



International Turf Management

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D. E. Aldous

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FOREWORD

Sports turf, and thus turf culture, is a comparatively modern idea. The roar of suburban turf was heard for the first time at the turn of the present century. It only reached a crescendo in the last fifty years or so, as motorised mowers and edging machines, aerators and scarifiers made their appearance even in small gardens and at every park, golf course and playing field. When I started work, not that long ago — not that long anyway — advertisements could still be found seeking scythe hands, even though the mowing machine was invented in 1830. Now forty years later, the skill which allowed the scythe to leave a surface as fine and even as a mowing machine, is almost unknown. The pace of change is still accelerating as new grass varieties are bred, new equipment is evolved, and new techniques, fertilisers, weed killers and pesticides are developed.

Turf culture only started to aspire to its present level of sophistication when people had the security and leisure to start gardens and to take part in sports. It is true that Pliny the Younger who lived from 61 AD until 113 AD mentioned a lawn at his villa in Tuscany, but it seems to have been a small affair. There was little or nothing written about lawns before that and not much to indicate that they existed on any extensive scale between then and mediaeval times. Boccaccio has some of his characters, in the *Decameron*, putting grassy meades to uses which

the modern Park Superintendent would easily recognise, but he was thinking of them as meadows filled with wild flowers and not as well kept, neatly mown, turf. If you look closely at paintings of the period you may see the corroborating evidence, grass, yes, but probably only scythed a couple of times a year and thus with a rich thatch of herbs as a major component of the sward. It would have lacked the durability given by modern methods of cultivation and new varieties of grasses, but it would in its season have looked pretty in a way that we have tended to forget.

As it happens, in central London we have now re-established three hundred acres of meadowland. Once familiar herbs like the meadow geranium, the harebell and scores of other wildflowers are shyly starting to appear in it, after decades of absence. It is within living memory that Hyde Park was kept trim by sheep which grazed it, and Richmond and Bushy Parks still have deer as the principle groundkeepers, just as they have been for half a millennium. Both permit a wide flora to flourish along with the grass. But tastes change. Neatly mown grass was until recently *de rigueur* in urban parks and gardens, at least in Britain, and a shift to a more relaxed style of upkeep for extensive areas of informal grass is a newish trend. Dealing with the problems that arise will be the next set of conundrums for management. There are plenty of questions to ask.

How do you keep an urban meadow clean? What do you do about the problems caused, and left, by dogs? How do you stop one or two species from dominating the sward at the expense of others? Should you deliberately introduce esteemed herbs or ought you to be patient enough to allow them to reappear naturally even though it may take many years? What kind of herb should be introduced, and ought its provenance to be considered important? There are plenty of problems to resolve. Nor are meadows a cheap option. They will not look after themselves. They must be kept clear of litter and debris just as a lawn has to be, and rubbish is more trouble to find and pick out of long grass than short. In the British climate meadows must be mown in the autumn after flowering, and again in the spring. Without this, they would turn into spinneys and after a titanic struggle between warring species into woodland, which is the destiny of all plantations in our climate, just as the bush would no doubt encroach in Australia.

But conservationists are wrong when they refer to a mown lawn as a green desert, though these days they are often bold enough to do so. It is in fact a green carpet on which people, sometimes in large numbers, can play, sit, walk, sunbathe and disport themselves. It can be highly decorative in its own right and it is the perfect foil for flowers. It is the most durable of all living surfaces.

Sports turf shares the need to be tough. But where the skill of the player can be subverted by the nature of the playing surface, the care and precision with which it is made, and then kept, is a matter of key importance. It deserves the greatest care and study. The greenkeeper who has faced a cricketer bowled out because of a crumbling wicket, or a golfer who has missed a putt because of the alleged quality of the green, or a bowler whose perfect shot has just finished in the ditch, will not wish to repeat the experience frequently. It makes no difference whether the

complaint was justified or not, in an extreme case the sportsman's irritation may not be far removed from road rage and is to be avoided in so far as skill can do it. If it can't then the biblical observation that 'The soft answer turneth away wrath' has much truth in it, and the Koran has an even blunter view of the matter 'When fools speak, say peace'.

This book has an international band of contributors. They come from Australia, Canada, China, New Zealand and the United States of America as well as from the United Kingdom. Techniques in all of these countries vary, different grass species may be used, and methods of cultivation must address the particular circumstances of climate and soil. But the basic principles of managing turf are abiding ones and apply everywhere. The purpose of the turf has to be known and understood. The type and frequency of its use must be assessed. The way the lawn or grassland is constructed has to be worked out so that it will provide an enduring surface, which is fitted for its chosen role and use. And then the great toil commences. The area has to be kept, perhaps for generations or even centuries, in ways that satisfy its purposes in life and give pleasure to those who use it or simply admire its appearance. Throw in the old, but newly relabelled, concepts of sustainability and biodiversity, and the frugal use of the earth's resources, and this subject can be seen for what it is; a highly complex, ever developing technology. I hope that this book, in drawing on the experience and wisdom of many contributors, will assist in the understanding and practice of turf management. It is fundamental to enjoying most sports, and essential to the beauty and usefulness of parks and gardens everywhere in the world.

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PREFACE

It has been estimated that grasslands occupy about one-quarter of the world's vegetative cover. Grasses constitute a major human food source, either as grain, or as pasture for our native and domesticated animals. Grass makes life worth living, turf makes life worthwhile. Turfgrasses influence many human and environmental activities by protecting our land surface from erosion, stabilising our soils, moderating our temperatures, providing low cost safe surfacing for many sporting and leisure activities, and bringing comfort and pleasure to the landscape.

Amenity grasslands, and turf in particular, not only form a significant part of the global landscape, but are also the basis of a multi-million dollar industry. Turfgrass venues, agencies, activities and services are highly valued and varied, and require highly motivated trained personnel with enquiring minds to manage them efficiently and effectively. This handbook provides a treatise on the establishment, maintenance, and management of natural turfgrass surfaces in Australia and overseas. Developed in association with more than 20 leading turf management authorities, this manual details how the natural turfgrass surface functions and the implications for its management. For this reason it is important reading for teaching and training staff, graduate students, students undertaking undergraduate and technically oriented programs in

agriculture, horticulture, and natural resource management, as well as all land managers and other allied professionals who intend to take leadership roles in the management of turf and amenity grasslands.

This handbook has been arranged into four sections. Section 1 covers Chapters 1 to 10 and systematically introduces the reader to the turfgrass industry, how turfgrasses are identified and selected, how turfgrasses grow, the significance of soils and drainage, and how grasses may be successfully established. The scientific names, and with few exceptions the common names, of the grasses in the manual closely follow Watson and Dallwitz's, *The Grass Genera of the World*, and Hanson and Juska's, *Turfgrass Science*. Subsequent chapters address irrigation and its application, nutrition and fertilisers, machinery and equipment operation, and plant health and protection. Section 2 covers chapters 11 to 13 and emphasises the management and administration of the turfgrass business, and the importance of contract establishment and management. Chapters 14 to 19 address the current performance standards in place today, and use them to effectively manage different cultural systems such as the bowling, croquet and golf green, the grass tennis court, the cricket table, the football and athletic field and arenas, the racetrack, and the golf course fairway. Both instructor and student alike

will need to relate the different management strategies that will need to be adopted with other natural (amenity grasslands, airfields, road reserves, school and institutional grounds, lawn cemeteries, military installations, the private and public landscape), and sporting fields (baseball, lacrosse, polo, and field hockey). The fourth section, chapter 20, addresses the important environmental issues in turf management such as the use of scarce water resources, pesticide and fertiliser pollution, and the effects of golf course activities on people and wildlife.

Numerous publications have been consulted for information; the more significant ones are listed at the end of each chapter. Trade names found in this book serve only to identify materials or equipment and no endorsement of them is implied or intended.

Many people have contributed material and helpful critical reviews on individual chapters in the publication of this manual. Thanks are due to all contributing colleagues from Canada, the United States of America, Great Britain, China, Australia and New Zealand, who gave of their time and experience in developing their

respective chapters. Thanks are also due to those who contributed by reviewing different chapters: Drs Greg Moore and Peter May, University of Melbourne-Burnley College, Melbourne; Philip Ford, Northern Institute of TAFE, Melbourne; Bruce Stephens, Chemturf Pty Ltd, Melbourne; David McGeary, Turfgrass Technology Pty. Ltd, Melbourne; Ian Chivers, Racing Solutions Pty Ltd, Melbourne; and Gary Beehag, Globe Australia Pty Ltd, Sydney, New South Wales.

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CHAPTER 1

Introduction to turfgrass science and management

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Introduction

Turf comes from either the ancient Sanskrit word, *darbha*, or the old English word, *torfa*, both meaning a tuft of grass. More modern definitions cite turf as a surface layer of vegetation, consisting of earth and a dense stand of grasses and roots. In profile, turf consists of verdure, the green aerial shoots remaining after mowing; thatch, the intermingled layer of dead and living stems and roots that develops between the verdure but above the soil surface; and soil, which contains underground stems and roots. Other terms used synonymously with turf include sod, which is a piece cut from this vegetative material plus its adhering soil; sward, which is the grassy vegetation often used in association with pastures; grass, which is any monocotyledonous plant belonging to the family *Poaceae*; a green, which is a smooth, grassy area used for sporting purposes; and a lawn, which had been defined as a flat and usually level area of mown grass.

Turfgrass science and management involves the art, culture and science of managing these natural grass surfaces. All turf managers aim for the best playing conditions and turf of the highest quality. Playing quality is a function of the natural grass surface and soil conditions in the field, and has a great influence on traction, impact absorbence and ball response. Measurable playing

standards are now in place for many natural grass surfaces (Canaway *et al.*, 1990). Turfgrass quality involves a composite, visual assessment of the natural grass surface, and has established standards against which performance is measured (Beard, 1973).

