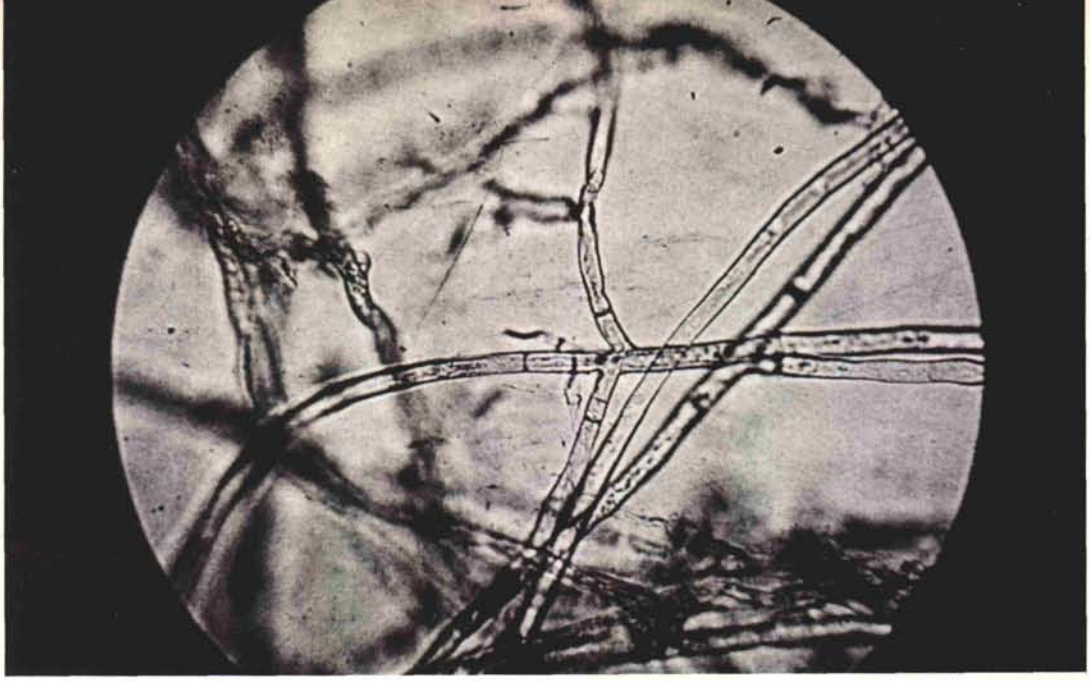


Fig. 1. **Rhizoctonia.** Hyphae, showing typical right-angle branching and crosswalls.

A Complete Disease Prevention and Control Program

by **JAMES W. TIMMERMAN,** USGA Green Section, Agronomist

Today more than ever, the golf course superintendent must understand the complete picture of disease and its relationship to plants if more effective control is to be achieved. Golfers' demands for the best playing conditions have forced those charged with course conditions to use higher rates of fertilizers, water more frequently, and mow closer and more often. Heavy traffic has led to compacted soils and added wear, which puts more stress on turf.

These conditions have resulted in an ideal environment for greater disease invasion. We must be completely prepared to meet this greater invasion in our efforts to achieve top conditions.

A complete disease prevention and control program can be grouped into five broad categories. These are:

- Nutrient relationship to disease.
- Visual recognition of turf disease characteristics.
- An understanding of fungicides and their use.
- An understanding of what disease is and how it occurs.
- A microscopic recognition of the disease-causing organisms.

Most of us are quite familiar with the first three categories. For example, we recognize that over-fertilization leads to more disease, and that brown patch disease is recognized by a characteristic smoke ring. However, it is in the last two categories that we usually find our knowledge lacking.

No longer can we get by just knowing disease is with us by noticing thread-like structures on the grass in the morning. The demands for quality turf compel us to know that these thread-like structures are called mycelium; why and how it got there; and how to recognize it under a microscope before it ever shows up on turf.

We must learn life and disease cycles of the causal organisms. We must know the terms related to disease so any material read or heard on disease is better understood. Becoming more familiar with disease and how it occurs, and being able to recognize the causal organisms under a microscope will allow us to become our own plant pathologist to a certain degree.

