What is DNA?

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In recent years, many biotechnology terms (DNA, sequence, cloning, transformation, transgenic material, molecular marker, genome, and biotechnology, for example) frequently appear in newspapers and non-scientific magazines, which most people can routinely access and subscribe. Millions of dollars have been spent and are still being invested into plant and animal genome projects (sequencing of whole chromosomes in human, Arabidopsis, and rice, etc.). Since we as taxpayers are contributing money for the support of these gigantic research projects, we should get an idea of what is being done and how we will benefit. When we are facing new topics for the first time, we tend to ignore them rather than spend the time to understand them. Perhaps one thinks that it is just too hard or too much to learn. However, once we pull up our chair to the desk and start to read the text sentence by sentence, then we begin to realize that the content is not so difficult. Instead, the subject is fun and arouses interest. For example, a person who has never played golf in his/her life, just like myself, does not know what kind of fun or joy people experience by playing golf. Once that person has a chance to play golf in any situation, the person's attitude toward golfing should change to a positive one.

What is DNA? DNA is an abbreviation for deoxyribonucleic acid. Perhaps many of you may have heard the term DNA, but not as many understand it. The DNA molecule is in the form of a double helix. Some DNAs are very long, and some are short, but all DNA is very tiny. Relatively large amounts of DNA can be found in the cells of living organisms packaged in a very efficient way. DNA contains the codes for an enormous variety of genes. And genes are the pieces of information, which all living organisms have inside them, enabling them to function, maintain life and reproduce, thereby passing on the genetic information to next generation.

If we want to make or reproduce the same house in multiple copies, all we need is a description or a blueprint of the original house. With the necessary raw materials and the directions/description, we could build the exact same house without any difficulty. Of course, someone else could produce the same house as well, if we gave him a copy of the description of the house. The description for building the house is analogous to the DNA found in living things (microorganisms, plants, and animals). Like the detailed description for building the house, DNA contains a coded description of the organism and is responsible for its capacity to reproduce. Living organisms, unlike the description of the house, do not usually make exact copies of themselves. If that was the case, there would be no diversity and life as we know it would not exist. Living organisms make variant copies of themselves. This is possible because of the nature of DNA.

By the mid 1800's, most biologists accepted the view that all plants and animals consisted of cells. New cells were produced from old cells through cell division. Frederick Miescher who was the son of a well-known physician in Basel, Switzerland unexpectedly discovered DNA. In 1869 he had gone to Tubingen in Germany to study the chemistry of white blood cells. He used pus obtained from postoperative bandages, as a source of the cells. When he added weak hydrochloric acid to the pus he obtained pure nuclei. When he added alkali and then acid to the nuclei a gray precipitate, or solid, formed. The precipitate was unlike any of the known organic substances. Because it came from the nucleus, Miescher called it nuclein. Today it is called DNA. Shortly after Miescher's discovery, new staining techniques were developed which revealed band-like structures in the nucleus of cells. In 1879 Walter Flemming introduced the term chromatin (Chroma:Greek for color) to describe the intensely stained material in the nucleus. In 1881 E. Zacharia performed an experiment with chromatin by reacting it with acid and alkali in the same way as Meischer's nuclein. He concluded that nuclein and chromatin were in fact the same material. Today, the chromatin material used by Flemming is called chromosomes. Chromosomes carry genes in a linear fashion, which are the basis of heredity.

While scientists were not sure how the chromatin (chromosomes) was passed on to the next generation, scientists studying fertilization made the connection between chromatin and heredity in 1870's. Two scientists, Hermann Fol in Switzerland and Oskar Hertwig in Berlin, independently showed the connection between chromatin and heredity by observing (using the light microscope) that the sperm penetrates the egg, and that the nuclei of the sperm and the egg fuse. Edouard Van Beneden, studying the threadworm Ascaris (a parasite of horses) noted that the sperm contributed the same number of chromosomes as the egg to the developing embryo. He also discovered meiosis, the halving of the number of chromosomes in the germ cells (the egg and the sperm). It was Flemming who observed cells dividing and saw chromosomes replicating. He concluded that chromosomes were a source of continuity from one generation to the next. So by the 1890's scientists had come to have a clear idea of the nature of fertilization, and were even declaring that DNA (Meischer's nuclein) was the basis of heredity.