Benefits derived from the turfgrass community

Living turf provides considerable aesthetic, ecological, functional, recreational and social benefits. Functional and ecological benefits include improved soil stabilisation at the surface by reducing the potential for erosion and wind blown soil particles, and acting as a filter for improving the quality of groundwater. In addition, turf can substantially influence heat loss, reduce noise, glare and visual pollution, and act as a safe, low cost impact surface for many sporting and recreational surfaces, highways and roadsides (Beard, 1973; Roberts, 1985; Beard and Green, 1994). Actively growing turf also maintains the fundamental abiotic components of the world's life support systems, such as air, soil and water (Carne, 1994).

In urban environments, plants generally modify temperatures by influencing the rate of energy exchange (Mastalerz and Oliver, 1974).

Grasses transpire at a rate that, in energy terms, exceeds the local radiant energy supply. If a substantial portion of this heat load is not dissipated through the processes of evapotranspiration, re-radiation, conduction and convection, temperatures at the surface of the leaf can reach lethal levels. Energy not dissipated remains to affect the specific heat balance and temperature of the leaf. Factors that influence the temperature of the leaf canopy are ambient air temperature, relative humidity, availability of soil moisture, and wind velocity. Under warm to hot conditions, the leaf surface may be up to 20°C cooler than nearby unprotected buildings or road surfaces. Finnigan *et al.* (1994) found that effective tree cover ameliorated the local temperatures and humidity by up to twice the regional average, with reductions of 4°C when compared to average temperatures of 30°C. Gibbs (1997) compared the temperatures between natural and synthetic bowling green surfaces, and found that the air temperatures were only likely to be large when the ambient air temperatures rose above 20°C. Surface temperatures of 60°C have been recorded on synthetic turf, alongside maximum temperatures for natural grass of 32°C (Mecklenburg *et al.*, 1972). Tree cover can also reduce surface temperatures by up to 15°C (Givoni, 1991), and can cool adjacent turf by conduction. Lowering the height of cut of turf will also influence surface soil temperatures. For example, soil temperature extremes are greater under a turf cut at four millimetres than at 37 millimetres. Research has shown that strategically placed vegetation can reduce noise levels by 15 to 45 per cent at distances of 9 to 21 metres (30 to 70 feet) along heavily used urban freeways, as well as reduce glare and associated eye discomfort from reflected light (Beard, 1977).

Turf provides a recreational benefit by providing a low-cost, low-impact, safe surface for many outdoor sport and leisure activities. Psychologically, aesthetically pleasing, green turf enhances

the beauty and attractiveness of a landscape by improving mental health and work productivity, as well as providing an overall better quality of life. Sociological benefits can also accrue to the individual and to the general community when people interact with plants. Relf and Dorn (1995) and Kaplan and Kaplan (1989) have shown that interacting with plants can develop an improved sense of self worth, create new friendships and social placement, as well as provide feelings of freedom and being in control of one's life. Researchers have also documented that people who interact with plants can recover more quickly from everyday stresses (Bennett and Swasey, 1996) and show improved self esteem (Smith and Aldous, 1994). Nursing home clients who care for plants have shown an improvement in alertness, participation and well-being (Langer and Rodin, 1976), and display a more positive outlook on life (Ulrich, 1990).

Historical perspectives in turfgrass

References in the early scriptures make frequent mention of fields of grass and ornamental gardens set in idyllic situations. Genesis (1: 11–12) makes mention, 'And God said, let the earth bring forth grass, . . . And the earth brought forth grass . . .'. The ornamental gardens of Emperor Babar and Chosroes I of Persia (AD 531–579) have been illustrated in the weave of early Persian garden carpets (Rohde, 1927). Gardens have long been expressions of luxury, such as the gardens of one of China's early emperors, Wu Ti (157–87 BC) (Malone, 1934); for pleasure, such as the Indian Taj Mahal and its surrounding gardens (Goethe, 1955), and as an expression of affection. For example Shah Jahan, the Grand Mogul, developed a number of ornamental gardens as an expression of love for his wife Mumtaz-i-Mahal (Huffine and Grau, 1969). The natural grass

surface has also played an important part in the development of many sporting and recreational pursuits. Chaugau or polo frequently occupied the day for Akbar, 1556–1605 AD, the Great Emperor of Hindustan. The Plains Indians of the United States played baggataway, an early form of lacrosse, on the grassed prairies, either on foot or on horseback. The shepherds of early England and Europe played many competitive 'ball and stick' games while tending their flocks on the lowlands. The native population of many countries threw clubs at discs bowled along the ground, and played sport with balls and stones.

However it was during the years of the Crusades (11 to 13th centuries) that we see an increasing exchange of ideas as Europe came into closer contact with the East. By the 13 to 15th centuries, grassed areas were considered an integral element in the classical gardens of medieval Europe and Britain. The English dramatist and poet, William Shakespeare (1564–1616), makes reference to grass in his play *The Tempest*, (Act ii., sc.1.); 'How lush and green the grass looks . . . Here, on the grass-plot, in this very place, to come and sport . . .'. Balt-hazar Nebot's series of paintings of Hartwell House, in Buckinghamshire, United Kingdom (circa. 1738), depicts gardeners with scythes and lawn rollers (Sanecki, 1997). Other literary sources include the works of Miss Eleanour Sinclair Rohde who paid tribute to grass in 'Nineteenth Century and After', 1928, CIV, 200 (Dawson, 1949). In the 1930s, Englishman John Evelyn's instruction manual states that 'bowling greens are to be mowed and rolled every fifteen days' (Evelyn, 1932).

With the advance of the Industrial Revolution, there developed an increasing demand for goods, and gardening and sport became major leisure occupations for many of the new middle and upper class town dwellers. This stimulated the manufacture of implements and machinery for maintaining the garden. Eighteen-century

lawns were originally grazed or cut with the scythe. In 1830 Englishman, Edwin Budding, an engineer at a textile mill, developed a cylinder or reel type mower, which consisted of a series of blades arranged around a cylinder with a push handle. The licence to manufacture this first lawnmower, based on Budding's design, was granted in 1832 to Ransome of Ipswich in England, although a prototype had been made as early as 1831 by another Englishman named Farrabee. In 1841 Alexander Shanks of Arbroath, Scotland, had registered a pony-drawn mower which also swept up the clippings. By 1870 Elwood McGuire of Richmond, Indiana, had also designed a machine that mowed turf. With these inventions the hand scythe and cradles were abandoned for horse-drawn machines, and the sickle-bar mower was brought from the hay field to mow larger turf areas of parkland and land put aside for golf courses.

Prior to 1700 all seed was hand sown. Around 1701 Jethro Tull (1674–1741), an English agriculturist and inventor, perfected the seed drill. The introduction of fencing wire in 1840 enabled animals to be inexpensively confined close to grazed areas, and the advent of galvanised wire in 1851 and barbed wire in 1860 improved this situation. Post-World War II saw Power Specialists of Slough, England, introduce a rotary Rotoscythe mower which offered both petrol-driven and electric models (Sanecki, 1997). In 1948 Australia entered the machinery market with the introduction of a petrol-driven Rotoscythe mower which was sold for 76 pounds, four shillings and sixpence by the Finally Brothers Pty Ltd of Melbourne. This was followed in the 1950s by the introduction of the first two-stroke rotary lawnmower by Australian designer and builder Mervyn Victor Richardson of Concord, New South Wales. By 1966 lightweight electric mowers were being developed and introduced by Flymo Ltd of Middlesbrough, England. Traction power for turf maintenance operations

had progressed from draught animals (Figure 1.1(a)), or even students (Figure 1.1(b)), through steam-driven tractors to those with petrol or oil engines. Over the 1920s and 1930s there was a general tendency to abandon the horse in favor of the tractor-mounted mower, not only for constructional work, but also for regular mowing of large areas.



Figure 1.1(a) Horse-drawn cylinder mower, circa 1941; (b) Student-powered cylinder mower, circa 1890 (Photos courtesy of Burnley Archives, University of Melbourne, Burnley College, Victoria)

History of significant turfgrass sports

Lawn tennis is thought to have evolved from the indoor game of real tennis, the word being derived from a corruption of the French *tenez*

meaning attention or hold. Others make mention of the term *jeu de paume* or the palm game. Lawn tennis was played in monasteries in France as early as the 11th century. The long-handled racket was not invented until about 1500. 'Field' tennis is mentioned as early as 1793 in a British magazine. The first lawn tennis club was established in Leamington Spa, Warwickshire, UK in 1872. The United States Lawn Tennis Association was formed in 1881, and the English equivalent, seven years later. The Wimbledon Championships were instituted in 1877, the US Open in 1881, and the Australian Championships in 1905. In Australia the first tennis match was played on an asphalt court laid at the Melbourne Cricket Club in 1878. The Club put down a grass court the following year. The Lawn Tennis Association of Australasia was formed in Sydney in 1904.