With this added knowledge, we can run ex-

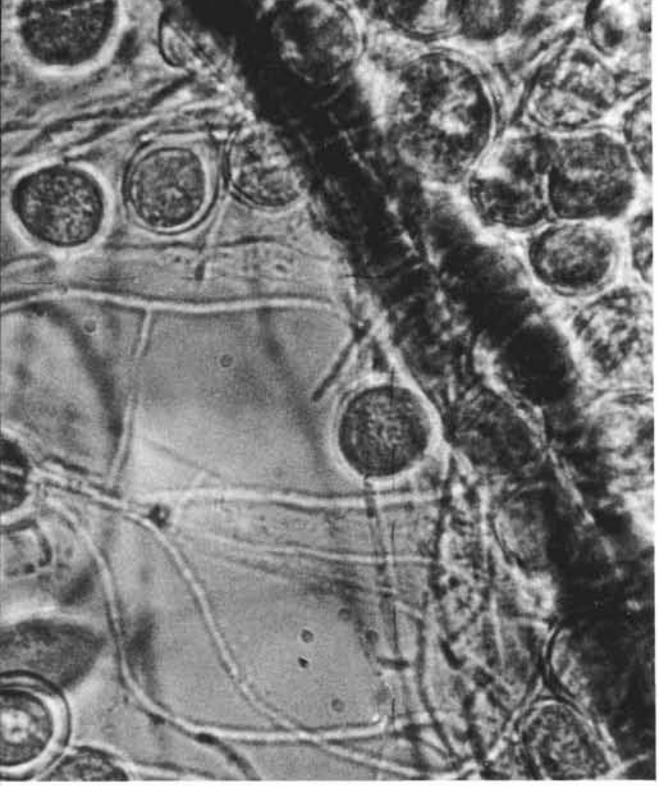


Fig. 2. **Pythium.** Hyphae without crosswalls. Spherical structures are called sporangia, in which nonsexual spores are produced.

ploratory tests before disease becomes prevalent. We can define quicker and to a more exact degree any disease outbreaks. Combining this information about the disease-causing organisms present in our soils and turf with our already existing knowledge of disease, we can plan prevention and control programs more precisely. A microscope should become part of every superintendent's equipment.

Plant Disease and Its Cause

For any variety of plant there is an optimum set of environmental conditions for its growth and development. In nature, however, these optimum conditions seldom exist, and plants are subjected to fluctuation of the environment. When one or more factors in the environment become unfavorable, the development of the plant is altered in some way and, in comparison to plants growing under optimum conditions, it appears to have abnormal characteristics.

Diseased plants, therefore, are distinguished by changes in their morphological and physiological processes to a point where signs of such effects are noticeable. These obvious external signs, which are characteristic of a disease, are known as symptoms. Whether all deviation from the normal in structure and function is considered a disease depends upon our definition of "normal" for a particular plant.

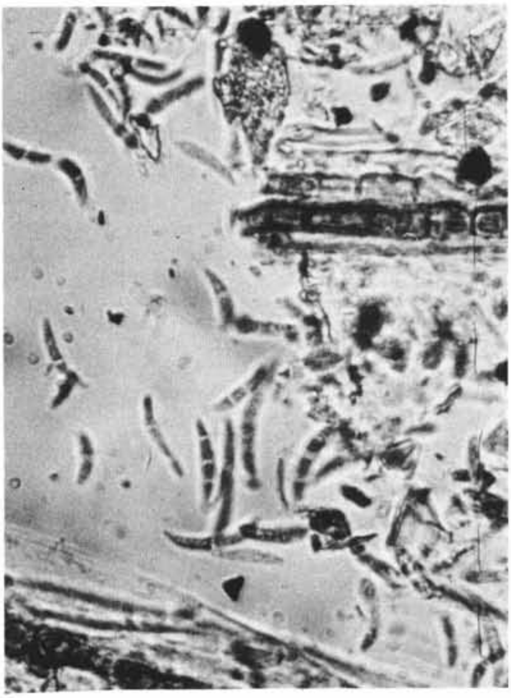
For our complete understanding of disease we must know what constitutes the cause of disease. The causes of disease are broken down into two groups—unfavorable environmental conditions and parasites. Adverse weather, air pollution and nutrient imbalance are examples of unfavorable environment and are easy to comprehend as a cause of disease when they interrupt plant processes.

