor" associated with the slimy presence of cyanobacteria, these organisms are also capable of producing toxins that can damage plants. Chauhan et. al. (1992) reported the discovery of an antibiotic produced by *Oscillatoria* that attacks photosystem II (PS II) in intact plant cells (PS II is a part of the process of photosynthesis, and is also the site of attack by the herbicide atrazine).

Oscillatoria may cause additional problems for turfgrass foliage by robbing it of an important nutrient -- iron. Brown and Trick (1992) found that *Oscillatoria tenuis* manufactures two siderophores (molecules designed to capture iron from the environment [Misaghi et. al., 1982 n). It is therefore likely that cyanobacteria are scavenging essential iron from turf leaves, resulting in chlorotic plants and impaired photosynthesis.

Control of cyanobacteria results in turf recovery: When bentgrass greens infested with the cyanobacterium *Oscillatoria* were treated with three weekly applications of chlorothalonil (Daconil, Concorde, Echo, Manicure, Thalonil) at the rate labeled for control or algae, the mottled, chlorotic symptoms disappeared, and the *Oscillatoria* was eliminated. In adjacent non-treated strips of turf, however, turf damage was still occurring, and *Oscillatoria* was still present.

Low mown turf and/or shade: inviting trouble

For cyanobacterial toxins to produce the maximum injury to the plant, they need to get inside the plant. In the case of turfgrass, the easiest point of entry is through cut leaf tips. Why is this so important? We believe that the slow movement of cyanobacteria such as *Oscillatoria,* combined with the production of toxins that can enter the plant primarily through the leaf tip, explains why this cyanobacterium is primarily a problem of low mown turf. Think about it. At ¼ inch per hour, it will take *Oscillatoria* more than 12 hours to climb from beneath the thatch to reach the top of a 3 inch tall turf plant – but it will probably never get there. Why? Because cyanobacteria will only move upwards towards the top of the plant if it is dim or dark outside. As soon as the sun comes up, they will turn around and hightail it back to the soil. In contrast, for lower mown turf, *Oscillatoria* can reach the leaf tip in a few hours, secrete its toxins, and return towards the soil before it gets too sunny. It is for this reason that some of the newer varieties of bentgrass and bermudagrass, which have been bred to tolerate extremely low mowing heights, are also more susceptible to cyanobacterial attack. The ability of cyanobacteria to move as the day progresses, so that they are always receiving the dim light that they prefer explains why even turf in very sunny locations can be susceptible to cyanobacterial attack.

However, the preference of cyanobacteria for dim light explains why they can cause even more damage to turf in shady areas. In these locations, the cyanobacteria will remain on the foliage for longer periods, because the sun rarely gets too intense to chase them back to the soil. And the longer they remain on the foliage, the more toxins they produce, and the more damage they will cause.

"Hiding in plain sight"

If cyanobacteria cause at least some of their damage by climbing up to the cut surface of turf leaves and injecting toxins, why don't we ever see them there? Why is it necessary to incubate turf in the dark before we can see the blue-black, slimy layers of cyanobacteria on turf, as in Figure 3?

The answer lies in the requirement that cyanobacteria have for low intensity light in order to conduct photosynthesis. During the late afternoon and nighttime, when light intensity gets progressively lower, they will move up the plant to seek light. However, after the sun rises and sunlight becomes more intense, they move down the plant and towards the soil where they are difficult to detect.

Thus, one of the most diagnostic symptoms for *Oscillatoria* (accumulation of the cyanobacteria at the leaf tips) is rarely seen by turf managers -- during the daytime, the cyanobacterium is shading itself from the sunlight and is present primarily near the soil surface. It is only when the turf is incubated in the dark for at least 12 hours that the signs of an *Oscillatoria* infestation become obvious.

Managing cyanobacteria

Because they are so ubiquitous in the natural environment, it is probably unrealistic to hope that cyanobacteria can be permanently eliminated from putting greens. However, there are some management practices that have shown consistent performance on both warm season and cool season putting greens across the country.

1. Be able to identify damage from cyanobacteria in the early stages of infestation – as with all pathogens, it is always easier to manage **before** turf is seriously damaged and before the pathogen gets a foothold. If the turf suffers from the symptoms illustrated in Figure 1 (the appearance of small, light green or yellow patches, usually at the edge of the green, followed by turf thinning and overall decline, as the symptoms progress towards the center of the green), take a cup cutter sample from a damaged area. Place the plug in a zip-lok bag, and seal the bag completely. Then put the sealed bag in a very dark location for 12-36 hours (a desk drawer or closet works well – but don't forget where you put it!). If cyanobacteria are the culprit, the turf will be coated with a black slimy layer (Figure 3) after their 12-36 hour incubation.
2. If you have the ability to increase your mowing height, do so. This will make it more difficult for cyanobacteria to reach the top of turf plants, where they appear to cause their most severe damage. In addition, turf will be less stressed, and therefore better able to fend off some damage.
3. If the problem is serious, consider 3 weekly applications of chlorothalonil, as described above. Most chlorothalonil based products are labeled for control of algae, though the label language is rarely updated to include the word "cyanobacteria".

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