Lawn bowls originated with the crowned heads of Europe. During the reign of England's kings, Edward III, Richard II and Henry VII, bowls was banned as a sport because the archers were often distracted by the game, thereby endangering the sustainability of the reserve military forces. Despite these legal restrictions, the game prospered with the world's first bowling club established as the South Hampton Town Bowling Club in 1299. It is reputed that the game of bowls was made famous by the English sea captain Sir Francis Drake (1540–96) who insisted he finish his game before his ships sailed to defeat the Spanish Armada in 1588. Lawn bowls has been played in Scotland since the 16th century. The modern rules were framed in Scotland by William Mitchell in 1848–9. The game is played mostly in the United Kingdom and the other Commonwealth countries. Bowls came to Australia with the first migrants, who often established greens next to their bars and taverns, as was the custom. Australian research suggests that the earliest bowling greens were built at Sandy Bay in Tasmania, and the 'Golden Fleece'

and 'Woolpack' hotels in Petersham, Sydney, as early as 1826. Victoria's first bowling green was commenced in late 1845 by a Mr W. Turner who aptly named his premises the 'Bowling Green Hotel' (Gerty, 1996). The first bowling associations were established in Victoria and New South Wales in 1880. The Australian Bowls' Council was formed on 22 September 1911. The New Zealand Bowling Association (NZBA) evolved as a national body in 1914. Bowls are now played on both grass and synthetic surfaces.

Croquet is believed to have originated in southern France during the 13th century. By the 17th century, it was a popular game with French Royalty and shortly afterwards was taken up by Royalty in England. During the 18 to 19th centuries it proved to be a favorite pastime, played mostly on the private lawns of country homes and estates in Europe and the United Kingdom. Croquet has been played in Australia since colonial times. The first croquet club in Australia was founded in Kyneton in 1866 and the next was in Kapunda, South Australia in 1869. In 1949 the Australian Croquet Council was formed. Croquet headquarters are co-located with the US Professional Golf Association (PGA) at Palm Springs, in the United States. Croquet comes in three main forms: association croquet, golf croquet, and kingball.

Hockey-like, curved sticks have been observed as part of sport in early Greek carvings (500 BC), and on Egyptian tomb paintings (2050 BC). However in its modern form, hockey developed in England around the second half of the 19th century, with Teddington Hockey Club, formed in 1871, standardising the rules. The English Hockey Association was founded in 1886. Field hockey is considered a modern version of the game played under such names as Hurley and Shinty in England, and Hoquet in France. It was thought to have been introduced into Australia by the Irish gold miners in the 1860s. Hockey clubs were formed in Adelaide in

1900, Perth in 1902, and Melbourne and Sydney in 1906.

Cricket is thought to have been brought to Britain by Flemish weavers from the Low Countries as early as the 14th century. The term cricket is suggestive of the Flemish phrase *met dekrik ketsen*, which literally means to chase with a curve stick. This was shortened to *kriket*, and finally cricket as we know it today. Other interpretations come from the Anglo-Saxon word *crice*, meaning a crooked staff; a game that became popular among shepherds playing on the short cropped grassed downlands of southern England. Other Low Country linguistic connections have emerged. For example, the word stump does not exist in Anglo-Saxon, but did exist as the word *stomp* in Holland. Illustrations of people playing cricket can be observed on medieval French manuscripts dating from the mid-14th century. The scene depicts monks and nuns playing cricket, or a bat-and-ball game similar in style to cricket. In the background are four nuns and monks, hands held out, ready to catch the ball. Certainly by the 17th century there were numerous references to cricket being played on the commons in medieval England. As a sport, cricket must have proven popular in Ireland, for Oliver Cromwell (1599–1658), English general and statesman, ordered the destruction of all bats and balls in Dublin. Cricket even appears in a poem entitled the 'Mysteries of Love', by the nephew of John Milton (1608–1674), who wrote, 'Would my eyes had been best out of my head with a cricket ball the day before I saw thee'.

The formation of the Marylebone Cricket Club (MCC) in 1787 resulted in codified laws being developed by 1835. The International Cricket Conference (ICC), so called since 1965, allowed for membership from non-Commonwealth countries. The seven test playing full members now include Australia, New Zealand, England, India, Pakistan, Sri Lanka and The West

Indies. Cricket has been considered Australia's first organised sport, with the game organised by officers of the HMS *Calcutta* in Sydney in 1802–03. In Australia, cricket clubs flourished in the early to mid 19th century with the establishment of Military and Australian, and the Royal Victoria (1826), Melbourne (1838), Prince Albert (1840), and in 1844, the Currency and City Cricket Clubs. In Melbourne the game was played as early as 1836 on Batmans Hill, which was later levelled to become the site of Spencer Street Station.

Football, as we know it, embraces association football (soccer), American gridiron, rugby union, rugby league, Australian rules, and Gaelic football. A game resembling football, *Tsu-Chu-Tsu*, and meaning to kick the ball with feet (*chu* meaning leather) was played in China around 400 BC. The game *calico*, which is closer to the modern game, existed in Italy in 1410. Official references to football date to King Edward II's reign in England, when he banned the game in London in 1314. The first soccer rules were formulated at Cambridge University in 1846. The Football Association (FA) was founded in England on 21 October 1863. From Britain, soccer quickly spread throughout the world to countries such as Denmark (1889), and by 1904 was being played in as many as fifteen European countries. In the same year the Federation Internationale de Football Association (FIFA) was formed. In Australia the first soccer club was formed in Parramatta, NSW, in 1880 through the efforts of English schoolmaster, J. W. Fletcher. Together with J. A. Todd they formed a club known as the Wanderers, with Fletcher becoming its first secretary. The first administrative soccer body in Australia was the (NSW) English Football Association formed in 1882. Gaelic football developed from a traditional interparish 'football free for all' with no time limit, no defined playing area and no specific rules. The Gaelic Athletic Association established the game

in its present form in 1884. Played throughout Ireland, the first All-Ireland Championship was held in 1887.

Gridiron, or American football, had its origins in the football played by the large ivy league colleges and universities on the east coast of the US in the second half of the 19th century. It is thought to have descended from soccer and rugby in Britain. The first recorded game, in the US, was between Princeton and Rutgers on 6 November 1869 at New Brunswick. Columbia and Yale joined this group in 1873. By 1876 the 'Boston game' based on running with the ball had gained almost universal approval. College football spread far and wide throughout the latter part of the 19th century and during this period developed in professionalism. The American Professional Football Association (APFA) was formed in 1920 and in 1922 renamed the National Football League. The American Football League was formed in 1960. These two leagues merged in 1970 and were later reorganised into the National Football Conference (NFC) and the American Football Conference (AFC). American football is played on both grass and synthetic surfaces.

Football had been played by Irish soldiers in Sydney in 1829 and by Victorian goldminers as early as the 1850s. Australian Rules was introduced through the efforts of Thomas W. Wills, the son of an eminent Victorian pioneer pastoralist. The first match was played between schoolboy teams from Scotch College and Melbourne Grammar in Melbourne on 7 August 1858. Australian football rules were codified in 1866 in Melbourne, with the use of an oval rather than round ball by 1867. Ten years later the Victorian Football Association was founded. Australian Rules football later spread to NSW (1866), South Australia (1875), Queensland and Tasmania (1879), and in 1883 to Western Australia. The VFL (now AFL) Grand Final is played annually at the Melbourne Cricket Ground. This

was the site of the first commercial flood lighting using electricity in August 1879.

Rugby Union was supposedly born when William W. Ellis, while playing soccer at the Rugby School, England, in 1823, picked up the ball and ran towards the opponents' goal line. The game spread, particularly among the wealthy and privileged of Britain as well as those who attended the private school system. Certainly rugby was being played at Cambridge University by 1839. The Rugby Football Union was formed on 27 January 1871. The International Rugby Football Board was formed in 1890. International Championships between England, Ireland, Scotland and Wales were first held in 1884. Since 1888, teams representing the British Isles have toured Australia, New Zealand and South Africa. In Australia, the first rugby union game was played in Sydney in 1829, forty-five years before the formation of Australia's first administrative body, the South Union. In 1892 the Southern Union was renamed the NSW Rugby Union. Other Unions were established in 1873 (Scotland), 1875 (Ireland), 1888 (Wales), 1892 (New Zealand), and in 1889, South Africa. Rugby League developed as an extension of the game of rugby union on 29 August 1895, following concern by English players that they should receive similar payments to their soccer counterparts in the British Football Association (BFA). Rugby League has been played principally in Great Britain, France, Australia, New Zealand and Papua New Guinea. In Australia, rugby league was formed in 1907 after a dispute with rugby union representatives over the payment of out-of-pocket expenses to injured players. The Australian Rugby Football League (ARL) Board of Control was formed in 1924 and became the ARL in 1984.

Baseball appeared as a grassed sport in the English language somewhere towards the beginning of the 18th century. Early references were made to baseball in the November 1748 entries of Lady Hervey's letters, and in 1774 in a series

of alphabetically arranged verses of children's sports entitled *A Pretty Little Pocket Book* (Anon, 1983). It is now generally accepted that baseball is a more sophisticated version of the English game of rounders, a game which was extensively played in England in the 18th century and taken to America in the early 1800s. In 1840, Alexander J. Cartwright, considered by many to be the real father of the modern game, codified the rules, and on 19 June 1846 the first real game of modern baseball was played between the Knickerbockers and the New Yorks in New Jersey. From this location the game spread widely throughout the US. There are two leagues: the National (NL) and the American (AL) founded in 1876 and 1901 respectively. While there is a tendency to think of baseball solely as an American sport, it is also popular in a number of Central and South American countries, Japan and Australasia where it was introduced in Sydney and Melbourne in the early 1880s. It is thought to have been introduced to Australia by the American miners who migrated during the gold rush of the mid 1850s. Australians took to the game around 1885 in Melbourne, and in 1888 the sports equipment magnate A.G. Spaulding brought two American teams to Australia. Competitive baseball in Australia began around 1899 in NSW. In 1965 the Australian Baseball Council was established.