However, when a parasitic micro-organism enters into the complex, as is the case with most turf diseases, the common tendency is to refer to the microbe as the cause of the disease. While this is true to a large extent, we must remember that variation in the environment is sometimes necessary to cause a plant to become susceptible to a parasite. Furthermore, the micro-organisms will require a certain range of favorable conditions to infect the plant.

Moreover, once a parasite has infected a plant, the interaction of plant and parasite which results in a disease is also subject to environmental influences which determine whether disease develops at all, at what rate, and to what degree.

Strictly speaking, it is not correct to refer to a given micro-organism as the sole cause of disease. Rather, it would be more correct to consider the microbe as the causal organism which is part of the causal complex.

Fig. 3. **Fusarium.** Nonsexual spores (conidia); sickle-shaped with 0 to 3 crosswalls.



Life and Disease Cycles

A complete disease program depends ultimately upon knowledge of parasite life and disease cycles and their behavior in nature. The control of parasitic agents is greatly complicated by their diversity and variability. Many have life cycles which involve more than one host plant. Others can live indefinitely as saprophytes, attacking living hosts only when the conditions are favorable. Some have spore stages specialized for dissemination in water, in air or in the soil, while others produce resting spores that can survive for many years under the proper conditions.

The chain of events in disease development is referred to as the disease cycle. When a parasite is involved, the disease cycle is intimately associated with the organism and is distinct from the life cycle, although part of it. The life cycle of an organism is composed of an overwintering (or oversummering) stage and the disease cycle.

The overwintering stage may be as dormant spores, sclerotia, hyphae or other organs; on other host plants; in debris of infected plants of the previous season; in or on seeds of the host plant; or in various other forms. Whatever the form, it becomes the source of inoculation. The disease cycle starts with inoculation, and is composed of four parts as follows:

Inoculation—refers to the set of conditions whereby the parasite and host plant come into contact with each other. This can be accomplished by any means that disseminate organs which can infect plants.

Penetration—refers to the initial invasion, either passive or active, of the host plant by the pathogen.

Infection—implies the establishment and development of a pathogen inside the host plant before any symptoms of the disease are noticeable.

Incubation—is the chain of events which occur between the time of infection and the complete expression of the disease.

Throughout the course of the disease cycle, reproductive organs are produced which can start the whole cycle over again. This second crop of infectious organs is referred to as the source of secondary inoculation.

A thorough understanding of life and disease cycles of plant parasites can easily lead to more effective control. It may be easier to control turf parasites before they come into contact with the plant, or once in contact, before disease expresses itself. Therefore, these should be studied carefully.

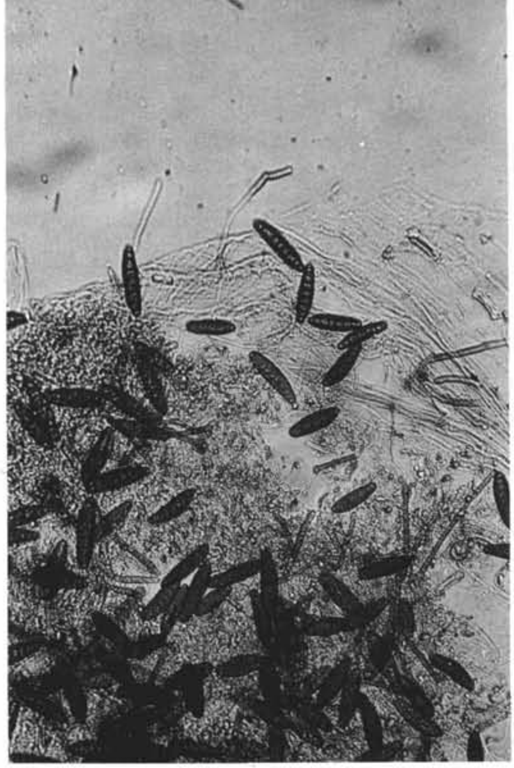


Fig. 4. **Helminthosporium.** Nonsexual spores (conidia); cylindrical-shaped with 1 to 10 crosswalls.

The Fungi and Turf Disease

The fungi are the group of microorganisms that cause the major turf diseases. Fortunately, only a small number of these are of particular importance to us. While it is possible for bacteria, viruses, and nematodes to infect turfgrasses, they have, up to this point, been of minor consequence.

