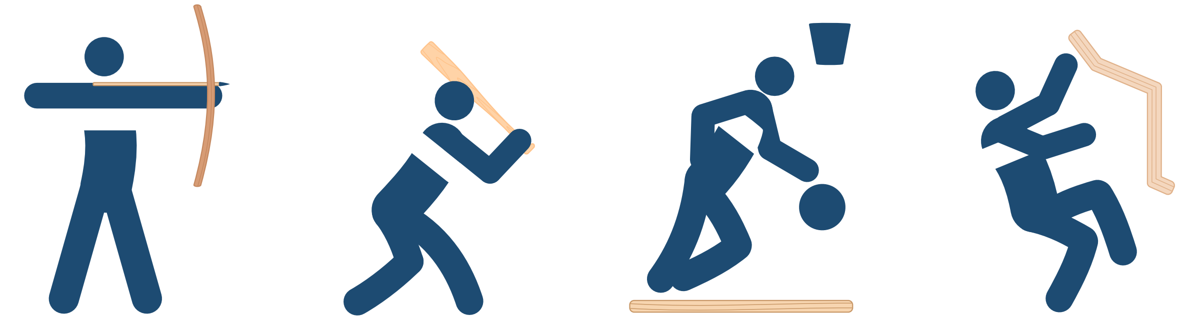

WOOD IN SPORT EQUIPMENT

HERITAGE, PRESENT, PERSPECTIVE

Edited by
Francesco Negro

DISAFA
Università degli studi di Torino

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DISAFA, University of Torino
May 2022

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The icons represent some of the sports considered in the book (including all sports would have resulted in too small images for proper visualization). The wooden equipment is outlined by the colors of the wood species from which it is made, and by lines representing the grain of wood and the characteristics of the relative wood-based products.

Edited by: Francesco Negro
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Preface

Wood in Sports is a treasure trove of interesting and valuable information for sports lovers and wood enthusiasts alike. From philosophical and ethical considerations to specialized wood technological information for individual sporting tools, there is much to be learned from this collection of essays for a broad public.

The World Wood Day Foundation (WWDF) which subsidized this project has a strong focus on the study of wood culture in past and present. Wood Culture is often seen as the use of wood in arts and crafts, but it encompasses a much broader field, from everyday use in building and packaging, to the environmentally highly sustainable burning of wood pellets and charcoal for heating, cooking and barbecuing. In that light, the use of wood in sports is definitely an important aspect of wood culture, with very ancient roots in wood used in hunting, warfare and transportation. Bows and arrows for hunting game or killing one's enemies developed into the noble sport of archery. Boomerangs and throwing clubs have not made it into modern Olympic sports, but they are together with throwing spears, and bows and arrows among the oldest wooden items in global archeology. The newly established *International Journal of Wood Culture* addresses all these aspects and is financially supported by the WWDF.

As a wood scientist and botanist, I have an extremely limited knowledge of sports. My first encounter with the subject was in 1968 when my supervisor at the Jodrell Laboratory in the Royal Botanic Gardens Kew (Greater London), Dr. C.R. Metcalfe (1904-1991) told me of his early research in the nineteen thirties into the wood structural causes of Cricket Bat Willows (*Salix alba* var. *coerulaea*) being so superior for making cricket bats, to other willow species, including alternative varieties and cultivars of the white willow. With the methodology available in 1931, no significant microscopic differences could be found between this highly priced variety and more common white willow, and I doubt whether modern research has meanwhile unraveled the mystery. This illustrates that we do not yet know all there is to understand about structure-property relationships of different wood species, and why traditional craftsmen have such strong preferences for certain species for specific end uses, also in sports utensils. They are always right of course, but I hope that the reader of this book will ask the question now and then as to why different woods are used for table tennis rackets, baseball bats, bows and arrows, and rifles.

The use of wood in heavily regulated Olympic sports has a rich history, but the role of wood in these sports has diminished over the last century and has often been replaced by metals and synthetic materials. As noted by some authors however, the use of wood has been making a comeback in recent years. This is for good reasons and thanks to two developments: 1) the realization that the lasting use of wood as a material contributes to carbon sequestration and sustainability, and 2) the emergence of new technologies, for instance the use of wood-based composites allowing the development of wooden tools of any desired combination of physico-mechanical properties. This comes above the great diversity of properties that is offered by the rich stock of timber species - thankfully not all rare and endangered - that the sports industry has at its disposal.