Modern golf started with the Scottish Parliament passing a prohibiting law in 1457 declaring 'goff be utterly cryit dounce and not usit'. This is the earliest mention of golf, although games of similar style date back as far as AD 400 to Holland and other parts of Europe. The world-renowned Royal and Ancient Golf Club of St. Andrews, in Scotland, dates from around 1400 AD on linksland that is now called the Old Golf Course. In 1888, St. Andrews, in Yonkers, became the first official American golf club. Today there are in excess of 15 000 golf courses in the United States. In Australia, Alexander

Reid, a transplanted Scot, was found playing the 'feathery' ball on farmland at Ratho, Bothwell, Tasmania in the 1820s. He had just returned from a trip to Scotland complete with several wooden golf clubs and featheries, a feather stuffed golf ball, and has since been credited with establishing Australia's first ever golf course. The royal and ancient game of golf was first played in Melbourne when it was reported that the Hon. James Graham, another Scot, had laid out a course on the site of the present Flagstaff Gardens, in Melbourne, in 1847. The Australian Golf Club was formed in Sydney on 12 December 1882 through the efforts of C.E. Riddell on a primitive course at Centennial (Moore) Park. The Sydney Golf Club was established on 3 August 1893 when prominent Concord landowner, Edith Walker, gave permission for the course to be laid out on her spacious property 'Yaralla'. In Melbourne, it was not until 1891 that J.M. Bruce, Thos. Brentnall and William Knox banded together and formed the Melbourne Golf Club, later Royal Melbourne, at Caulfield and later at Sandringham. The Royal Melbourne Golf Club can claim to be the oldest golf club in Australia through the continuity of its existence, followed by The Geelong Golf Club (1892). In Adelaide, South Australia, there was an attempt to establish golf in 1869, with the course being laid out on common park land to the north-east of the present Victoria Park Royal. Other golf clubs, which also commenced prior to the turn of the century but which failed to maintain existence in their embryonic period but were subsequently revived and are now part of the establishment include The Royal Sydney (1893), North Adelaide Golf Club (1890), Adelaide Golf Club (1892), North Queensland Golf Club (1893), later to become the Townsville Golf Club in 1924, and the Newlands Golf Club, Hobart, in 1896.

The rules of golf run according to the Royal and Ancient Golf Club of St. Andrews throughout

the world, except for the USA where the game has been legislated by the United States Golf Association. In Australia, golf is governed by the Australian Golf Union which originated from a meeting held at Royal Melbourne Golf Club in 1898 between interstate representatives. The Australian Ladies' Golf Union was established in 1921.

Horse racing appears to have been confined to the early chariot races of the Greeks and Romans. The first recognisable race meeting was held at Smithfield, London, in 1174. The first prize money was a purse of gold offered by English King Richard I in 1195. In Britain the Jockey Club is the governing body of flat racing, steeplechasing and hurdle racing, after merging with the National Hunt Committee in 1968. In Australia horses came in with the First Fleet. The first race meeting was held at Parramatta, NSW, in 1810. Racing during the colonial era lapsed in 1813 when the 73rd Regiment was sent to Sri Lanka and was not restarted until 1825 when a program was held at the newly established course near Bellevue Hill, Sydney. From this site the Sydney Turf Club emerged. In 1838 the Melbourne Racing Club was formed. However it was not until 1861 that the first Melbourne Cup was run. The New Zealand Racing Industry Board (NZRIB) was established in 1991, and now conducts over 600 race meetings annually (Williams, 1994).

Lacrosse is thought to take its beginnings from the early Plains Indians of the United States who played baggataway on the grassed plains and prairies. Early French settlers thought the throwing instrument used by the Iroquois Indians resembled a bishop's crozier and gave the game the French equivalent of 'La Crosse'. Another interpretation is that French settlers may have named lacrosse after their game Chouler a la crosse, played in France as early as 1381. Certainly lacrosse had reached Europe by the 1800s and England by 1867. In North America the first

England, where it combined polo, lacrosse and netball, and was introduced to Australia in 1938 by Edward Hirst of Ingleburn, NSW. The early sport of polo, which also involves horse and rider, had its origins in Manipur State, India, circa. 3100 BC when it was played at Sagol Kangjei. Polo was introduced to England from India in 1869 and now has a keen following in the United States, Argentina and Australia.

Table 1.1 Turfgrass time line for Australian grass sports (1800–1900) (adapted from Blanch, 1978; Anon., 1983)

1802-3	First recorded game of cricket organised by officers of the HMS <i>Calcutta</i> in Sydney, NSW.		The Tasmanian Horse Racing Club established. The South Melbourne and North Melbourne Australian Rules Clubs are founded. Lacrosse is first played in Australia. First women's cricket played at Bendigo, Victoria. First lacrosse game in Melbourne.
1810	First race meeting at Parramatta, Sydney on 30 April; second meeting was at Sydney's Hyde Park on 15, 17 and 19 October, organised by officers of the 73rd Regiment.		
1820s	First golf match in Australia at Ratho, Bothwell, Tasmania.		
1826	First Australian Cricket Ground, Sydney Racecourse, now Hyde Park.		
1829	First Rugby football played as 'an amusement for the military' in Sydney, NSW.		
1830	First steeplechase race in Australia.		
1832	First Cricket Club, Hobart, Tas. Cricket was also played in Tasmania in the 1820s.	1875	The first official polo game is staged at Albert Park, Melbourne, between teams of service officers recruited from vice-regal staff. Morphettville Racecourse opens in SA. Australian Rules football is established in Tas. The Victorian Amateur Turf Club is established. Hobart Cup's inaugural horse race takes place in Tas. The Queensland Cricket Association is established.
1844	First Bowling Green, Sandy Bay, Hobart, Tasmania.	1876	Sydney Bowling Club, Government House, Domain, comes into existence. Lawn bowls come to South Australia.
1845	First Bowling Green, 'Bowling Green Hotel', Melbourne, Victoria. First Bowling Club in NSW, 'Woolpack Inn', Petersham, Sydney. First Bowling Club, 'Boundary Road Hotel', Surry Hills, Sydney.	1877	First Test between England and Australia played in Melbourne. Victorian Football Association formed.
1856	American miners who migrated to Australia and the goldfields at Ballarat, Vic., introduce baseball.	1878	Tennis is first played at the Melbourne Cricket Club. The Sydney Lawn Tennis Club is established. First white Australian cricket team tours England.
1858	First reported Australian Rules match between Melbourne Church of England Grammar School and Scotch College, Melbourne.	1879	First lawn tennis match at Melbourne Cricket Club. First lacrosse team is established in Melbourne. First lawn tennis court is built in Melbourne. Southern Tasmanian Football Association is founded in Hobart.
1864	Melbourne Bowling Club established.	1880	First Victorian Tennis Championships held at Melbourne Cricket Club. First soccer club is founded in Parramatta, Sydney. First match between Clubs Wanderers and King's School, Australian Rules football begins in NSW. First golf match is played in Queensland. Formation of the New South Wales Bowling Association.
1868	First Australian cricket team to tour overseas. First Australian Croquet Club, established in Kapunda, South Australia.	1881	Victoria wins NSW/Victoria intercolonial cricket match. NSW plays first intercolonial Rugby Union match against Queensland. NSW wins. First women's lawn bowls competition is held in Melbourne. First Queensland bowling club at Booroodabin.
1869	First golf course, Adelaide, with nine holes is constructed.		
1871	First Brisbane Cup is run at Eagle Farm. Tasmanian Turf Club is established. The SA Cricket Association is established. First bowling green went down in the 1870s at the Maryborough home of James Fairlea.		
1872	The Sydney Amateur Athletic Club is established.		
1873	Adelaide Cricket Ground is opened.		
1874	First tennis court; England's Major Wingfield applies for a patent for 'portable court for playing the ancient game of tennis'. The Southern Rugby Union Football administrative body established.		

continued

Table 1.1 Turfgrass time line for Australian grass sports (1800–1900) (adapted from Blanch, 1978; Anon., 1983) *continued*

1882	NSW Soccer Association formed. The first golf club in Australia, the Australian, formed in NSW. Victorian Lacrosse Championships are first held. South British Football Soccer Association is established.		
1883	Launceston Bowling Club, Tas., established. Moonee Valley Cup is first run in Melbourne. Footscray Australian Rules Club is established in Melbourne. Queensland's first soccer team, the Rangers, establish a club.	1890	Park Lawn Tennis Club is established in Victoria. NSW Lawn Tennis Association is founded.
1884	Canterbury Racecourse opens in Sydney. First Lacrosse Club established in NSW. Fitzroy Australian Rules Club is established in Melbourne.	1891	Caulfield Golf Club is established in Melbourne.
1885	Rosehill Racecourse opens in Sydney.	1893	Royal Sydney Golf Club is completed.
1886	First women's cricket match played at Sydney Cricket Ground.	1894	First men's golf championship is held in Melbourne. First Croquet Club formed in Melbourne (Lilydale).
1887	NSW Amateur Athletics Association is formed. Wallsend Rovers soccer club is established in NSW.	1895	The first lawn bowling green opens in Perth. Perth Golf Club is founded.
1888	First state athletic meet is held in Sydney. The Queensland Lawn Tennis Association is established.	1896	Newlands Golf Club is founded in Tasmania. Eight Football Association Clubs form the Victorian Football League.
1889	Rugby Union Football is established in Victoria. Grace	1897	Adelaide Lawn Bowling Club is established.
		1898	The Australian Golf Union is established. The first women's bowling club is established in Rainsford, Victoria.
		1899	Albert Park Ladies Bowling Club, Melbourne, is established. The first polo club in Australia, Northern Challenge Polo Club, is established in NSW.
		1900	First game of hockey played between officers and ratings of Royal Navy ships stationed in Adelaide.