The fungi are living organisms and therefore require a source of food. Since they lack chlorophyll, they cannot produce their own food (like plants do) and must obtain food from an external source. The fungi that attack living plants are called parasites and are grouped into two categories—obligate parasites (those which grow only on living host plants), and facultative parasites (those which grow on living plants but at times do grow on non-living plants). These are distinguished from saprophytic fungi which live only on non-living organic matter.

Characteristically, the fungi are composed of microscopic thread-like filaments (Fig. 1). Each individual filament is called a hypha (plural, hyphae), and the hyphae collectively are called mycelium. It is the mycelium that is sometimes seen on grass. The hyphae can have cross-walls (Fig. 1) or can be without cross-walls (Fig. 2). It can be colorless, brightly colored, dingy brown or black. Essentially, the filaments resemble the cells of other plants; that is, they are surrounded by a thin membraneous cell wall and are composed of protoplasm.

Fungi, like most biological entities, reproduce. They do this by forming microscopic bodies called spores. The spores of a fungus are similar to seeds of green plants and are designed for dissemination and reproduction. A spore, however, differs from a seed in that it contains no embryo. Spores may consist of a single cell or be a compound structure of several cells, each consisting of a mass of protoplasm surrounded by a firm containing wall.

Spores have many distinguishing characteristics. They vary greatly in size, shape, color and the ability to survive heat and cold, to name just a few. A small number can move under their own power, but the great majority are disseminated by wind or water.

Fungus spores are formed sexually and vegetatively (non-sexually); that is, they develop at the ends of hyphae by constriction of the walls. These vegetative spores can occur randomly over the surface, be dispersed throughout the mycelium, or be enclosed in a fruiting body. A fruiting body develops from existing hyphae, but differs from ordinary hyphae by having a distinct shape and color. Fruiting bodies serve as a useful means of identifying one fungus specie from another.

The non-sexual spores are typical of the early stages of disease, while the sexual spores occur later on in the disease cycle, usually during the period of winter dormancy. Non-sexual spores are produced in indefinite numbers, while sexual spores are produced in definite numbers.

Before discussing the classification of the various fungi it is necessary to define a number of terms used in describing spores and fruiting bodies. This list by no means includes all the terms applied to the fungi, but it does define and describe most of the structures encountered when studying turf diseases under a microscope.

ACERVULUS pl. acervuli—a mass of hyphae that produces a cushion-like mass of conidiophores, and is sometimes accompanied by stiff, sterile hyphae known as setae. The mass of hyphae (or stroma) forms just below and then ruptures the cuticle or epidermis of the leaf.

APOTHECIUM pl. apothecia—a cup-shaped or saucer-shaped fruiting body, inside which are numerous, closely packed, cylindrical or club-shaped asci.

ASCUS pl. asci—a structure found only in the Ascomycetes. It is a thin-walled sac containing spores. The number of spores in each ascus is usually eight, but in certain cases is some multiple of two. The ascus can be rounded, with the spores packed tightly inside or it can be cylindrical or club-shaped with the spores arranged in one or two rows.

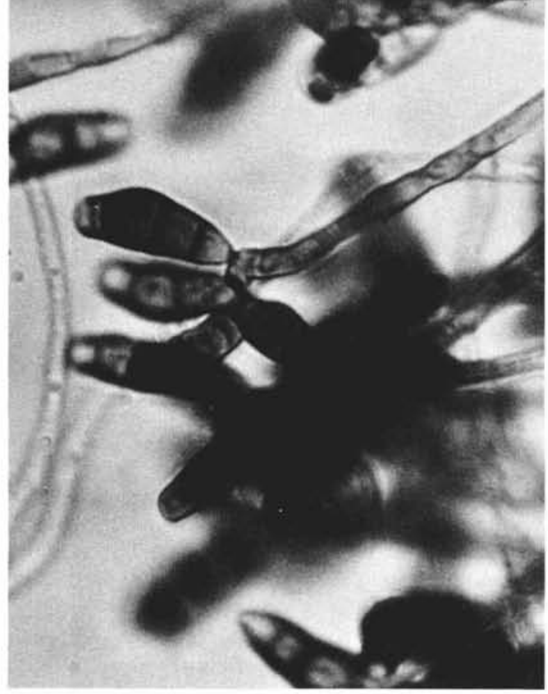


Fig. 5. **Curvularia.** Nonsexual spores (conidia) borne on tip of specialized hyphae called conidiophore. Spores distinctly bent with one of the center cells larger than others, 3 to 4 crosswalls.