I congratulate the editor Dr. Francesco Negro for the great breadth and depth of subject matter, and for recruiting a number of such knowledgeable experts as authors of the specialized chapters. The World Wood Day Foundation made a wise investment when awarding Francesco's grant application.

Pieter Baas
Board Member of WWDF
Associate Editor of the International Journal of Wood Culture
Emeritus Professor of Systematic Botany at Leiden University and Naturalis Biodiversity Center, Leiden, The Netherlands

THE WORLD WOOD DAY FOUNDATION

The *World Wood Day Foundation* (WWDF, www.worldwoodday.org) is a non-profit organization established in California in 2013 to manage funds and grants to carry out the foundation's missions[1]. The WWDF is active at a global scale to raise public awareness of wood as an eco-friendly renewable biomaterial and to encourage academic research and responsible uses of wood and forests for a sustainable future.

The foundation's mission is:

- to raise public awareness of wood as an eco-friendly renewable biomaterial and to encourage academic research and responsible uses of wood and forests for a sustainable future;
- to advocate and annually celebrate World Wood Day on March 21st;
- to manage funds and grants for World Wood Day and the global research, education, and promotion of wood culture.

In particular, the World Wood Day Foundation organizes an annual celebration of *World Wood Day* (WWD) on March 21st to highlight wood, its potential, and the role it plays in a sustainable world through biodiversity and forest conservation. The day serves as a reminder of the importance and true value of wood and its responsible uses. The selected date has a special meaning since it coincides with the vernal equinox and the International Day of Forests proclaimed in 2012 by the United Nations General Assembly.

The first World Wood Day was held in 2013 in Tanzania (FIGURE I). The event is usually week-long and celebrates wood across disciplines: artists, educators, hobbyists, and industries come together from different countries, languages and cultures to share experiences, skills and passions for wood. The event focuses on various uses of wood to encourage extrapolation and eventual application to individual lifestyles throughout the year. In this view, the World Wood Day can also be seen as a platform for people to make their own contribution, however they can, to the environment and planet for a sustainable future.

Satellite events are organized in different regions throughout the year to continue the exploration and experiences. These include regional events, online streams, contests, educational activities, co-organization of congresses, etc. Overall, such activities have always been characterized by a multicultural environment and aimed at showing the beneficial effects of the conscious use of wood on both society and the environment. Efforts have been made to pass on the cultural legacy of wood craftsmanship while emphasizing the importance of sustainable forest use through academic symposia, wood craft activities, folk art workshops, children's events, design contests, and tree planting ceremonies.

Among the various initiatives, the World Wood Day Foundation has announced a Research Grant call for proposals every year since 2014. Applications from scholars and graduate students focusing on wood and culture are invited, and both ongoing projects and new initiatives are encouraged to apply. The proposals are evaluated on their originality and scholarly excellence by a group of professionals from various disciplines. The following projects have been funded over the past three years:

- 2021-2022: *Neapolitan wood craftsmanship of the 18th century: discovering ancient technologies in lutherie; Wood in sport equipment - Heritage, present, perspective;*
- 2020-2021: *Let the wood speak 2: Dendroprovenancing and Strontium analysis of*

[1] This text is taken and rearranged from the website www.worldwoodday.org (accessed on 15 January 2022). Please refer to it for further details on the World Wood Day Foundation and its initiatives.

Thule architectural woods in Northwestern Alaska at the beginning of the second millennium AD; Reconstruction of Forest management activities in prehistoric Hallstatt, Austria;

- 2019-2020: *Choice of wood in musical instruments: Italian Red Spruce and traditional mandolins; Let the wood speak: Dendro-Archaeology, Climate and Culture in Northwestern Alaska at the beginning of the second millennium AD; Wood Identification: A Tool For Preservation Of Indigenous Architecture Of Traditional Houses In Ifugao, Philippines.*

The present book is the outcome of the same named project granted by the WWDF in 2021. The book and the related project have also been presented during the WWDF Symposium *Trees and Non-Wood Forest Products: Challenges, Opportunities and Sustainability*, held online on 21-22 March 2022.