Turf research

American W. J. Beal initiated the first acknowledged turfgrass evaluation trials at the Michigan Agricultural Experiment Station in the United States around 1880. These were followed in 1886 by further evaluation trials at New Haven, Connecticut. In 1890 lawn grass experiments were commenced by J. B. Olcott of South Manchester, Connecticut (Olcott, 1890). By 1890 the Rhode Island Agricultural Experiment Station had commenced some lawn experiments and had them extended in 1905. In 1894 the US Golf Association was formed, the Professional Golf Association in 1916, the Green Section of the USGA in 1920, and the Golf Course Superintendents Association of America in 1926. The USGA Green Section was also responsible for the laying down of turf experiments at Arlington, Virginia, which were directed primarily toward the requirements of golf. Today turf research is conducted at a number of universities in North America including The Guelph Turfgrass Institute and the Department of Horticultural Sciences, University of Guelph, Ontario, Canada,

and in the United States, Michigan State University, East Lansing; Texas A&M University, College Station; Mississippi State University, Mississippi State; and The University of Georgia, Griffin, as well as government agencies such as the United States Department of Agriculture.

In Britain efforts were made as early as 1924 by the Royal and Ancient Golf Club to form a consultative body on greenkeeping. However it was not until 1929 that the Joint Advisory Council of the British Golf Unions established the world's first turf research station on the St. Ives estate at Bingley, Yorkshire (Dawson, 1929). In 1951 the original Board of Greenkeeping Research was re-organised into the Sports Turf Research Institute (STRI). In the United Kingdom turf research is also being undertaken at such institutions as the Institute of Biological Sciences, the University of Wales; The Institute of Grassland and Environmental Research, Plas Gogerddan, Aberystwyth; Strathclyde University, Glasgow; and the School of Biological and Earth Sciences, Liverpool John Moores University, Liverpool. The Amenity Grass Committee

(NERC, 1977) listed among their research priorities, the standards of management and measurement, establishment and renovation, species and cultivar selection, mowing and growth control, fertilising, wear, weed control, and use of semi-natural areas.

The South African effort commenced with the establishment of a few grass greens in the Durban area in 1891. C. M. Murray of Capetown pioneered much of the early turf research in the early 1900s when he established bermudagrass greens at the Royal Cape Golf Course. It is thought that bowls were first introduced to South Africa in the early 1800s with the establishment of The Port Elizabeth Club, in Port Elizabeth (Louw, 1996). It was not until 1933 that The University of Witwatersrand, Frankenswald Turf Research Section, in Johannesburg, commenced investigative work in turf.

Turf research is also being undertaken in other parts of the world. For example, in Japan, through the Chiba University and the Japan Turfgrass Inc, Chiba, the Institute of Biological Research, Yokohama City University, Yokohama-City; in the Peoples Republic of China through the Institute of Turfgrass Science, China Agricultural University, Beijing, and the Hangzhou Botanical Gardens; Germany through the Department of Crop Production and Grassland Science, University of Hohenheim, Stuttgart, and the INRA-Station d'Amelioration des Plantes Fourageres, Lusignan, France.

In Australia, early reports given by Department of Agriculture agrostologist, F. Turner (1891), made mention of the native weeping grass (*Microlaena stipoides*) as a grass having potential as 'a close turf', and couch (bermudagrass) (*Cynodon dactylon*), as the most 'valuable pasture grass on the eastern side of the Great Dividing Range' in New South Wales. King (1902) conducted research on a number of cool-season grasses in south Gippsland in south-eastern Victoria early in the 20th century.

Those of turf interest were the cool-season grasses, meadow fescue (*Festuca pratense* or *F. elatior*), tall fescue (*Festuca arundinacea*), rough-stalked meadow grass (*Poa trivialis*), crested dogstail (*Cynosurus cristatus*), Italian ryegrass (*Lolium multiflorum*), Kentucky bluegrass (*Poa pratensis*), red fescue (*Festuca rubra*), sheep's fescue (*Festuca ovina*), hard fescue (*Festuca ovina*) and chewings fescue (*Festuca rubra* L. var. *commutata*). In 1906 work was being carried out on the grasses, paspalum (*Paspalum dilatatum*), Kentucky bluegrass, Italian ryegrass, and perennial ryegrass (*Lolium perenne*) at Wollongbar, New South Wales (Gorman, 1906). By 1909, meadow fescue and small patches of tall fescue were sown down in the Shoalhaven and Milton areas in New South Wales, principally for pasture use for the fledgling dairy industry (Gennys, 1909). Early work on Australia's native grasses for pasture production was also carried out by Baron von Mueller in the Royal Melbourne Botanic Gardens, and a Mr Bacchus near Ballarat, Victoria.

It was not until the 1930s that three eastern Australian states were setting the agenda for addressing the need for turfgrass information, particularly for golf clubs. The Victoria Golf Association (VGA) had been investigating field trials on several Melbourne golf courses since 1938 (Beehag, 1994). In 1970 this organisation, as well as the Royal Victorian Bowling Association (RVBA), lobbied the Victorian government to establish The Turf Research and Advisory Institute (TRAII) in 1973. The Institute remained part of the Victorian Department of Agriculture until 1992 when it ceased to operate. In 1935, the NSW Golf Council, and predecessor to the NSW Golf Association, published the first issue of its turf newsletter 'The Bulletin'. In 1954 the same Association formed the Grass Research Bureau (NSW) Ltd., at Ryde, NSW, and provided funding to support the part-time teachers of greenkeeping to conduct basic research and offer advice to golf

clubs. By 1955 the Bureau had established its first newsletter 'Grass Research'. One year later the Royal New South Wales Bowling Association (RNSWBA) commenced contributing to the financing and administration of the Grass Research Bureau. In 1970, the Grass Research Bureau was re-named the Australian Turfgrass Research Institute Ltd (ATRI) (Beehag, 1994). In Queensland, experimental work had commenced as early as 1934 by a small group of golf course enthusiasts. By 1936 the newsletter 'The Australian Greenkeeper' was in production. Currently little research is conducted into warm-season turfgrasses in Queensland.

In Australia, turf research is currently being undertaken by institutions such as the Cooperative Research Centre for Soil and Land Management, and The University of Adelaide, in South Australia; the CSIRO Plant Industry, Canberra; Turfgrass Technology Pty. Ltd., and The University of Melbourne-Burnley in Victoria; the Department of Crop Sciences, The University of Sydney, the Australian Turfgrass Research Institute Ltd. and the Agricultural Research Institute, Wagga Wagga, in NSW; and through CSIRO Tropical Agriculture, Brisbane, Queensland. In 1935 the New Zealand Golf Association established a Greenkeeping Research Committee. In 1949 this committee was re-organised as the New Zealand Institute for Turf Culture and has since been re-named The New Zealand Sports Turf Institute. The majority of turf research in New Zealand is carried through this organisation, often in partnership with other research organisations.

Turfgrass training and education

Degree and diploma courses in turf management are of long standing in universities, polytechnics and colleges in Canada, the United States, Britain, Australia and New Zealand (Aldous, 1997). There

is also a tradition of turf management training in South Africa, Switzerland, Germany, France, Japan, Italy and Sweden, and the development of programs in other countries, such as Singapore, China and Malaysia. In the United States, turf management programs are available through a number of universities, either as a four-year program, or as two-year programs at community colleges. The university system also has provision for a comprehensive graduate education program in turfgrass science. The academic structure in Canada is similar to that of the United States with turf management available through colleges and universities. In Britain, as well as Australia and New Zealand, education and training is available at either technical and further education (vocational) level, as well as university level. Vocational training is available at some 26 colleges in Britain at N/SVQ Levels 2 to 4, and as a National Certificate and Diploma. In Australia, vocational training in turf management at National Certificate levels 1 to 6, are offered principally through the Institutes of Technical and Further Education. Britain's higher education institutions also offer turf management training at the Higher National Certificate and Diploma level, and as Bachelor of Science modules. In Australia there are no first degrees in turf management but introductory turfgrass science and management may be taken through the Universities of Sydney and Melbourne, as part of the baccalaureate degrees in agriculture and horticulture, as well as graduate diplomas and postgraduate studies. In New Zealand, turf management is available as a Diploma in Turf Culture or polytech short course level of qualification (Way, 1994), as well as a senior subject in the Bachelor of Applied Science degree and Diploma of Rural Studies at Massey University in Palmerston North.

Many institutes and associations continue to play a significant part in the training of turf personnel. For example the Canadian Golf Course Superintendents Association (CGCSA) and United

States Golf Association (USGA) provide such training, often in association with local Colleges, Institutes and Universities. In Australia these organisations include Parks and Leisure Australia (PLA), the Australian Golf Course Superintendents Association (AGCSA), and Turfgrass Technology Pty. Ltd; in New Zealand, the New Zealand Sports Turf Institute; and in Britain, the Institute of Leisure and Amenity Management (ILAM) and the Institute of Groundsmanship (IOG). Five countries offering the major turfgrass education and training programs, by population, gross domestic and national product, and estimated student and staff numbers in certificate, diploma, degree and postgraduate training in turf management, are summarised in Table 1.2.

Future growth and development in the turfgrass industry will require the implementation of a balanced set of education and training policy measures, based on industry requirements and implemented in line with labour planning requirements. It is also important that a career structure be developed that enables people in the

turfgrass industry to establish and progress through career goals consistent with their aspirations and ability. To achieve this universities, community colleges, polytechnics and institutes of technical and further education must maintain strong contacts with the turfgrass industry. In turn, the industry must also be more involved with the substance and monitoring of turf management programs and the placement of graduates, diplomats and operators.

The turfgrass industry

Nutter (1965) described the turfgrass industry as comprising the production and maintenance of specialised grasses and other ground covers as required in the development, maintenance and management of facilities for utility, beautification and recreation. In 1969, Nutter and Watson analysed the industry under four sections: (1) facilities or agencies that deal with the management and maintenance of turfgrass; (2) manufacturing, or the provider of turf products to

Table 1.2 Comparison of selected socio-educational characteristics between Australia, New Zealand, Canada, the United States of America, and the United Kingdom in Turf Management (after Aldous, 1997).