BASIDIUM pl. basidia—an organ characteristic of the class Basidomycetes. It typically is a club-shaped or tubular organ bearing four tiny projections (sterigmata) on each of which a spore is borne.

CONIDIOPHORE (Fig. 5)—a specialized hyphae bearing conidia, either at the tip or rarely along its length. In some genera the conidiophore terminates in a series of branches on which conidia are formed.

CONIDIUM pl. conidia (Fig. 5)—a term applied to a variety of non-sexual spores. The spores are cut off successively from a phailide, which is a highly specialized terminal cell of a conidiophore, or more rarely, the conidiophore itself, more or less flask-shaped, which continually elongates, but as the conidia are cut off it remains sensibly constant.

PERITHECIUM pl. perithecia—a fruiting body found in the majority of Ascomycetes, and consisting of a receptacle in which asci are produced. The perithecium may be roughly spherical and break up at maturity to release the spores, or more usually, it is flask-shaped and liberates the spores through the neck.

PYCNIDIUM pl. pycnidia—a fruiting body resembling a perithecium, flask-shaped or somewhat irregular in shape, usually large enough to be seen with the naked eye. Unlike perithecia, pycnidia do not contain asci but are lined with short conidiophores. When crushed, it releases its spores as an irregular mass.

SCLEROTIUM pl. sclerotia—not a spore or spore-bearing structure, but a compacted mass of mycelium, often very hard, and varying in size from a millimeter to several millimeters in diameter. It serves as a resting body to carry a fungus through unfavorable weather and the impacts of other organisms, and is able to germinate and produce more hyphae.

SPORANGIOPHORE (Fig. 2)—the specialized hypha or system of hyphae that bear sporangia at its tip.

SPORANGIUM pl. sporangia (Fig. 2)—a closed receptacle, usually round or pear-shaped, borne on a sporangiophore and containing an indefinite number of spores.

STROMA—a mass of hyphae, bearing spores on very short conidiophores or having embedded in it perithecia or pycnidia.

The fungi are divided into four main classes. Because spores show much more variation between species, and at the same time are more constant in shape and color for any one specie, most systems of classification are based chiefly on methods of spore production and characteristics. However, mycelium and fruiting bodies are helpful.

The **Phycomycetes**—the mycelium of these fungi are mostly nonseptate (no cross-walls); mycelium lacking in some primitive forms. Sexual reproduction by oospores and zygospores. Non-sexual reproduction by sporangia and spores liberated may be motile in some cases and not in others. These fungi are primarily found in wet places. The Pythium fungi are of particular importance in this group.

The **Ascomycetes**—possess several spore stages. Sexual spores formed in asci; normal number of spores in ascus eight; perithecia present. Non-sexual spores (conidia) often present and very varied in form and disposition; pycnidia present.

The **Basidiomycetes**—sexual spores exogenous (not enclosed), formed on basidia; normal number of spores on basidium four, rarely two. Non-sexual spores uncommon. The smut and rust fungi make up an important segment of this class. They have a modified basidium, called a promycelium, but it is clearly homologous to the true basidium.

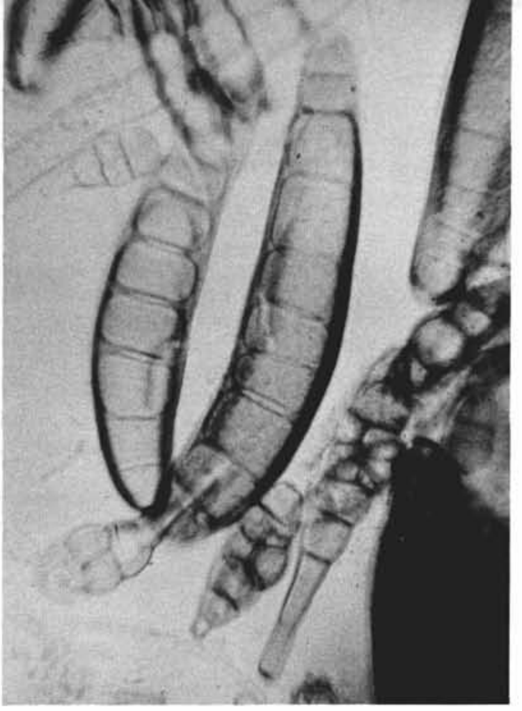


Fig. 7. Nonsexual spores and hyphae of the **Helminthosporium** and **Alternaria** genus of fungi. These structures have distinctive characteristics for each specie of the fungi and are extremely helpful in identifying a disease-causing organism microscopically.