Modern genetics begin with Gregor Mendel's famous experiments with garden peas in the 1860's. Mendel had chosen peas that had certain pure traits, which when bred, always give the same traits. Pea is a self-pollinated crop (the transfer of pollen to stigma within the same flower). Plants derived from vegetative propagation, or from apomictic or self-pollinated species can be homogeneous at the genetic level, exhibiting little genetic difference. Alternatively, cultivars with a cross-pollinating reproductive system can be genetically heterogeneous. Most turfgrass, except Kentucky bluegrass, has a reproductive system of cross-pollinated seeded species. Kentucky bluegrass had an apomixis, which is forming the seed by an asexual method of reproduction, basically mimicking sexual reproduction in that the seed develops in the ovule of the flower, but without union of the sperm and egg. Mendel had plants that always produced yellow seeds, and others that always produced green seeds. When he manually made crosses by rubbing pollens from the green plant onto the stigma of the yellow plant, all the progeny were yellow-seed bearing plants. Mendel called the yellow trait Dominant, and the green trait Recessive. He argued that the progeny of these first generation crosses had each received an equal genetic contribution from each parent, but only the dominant yellow trait was manifested. When he crossed these first generation hybrids with each other he found that 75% of the progeny were yellow and 25% were green, confirming his hypothesis that the green "gene" (he didn't use this term, however) had been there all the time. This is the story of how the science of the genetics was developed.

In the early part of the 20th century, scientists discovered the Mendelian 'factors' controlling inheritance, which we now call genes. They discovered these "factors" to be organized in linear order just like beads on a string (cytogenetically defined structures called chromosome). Since then, concepts of genes linearly placed on chromosome have been tremendously utilized in many areas of the biological sciences. For many years the principles of genetics based on this concept have been applied to unveil biological mechanisms such as the interaction of pathogen and host for causing disease, pathogenecity, and to improve crop varieties. During the last decade one of the applications of the concept of a linear pattern of genes, is the advent of DNA marker technology. Today DNA marker technology has become an essential tool in all areas of research of living organisms.

Over a last decade biotechnology has grown rapidly and begun to play a very important role in agriculture because of its ability to modify microorganisms, plants, animals, and agricultural processes. The definition of biotechnology may be described as "any technique that uses living organisms, or substances from those organisms, to make or modify a product, to improve plants or animals, to develop micro-organisms for specific uses." In agriculture, biotechnology has found applications in cell and tissue culture, for rapid propagation of plant species; in diagnosis, for detecting plant pests and diseases based on the use of antibodies and DNA probes; and in genetic engineering of plant species, to introduce new traits (disease resistance genes) and in facilitating conventional plant breeding programs using molecular markers. How about any progress in turfgrass research? Of course, turfgrass research has been changed by rapid progress in the above categories. In particular, researchers have favored the development of transgenic plants inserted with useful genes and the application of DNA marker technology in recent years.

In the breeding world, one of the main objectives of plant breeders is to improve existing cultivars, which are deficient in one or more important traits (better quality, disease resistance, and drought tolerance, for example), by crossing such cultivars with lines that possess the desired trait. A conventional disease resistant breeding program thus involves crossing between a resistant cultivar with undesirable traits and a susceptible elite cultivar. Then the particular progenies (called recombinants), with combination of all desirable traits from the elite cultivar with disease resistant trait from the resistant cultivar, need to be selected from among a series of progenies, which have a combination of different traits contributed from both parents. Such a procedure is laborious and time consuming, involving several crosses, several generations, and careful phenotypic selection followed by inoculation with pathogen isolates. With the advent of DNA markers (specific locations on a chromosome, which serve as landmarks for genetic studies), several types of DNA markers and molecular breeding strategies are now available to plant breeders and geneticists in crops, including turfgrass, helping them to overcome many of the problems faced with conventional breeding.

Then, what are the practical applications of DNA marker technology for research in areas of turfgrass pathology? Stay tuned for the next issue of the Grass Roots.