Item	Australia	New Zealand	Canada	United States of America	United Kingdom
Population (1990) — millions	18	3.5	26.5	250	57
Values					
Gross Domestic Product (\$US)	16 050	13 490	19 650	21 360	14 960
1990 — (per person)					
Gross National Product (\$US)	242 131	39 437	500 337	5 237 707	834 166
1989 — millions					
Estimated students numbers (1996) ¹					
Postgraduate degree number per 100 000 pop'n	2.9	4.6	15.7	10.6	1.7
Diploma number per 100 000 pop'n	13.3	28.6	18.1	14.8	14.6
Certificate number per 100 000 pop'n	77.8	142.5	45.3	20.0	26.5
Estimate total enrolled	1690	616	2080	11 350	2438
Academic turf management staff employed for degree and vocational programs (full-time equivalents) ²	0.5–3.5	0.5–1.5	1.0–8.0	0.4–7.5	2.0–13.0

1 Student estimates from academic and vocational programs majoring in turf management, as well as courses having only an introductory program in turf management.

2 Staff estimates only.

the industry; (3) servicing, or those that use the products and facilities; and (4) institutions, which provide education, extension and research expertise in advancing the turf management industry. Facilities that include turf in the landscape are many and wide ranging: airports, athletic fields, bowling and croquet greens, the grounds and athletic fields of universities, community colleges and institutes, lawn cemeteries, crematoria and memorial parks, churches and synagogues, courthouses and governmental buildings, exposition and fairgrounds, garden apartments, golf courses and driving ranges, grass tennis courts, highway median strips, roadside verges, hospitals and nursing grounds, hotel, motel and caravan parks, housing projects and subdivisions, industrial parks and estates, commercial, industrial and residential lawns, military bases, parks and playgrounds, racecourse and tracks, retirement villages, schools (kindergarten, primary and secondary), zoological and botanic gardens, and the natural estate. The manufacturing sector involves machinery, equipment aides for sowing, mowing, fertilising, topdressing, irrigating, rolling, spraying, fertilisers and nutrition, growth regulator chemicals, irrigation system components, pesticides, seed and vegetative materials, instant lawn, computers, and special products such as soil components and amendments. The servicing section involves people associated with sales, distribution, retail (all products), contracting and consultancy services, architects and designers, maintenance, and soil and water testing laboratories. The institutional section includes the universities, polytechnics, colleges, trade and professional organisations, both private and publicly funded, that provide relevant teaching, research and extension for the industry.

Land area, labour and wealth

The value of the industry has been difficult to quantify, both from the value of the land, its labour requirements, as well as the benefits that

turf contributes to human physical and mental health, health and safety, and improving the environment. Some attempts have been made to determine the value of the turfgrass industry in a number of countries. In 1965, American Gene Nutter estimated that turfgrass maintenance expenditure in the United States was \$US4 326 546 994 to maintain more than 20 million acres of its major turfgrass facilities. This value constituted eleven categories of specialty turfgrass use, namely, airfields, lawn cemeteries, commercial, industrial and residential lawns, churches, colleges and universities, golf courses, roadsides, municipal parks, public schools, and miscellaneous areas. Labour, equipment and water were the major expenditures in the 1965 survey. In 1993, the US Environmental Protection Agency, DPRA Inc., in Manhattan, Kansas, estimated that the current turf acreage (based on the assumption that turf acreage is directly proportional to the population) was 46.5 million acres, with maintenance expenses ranging from \$US58 per acre (roadsides) to \$US1651 per acre (golf courses). In addition the US Department of Commerce, Bureau of the Census, estimated that more than 4.3 million American households now purchase in excess of \$US420M of turfgrass sod annually.

In 1895, there were 80 golf courses in the United States and by 1920, 477 member clubs. In 1997 there are now over 0.53 million hectares of high-use turf managed on 15 000-plus golf courses in the United States (Haydu *et al.*, 1997). Research studies conducted in Florida between 1974 and 1994 indicated that total maintenance costs rose from \$US2818 per hectare to \$US8855 per hectare for the golf course industry. However when adjusted for inflation, the differences in these costs were much smaller (Haydu *et al.*, 1997). In Florida alone, total employment in the turfgrass industry amounted to 130 000 full-time equivalent employees (FTEs), which is three times as great as all other agricultural industries

in the state (Hodges *et al.*, 1997). Annual labour costs averaged \$US1542 per hectare (\$US624 per acre) of turfgrass maintained or \$US10 825 per FTE employee.

Britain's amenity grasslands, which have been defined as grasslands having a recreational, functional or aesthetic value, and which are not primarily used for agricultural production. These grasslands constitute 8500 square kilometres in area with maintenance costs of 137M pounds (NERC, 1977). In 1973 there was an estimated 490 square kilometres of school playing fields, 871 square kilometres of golf fairway, greens, tees and roughs, and 1345 square kilometres of urban parks and open spaces in Britain (NERC, 1977). Semi-natural and amenity areas account for an estimated 586 187 hectares, ten per cent of which is golf course rough and intensively managed amenity grassland (Cobham, 1983). In 1989, the Institute of Horticulture in Britain estimated that the number of employees in the amenity horticulture area, in which turf is included, was up to 32 920 people. In the public sector 28 797 of these individuals were employed in urban parks and open spaces, 2800 in sports facilities, and 808 in public golf courses. In 1992 the British Association of Landscape Industries reported that some 13 500 individuals were employed in the field of landscaping and grounds maintenance, followed by 11 000 in golf and greenkeeping, and 4000 as curators of pitches at independent schools and universities (Anon, 1995). Bowling green curators, horse and greyhound racetrack greenkeepers only constituted 1000 and 220 employees respectively. In 1992, the European Golf Association quoted in 'Golf Enterprise Europe' that the number of golf courses in Europe was 1750, which included France (425), Germany (329), Sweden (257), Spain (131), Netherlands (119), Italy (117), Finland (71), Denmark (69), Austria (55), Belgium (49), Switzerland (40), Iceland (37), Portugal (26), Norway (19), Greece (5) and Luxembourg (1).

In Australia, some 180 000 hectares of land are dedicated to high-use turf, with established annual maintenance costs of \$A1.3 billion. This is exclusive of the capital costs in establishing new facilities, as well as the annual costs of maintenance of the more naturalised amenity grasslands. In 1996, McIver estimated that there were 1500 golf courses covering 48 000 hectares and employing 6500 maintenance staff; 2000 lawn bowling clubs employing 3000 greenkeepers to maintain 3200 greens, a total of 450 hectares, and a turfgrass sod industry of 200 primary production farms of over 5000 hectares. In addition, there were 748 city and shire councils each maintaining playing fields, parks, gardens and golf courses. Valuations placed on the land used for sports turf in Australia are in the order of \$A4.5 billion, or an average of \$25 000 per hectare of sports turf. These land values range from \$A130 000 to 140 000 per hectare for bowling and croquet clubs to golf courses at \$A3700 per hectare. In addition, the sod production industry in eastern Australia has an estimated market value in excess of \$A100 million per annum (Martin and Aragao, 1996), with smaller numbers of sod farms also found in Tasmania, South Australia and Western Australia. Results indicate that there is the equivalent of one hectare of sports turf to every 100 Australians, which equates favourably with 85 New Zealanders (Way, 1994), 500 Americans, and 769 Britains (McLaughlin, 1994).

Sports turf in New Zealand is managed over 40 000 hectares of sports turf and 61 000 hectares of non-sports turf, with an established total worth of \$NZ86 million per annum (Dale, 1994; Way, 1997). Golf courses constitute the largest proportion (42 per cent), then schools' sporting fields, followed by councils and racing clubs. There are over 400 golf courses in New Zealand, which provides one course for every 8750 people. The total value of expenditure for New Zealand turf has been estimated at \$NZ86.3

million with labour constituting just under half of this amount. New Zealand employs approximately 3200 grounds staff, with one-third of those employed on a part-time basis. New Zealand golf clubs employ 1.6 full-time workers per course with voluntary workers contributing a significant part of the workforce. Bowls in particular is the major beneficiary of voluntary workers, but also golf, racing clubs, croquet and other users, all have significant contributions from volunteers. The horse racing industry in large in New Zealand, employing some 28 000 people, and has an export income of approximately \$NZ69 million (Williams, 1994).

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CHAPTER 2

Turfgrass identification and selection

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Introduction

One of the largest angiosperm families, the *Poaceae*, contains approximately 785 genera and 10 000 species (Watson and Dallwitz, 1992). Sixteen genera are found within this family, and about 40 species in the subfamilies of *Eragrostioideae*, *Festucoideae* and *Panicoideae*, contain the world's principal turfgrasses. The *Festucoideae* contain the main cool-season turfgrasses, such as the fescues (*Festuca*) and bluegrasses (*Poa*), while the *Eragrostioideae* and *Panicoideae* contain examples of the main warm-season turfgrasses, such as the bermudagrasses (*Cynodon*), and Queensland blue couch (*Digitaria*). However less than 30 of all these grass species have the desirable

characteristics to be maintained as turfgrasses worldwide (Beehag, 1995b). The taxa used in grass classification are illustrated in Table 2.1.