The **Fungi Imperfecti**—no sexual spores known; reproduction exclusively by non-sexual spores. This group contains many of the leaf-spotting fungi.

The fungi are named according to the Latin binomial system of nomenclature. The fungus, if fully described, is given a specific name within a genus and this is referred to as the Latin binomial of the organism. The name, or abbreviation thereof, of the investigator who first described the species follows the binomial. These names are always put in italics when printed, and should be underlined when hand written. The genus name is always capitalized, but not the investigator's name.

The following features characterize the parasitic fungi of some of the more common turf diseases and are the ones to look for when studying the fungi microscopically.

RHIZOCTONIA (Fig. 1). Hyphae light to dark brown, characterized by rightangled branching with cross-walls; first cross-wall of branch slightly near parent hypha. No spores produced; may form sclerotia. **Brown Patch.**

SCLEROTINIA. Characterized by a fine white cobwebby mycelium; conidia borne singly on hyphae inside an apothecia; sclerotia black. **Dollar Spot.**

PYTHIUM (Fig. 2). Hyphae is colorless and has no cross-walls; sporangia spherical and terminal; spores rarely seen. Mycelium located in root and crown regions. **Pythium Blight.**

FUSARIUM (Fig. 3). Spores sickle or banana-shaped with 0 to 3 cross-walls. Mycelium white to faint pink or pale rose with cross-walls. **Pink Snow Mold.**

TYPHULA. Characteristic light to reddish-brown sclerotia that can be seen with the naked eye. Mycelium grayish-white. **Typhula Blight.**

HELMINTHOSPORIUM (Fig. 4). Spores more or less cylindrical, brown, with 1 to 10 cross-walls; hyphae (conidiophores) emerging from the stomates, brownish, with cross-walls. **Melting-out or Eyespot.**

CURVULARIA (Fig. 5). Spores, brown, distinctly curved or bent with one of center cells conspicuously larger than the other cells; end cells paler; three to four cross-walls. Hyphae emerging from stomates; brownish, with cross-walls.

PUCCINIA Spores (known as urediospores) are reddish-brown, roughly-rounded, with a slight constriction at the top. **Rust.**

There are numerous other diseases caused by fungi that strike turf-grasses, such as copper spot, pink patch and other leaf spot diseases, but these occur only rarely. However, these fungi should also be studied to familiarize ourselves with their characteristics.

It is not possible in an article of this size to give all the information useful in studying and identifying the fungi that cause turf diseases. Therefore, a list of books appears at the end that will be most helpful. These describe life and disease cycles in detail, identifying structures and other keys helpful in identifying fungi. They should be consulted and studied as a valuable aid in a disease control program.

A good microscope and a knowledge of isolation techniques are necessary to study the fungi effectively. There is a wide range of microscopes available, but a compound microscope that will magnify in a range of 3 to 1,000 times will be sufficient. Isolation in pure culture may be necessary to determine what fungus specie is causing the disease. However, before this is attempted study the tissue thoroughly under the microscope, because some fungi sporulate readily on diseased material, allowing for easy identification. Examine both healthy and diseased material for hyphae, spores and fruiting bodies. A portion of the leaf should be scraped with a moistened razor blade and the scrapings added to a drop of water on a microscope slide. Cover with a cover slip and examine.

Isolation in pure culture involves placing small pieces of both healthy and diseased tissue in petri dishes containing agar. Incubate for a few days, and examine for any spores or fruiting bodies produced. Because this is quite a tricky technique, the books listed at the end of this article, or a turf pathologist should be consulted to determine the proper technique and materials needed for pure isolation.

It should be emphasized that the turf disease situation is not static; it is always changing. Microorganisms are as variable in genetic make-up as any other organism, and no matter how up-to-date our information, there is always the chance new races able to attack formerly resistant varieties of turfgrasses will appear. We must be prepared to meet this possibility as well as be better prepared to prevent and control existing diseases if the goal of total turf perfection is to be met. By increasing our knowledge of disease with the use of a microscope we will be in a more advantageous position to gain effective control over them.

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