The need for classification has largely arisen because of the uncertainty of like grasses bearing different names, and to remove confusion in identifying other grass-like species. For example, in Australia, common couch (*Cynodon dactylon*) is better known as bermudagrass in the United States, skireek grass in South Africa, neguil in Egypt, ohoob or doob in India and serangoon in Malaysia. Similarly, nutgrass (*Cyperus rotundus*); Family *Cyperaceae*, mullumbimby couch (*Kyllinga brevifolia*); Family *Cyperaceae*, onion weed (*Nothoscordum inordinum*); Family *Amaryllidaceae*,

Table 2.1 Taxa used in the classification of tall fescue (*Festuca arundinacea*) cv. SR.8200 and Queensland blue couch (*Digitaria didactyla*) (adapted from Beard, 1973).

Trinomial: <i>Festuca arundinacea</i> Schreb. SR. 8200		Trinomial: <i>Digitaria didactyla</i> Willd.	
KINGDOM	Plantae, plant kingdom.	KINGDOM	Plantae, plant kingdom
DIVISION	Embryophyta, embryo plants	DIVISION	Embryophyta, embryo plants
SUBDIVISION	Phanaerogame, seed plants	SUBDIVISION	Phanaerogame, seed plants
BRANCH	Angiospermae, seeds enclosed in ovary	BRANCH	Angiospermae, seeds enclosed in ovary
CLASS	Monocotyledoneae, monocotyledons	CLASS	Monocotyledoneae, monocotyledons
SUBCLASS	Glumiflorae, having chaffy leaves	SUBCLASS	Glumiflorae, chaffy leaves
ORDER	Poales, grasses and sedges	ORDER	Poales, grasses and sedges
FAMILY	Poaceae, grass family	FAMILY	Poaceae, grass family
TRIBE	Festuceae, fescue tribe	TRIBE	Paniceae
GENUS	Festuca, fescues	GENUS	Digitaria
SPECIES	arundinacea	SPECIES	didactyla
CULTIVAR	SR.8200	CULTIVAR	none available

and rushes (*Juncus spp.*); Family *Juncaceae*, are all grass-like in appearance. The structural features

that provide a basis for separating the *Poaceae* from the *Cyperaceae* and *Juncaceae* are listed in Table 2.2.

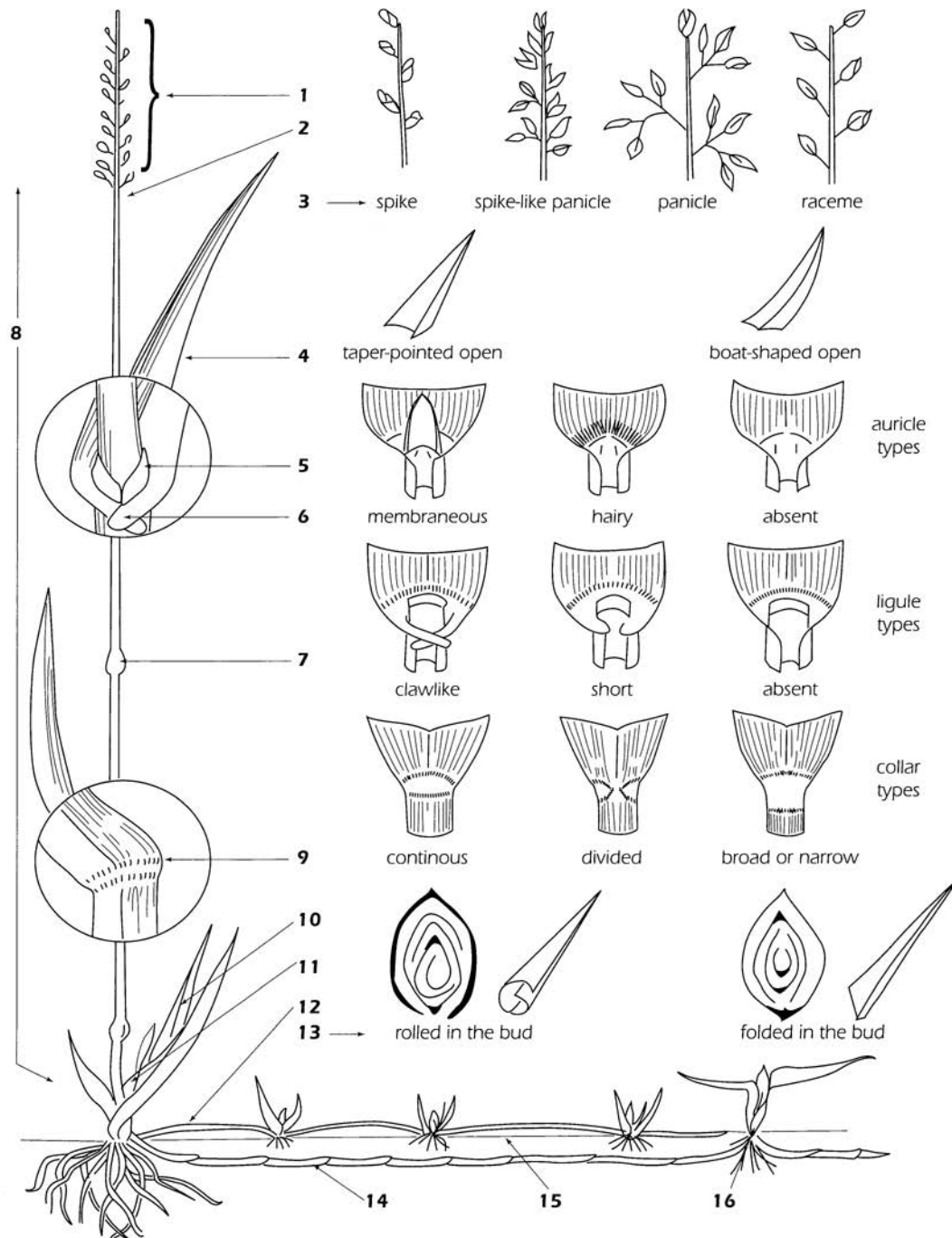


Figure 2.1 Grass plant showing typical structures: 1 inflorescence, 2 rachis, 3 inflorescence types, 4 blade, 5 ligule, 6 auricle, 7 node, 8 culm, 9 collar, 10 tiller, 11 crown, 12 stolon, 13 vernation, 14 rhizome, 15 internode, 16 new shoot

Table 2.2 Morphological and anatomical features separating the *Poaceae*, *Cyperaceae*, and *Juncaceae* families (adapted after Lambrechtsen, 1986).

	GRASSES (<i>Poaceae</i>)	SEDGES (<i>Cyperaceae</i>)	RUSHES (<i>Juncaceae</i>)
Leaf whorl	(Top view)–two rows	(Top view)–three rows	(Top view)–two rows
Leaf sheath	Usually split	Never split	Sometimes split, sometimes closed
Leaf blade	Flat, rolled	Folded	Usually not present expanded
Leaf margins	Rough or smooth	Rough	Smooth
Leaf bud (vernation)	Round or oval in cross section, rolled or folded in bud Hollow internodes Interrupted by nodes	Triangular in cross section Not hollow, Round nodes inconspicuous	Round in cross section Not hollow Inconspicuous nodes

The classification system is related to a pattern of nomenclature at the genus level. Further division takes place at the genus and species level. For example, bermudagrass belongs to the Family *Poaceae*, the genus *Cynodon*, and species *dactylon*. In selecting the species name, in most instances botanists have given some indication of the appearance of the plant, its geographic habitat or indicated the person who either discovered, described, or assisted with introduction of the plant. For example, South African couchgrass (*Cynodon transvaalensis*), originated in the Transvaal region of South Africa. The scientific name is then followed by the authority (or authorities) credited with naming the species. For example, Kentucky bluegrass, *Poa pratensis* L., the L. referring to the Swedish botanist Carolus Linnaeus (1707–78), who identified this species and published the name in *Species Plantarum* in 1753. In other cases the botanical name has become the common name, such as with *Poa annua*, also called winter grass or annual bluegrass.

Identification of turfgrass genera and species

The typical grass structure is illustrated in Figure 2.1. The vegetative plant parts of a grass given

here are essential to an understanding of the family and to the use of keys for identification.

Auricle: outgrowths of the edge of the leaf occurring in some grasses from either side of the collar at the junction of the leaf; present in varying sizes and shapes, or may be absent.

Awn: slender hairlike projection(s) arising from small flowers of grasses; variable in length and texture.

Blade: the extended upper portion of the leaf beyond the sheath; present in cross-section as flat, v-shape, thread-like; blade tip as sharply pointed, boat or canoe shape; leaf surface and margin as hairy, saw-like; and leaf colour as light to dark green.

Collar: strengthening tissue at the back of the ligule, immediately above the leaf sheath, often a different colour from the rest of the leaf blade; present as a broad, narrow or divided band.

Crown: refers to the junction of the root and stem, usually at ground level.

Culm: the stem of grasses and sedges.

Fibrous or bunch root system: a root system in which the roots are finely divided, usually in a clump.

Inflorescence: refers to the part of the turfgrass that consists of the flower bearing stalk.

Internode: refers to the stem section between the swollen nodes, often hollow.

Keel: leaf shape of lower surface of the leaf; protrudes like the keel of a boat or canoe.

Lateral shoot: Shoots originating from vegetative buds in the axils of leaves or from the nodes of stems, rhizomes or stolons.

Ligule: the small membrane or ring of hairs that occurs on the upper side of the leaves, just at the junction of the leaf blade and the sheath and wraps around the stem; reduced or absent in some species; present as fringe of hairs, acute, truncate or ciliate.

Margin: refers to the outside edges of the leaf blade.

Midrib: central vein of the blade of the leaf, often forming a pronounced ridge on the upper surface and a keel below.

Node: refers to the point of the plant stem from which the leaves or lateral stems grow.

Panicle: an open, often branched and spreading flowering structure; one type of common inflorescence.

Papery bracts: a series of small dry structures that surround or enclose the seed of almost all grasses.

Perennial: a plant that lives for an indefinite number of growing seasons; usually propagated vegetatively, perhaps seed; may or may not flower the first growing season, but continues to grow and flower thereafter.

Rhizome: refers to a horizontal, non-green, underground creeping stem. Often has short, scale-like leaves and may produce roots and/or leafy shoots from the nodes. Turf-grasses bearing them exhibit a rhizomatous habit of growth.

Rachis: the axis of the inflorescence.

Scabrous: rough and harsh to the touch; often show short stiff bristles or saw-like teeth on the part concerned.

Sheath: refers to that part of the leaf originating from the node, and surrounds part of the stem. It can be cylindrical or compressed with overlapping, open or closed margins. The leaf

sheath may be split, split to near base with margins overlapping or closed.

Spike: a narrow and usually longer than wide inflorescence, the flowers borne along one stem.

Spikelet: the small flowering unit of grasses, consisting of a series of bracts placed one inside another, attached to a branch of the main flowering stem. There are many spikelets in one inflorescence.

Stolon or runner: refers to the horizontal stem, usually prostrate or trailing at ground level, always above the ground, often rooting at the nodes. Turf plants bearing them exhibit a stoloniferous habit of growth.

Tiller: a shoot or stem that arises from the base in grasses. Termed vegetative tiller if it produces leaves only, and a flowering tiller if it bears an inflorescence.

Vein: refers to the specialised organs which conduct plant foods to the sheath and leaf, and which removes from these organs, substances synthesised under the action of photosynthesis. Often prominent on the upper surface of the leaf blade.

Venation: refers to the veins running parallel to the apex of the blade. Some species have distinct mid-veins, while others have veins uniformly distributed across the leaf. The prominence of venation, on the upper and lower leaf surface, is useful in identification.

Vernation: refers to the arrangement of the youngest leaf in the bud shoot; either folded (conduplicate) or rolled (convolute) in bud-shoot.

Use of turfgrass key

A key is an artificial guide used to separate out unknown grasses. Keys are typically dichotomous, composed of couplets of two sentences with the same letter. Keys are intended to cover only a restricted number of grasses for which

detailed descriptions have been carried out, and are not designed to provide a positive means of identification. However by using the couplets, and by the process of elimination, a point is arrived where you may be reasonably sure of the result. Confirmation requires a more detailed description.

To use this key, which has been adapted from Nowosad, Swales and Dore (1936), and Hanson, Juska and Burton (1969), begin with the first set of couplets, either Group 1 or Group 2. Group 1

describes the specimen as being leaf venation folded in the bud, whereas in Group 2 the leaves are rolled in the bud. If the specimen has a folded bud shoot, the user then proceeds to A. Auricles present, where there will again be two alternatives, i.e. Auricles present or AA. — auricles absent or small. Choose the one which applies, and proceed on as before. Eventually the specimen will align with a scientific name. If unsuccessful, study the specimen carefully, or use another representative specimen, and commence again.

Table 2.3 Vegetative identification key for naming some common turf and amenity grasses.

Group 1. Leaf venation folded in bud

- A. Auricles present
 - B. Blade glossy on under surface; margin of ligule not hairy; auricles blunt to claw-like
 - C. Auricles with short hairs *Festuca arundinacea* (**tall fescue**)
 - CC. Auricles glabrous
 - D. Blade scabrous on margins, ligule generally < 0.5 mm long *Festuca elatior* (**meadow fescue**)
 - DD. Blade smooth on margins near base, ligule generally 1.0 mm + *Lolium multiflorum* (**Italian ryegrass**)
 - BB. Blade not glossy on under surface; margin of ligule hairy; auricles, clawlike
 - C. Collar slightly pubescent; midrib not prominent on under surface of blade; upper surface not prominently ridged *Agropyron repens* (**twitchgrass**)
 - D. Collar smooth; midrib conspicuous on under surface of blade; upper surface of blade prominently ridged *Agropyron cristatum* (**fairway wheatgrass**)
- AA. Auricles absent or small
 - B. Ligule a fringe of hairs *Zoysia japonica* (**Japanese lawngrass**)
 - BB. Ligule membranous
 - C. Sheath closed
 - D. Sheath and blade smooth *Bromus inermis* (**smooth brome**)
 - DD. Sheath and blade hairy
 - CC. Sheath split (margins generally overlapping)
 - D. Hairs present on sheath, blade, or collar
 - E. Sheaths compressed
 - F. Sheath smooth *Digitaria ischaemum* (**smooth crabgrass**)
 - FF. Sheath hairy
 - G. Stolons or creeping stems present *Digitaria sanguinalis* (**large crabgrass**)
 - GG. Stolons absent
 - H. Blade, soft, flat, short, hairy on upper surface *Holcus lanatus* (**Yorkshire fog**)
 - HH. Blades not dense, short hairy on upper surface
 - I. Ligule with dense row of whitish hairs at back *Paspalum notatum* (**bahiagrass**)
 - II. Ligule without whitish hairs at back
 - J. Ligule rounded to acute; sheaths very hairy below, sparsely above *Paspalum dilatatum* (**dallisgrass**)
 - JJ. Ligule truncate; sheath slightly hairy on margins and midrib *Paspalum laeve* (**field paspalum**)
 - EE. Sheath not compressed, ligule membranous, ciliate, sometimes dense ring of hairs *Bouteloua curtipendula* (**sideoats grama**)
 - DD. Lack of hairs on sheath, blade or collar
 - E. Ligule >1.5 mm long

continues

Table 2.3 Vegetative identification key for naming some common turf and amenity grasses. *continued***Group 1. Leaf venation folded in bud** *continued*

- F. Margin of collar slightly hairy; ligule with prominent notch on either side; culms with a bulbous base *Phleum pratense* (**timothygrass**)
- G. Margin of collar smooth; ligule without a notch on either side; culms lack bulbous base
- G. Ligule white, papery, 2.0–8.0 mm long, acute or obtuse; leaf blade 6.0–15.0 mm wide *Phalaris arundinacea* (**reed canarygrass**)
- GG. Ligule-thin membranous, 1.5–4.0 mm long rounded or acute; blade 1.5–7.0 mm long
 - H. Stolons absent; rhizomes present *Agrostis alba* (**redtop**)
 - HH. Stolons long, prostrate *Agrostis stolonifera* (**creeping bentgrass**)
- EE. Ligule short (<1.5 mm long), truncated
 - F. Blade 1mm wide, smooth upper and lower surface *Agrostis canina* (**velvetgrass**)
 - G. Blade 2.0–3.0 mm wide, smooth to rough on upper and lower surface *Agrostis tenuis* (**colonial bentgrass**)

Group 2. Leaf venation rolled in bud

- A. Auricles present; lower sheaths reddish at base; smooth throughout *Lolium perenne* (**perennial ryegrass**)
- AA. Auricles absent
 - B. Ligule a fringe of hairs
 - C. Sheaths greatly overlapping between nodes, rhizomes and stolons present *Cynodon dactylon* (**bermudagrass, common couchgrass**)
 - CC. Sheaths not greatly overlapping between nodes, no rhizomes, stolons present
 - D. Blade petioled above ligule *Stenotaphrum secundatum* (**St. Augustine grass**)
 - DD. Blade not petioled above ligule
 - E. Blade with few long hairs scattered on both surfaces *Buchloe dactyloides* (**buffalograss**)
 - EE. Blade without long hairs scattered on both surfaces
 - F. Blade 1.0–2.5 mm wide, sharp point, scabrous or hairy on upper surface near base *Bouteloua gracilis* (**blue grama**)
 - FF. Blade 4.0–8.0 mm wide, obtuse, smooth or hairy at base *Axonopus affinis* (**narrowleaf carpetgrass**)
 - BB. Ligule, short-membranous; short and hairy
 - C. Collar continuous, broad, hairy, turfted at lower edge *Eremochloa ophiuroides* (**centipede grass**)
 - CC. Collar divided, narrow, mostly hairy on margins *Andropogon virginicus* (**bromesedge**)
 - BBB. Ligule membranous
 - C. Hairs on margins of collar, sheath and upper leaf surface *Eleusine indica* (**crowsfoot grass**)
 - CC. No hairs at margins of collar, sheath smooth or very hairy
 - D. Blade prominently ridged on upper surface, narrow to bristle-like
 - E. Ligule < 0.5 mm or absent; sheath split; leaves smooth, blue-green; turfted *Festuca ovina* (**sheep's fescue**)
 - EE. Ligule some 0.5 mm long; sheath closed nearly at top; leaves generally dark green; not turfted *Festuca rubra* (**red fescue**)
 - DD. Blade not prominently ridged on upper surface, flat, not bristle-like
 - E. Median lines present; tip of blade canoe shaped, abruptly pointed
 - F. Ligule truncate, <1.0 mm long.
 - G. Sheath keeled, ligule usually 0.5 mm long, tapering to apex, foliage blue-green, often smooth; small hairs on margin of collar absent *Poa compressa* (**Canada bluegrass**)
 - GG. Sheath not keeled, ligule usually 0.5 mm long, blade parallel-sided; foliage deep green, not smooth; small hairs often present on margins of collar *Poa pratensis* (**Kentucky bluegrass**)
 - FF. Ligule obtuse or acute, > 1.0 mm long
 - G. Blade truncate at base and tapering to a narrow canoe-shaped tip; sheath usually scabrous; perennial *Poa trivialis* (**rough bluegrass**)
 - GG. Blade not tapering (parallel-sided), tip abruptly pointed and canoe-shaped; sheath smooth; annual *Poa annua* (**winter grass**)
 - EE. Median lines absent; tip of blade taper-pointed; blade-broad, turfted *Dactylis glomerata* (**cocksfoot**)