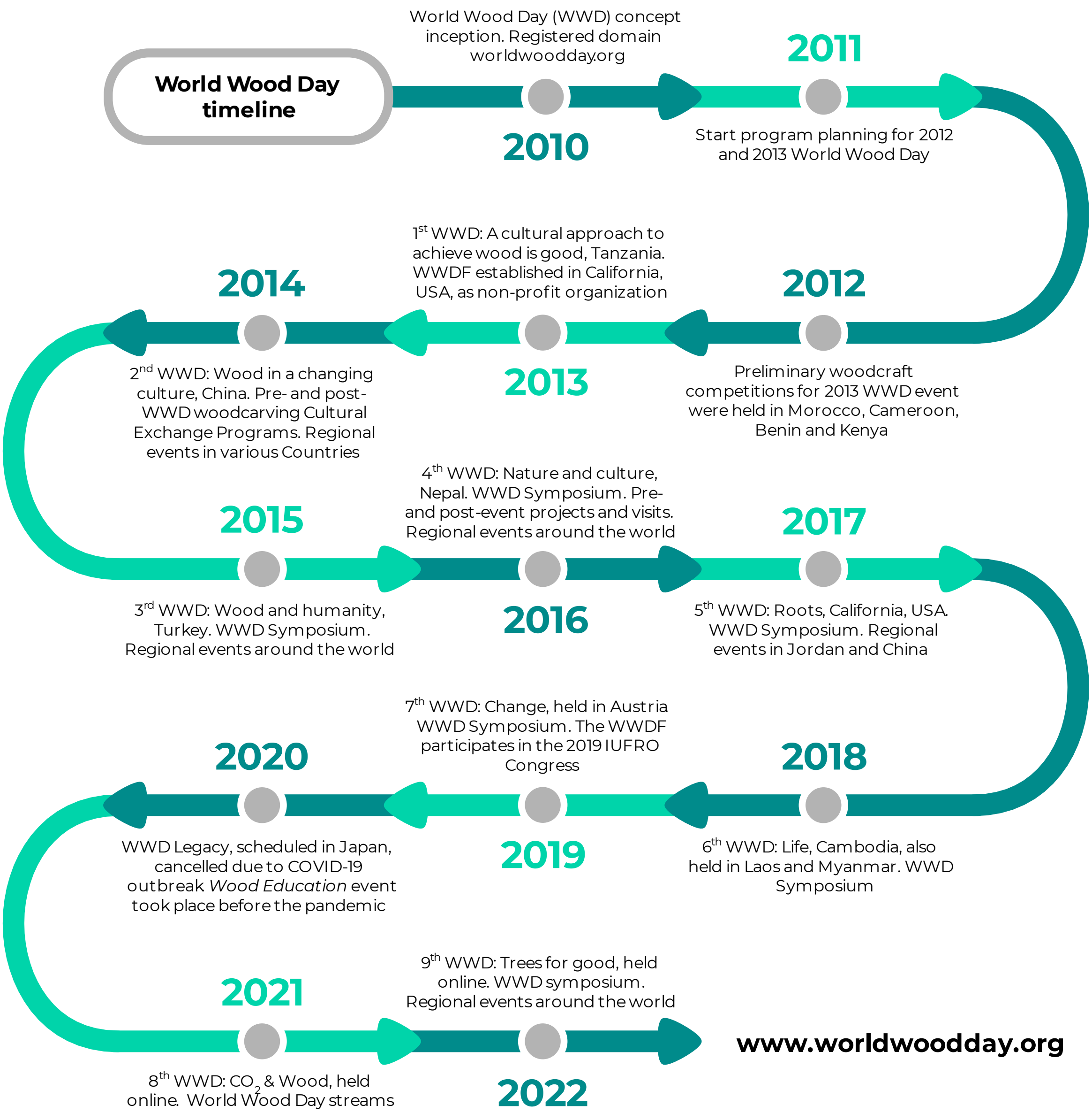

FIGURE I Outline of the main initiatives organized by the World Wood Day Foundation since 2010.

Acknowledgements

The World Wood Day Foundation is thanked for having funded the project.

This book would not exist without the contribution of all the authors who participated. I thank them for their commitment, for having fully hit the purpose, and last but not least, for the passion they have put into it.

I thank the several sport federations, sport societies, institutions, producers, retailers, and artisans for their kind and key collaboration.

Prof. Alessandro Cogo is thanked for his kind availability.

Tiziana is thanked for her support: an impressive endurance indeed.

As for me, after a lot of writing about wood and sport it is now time to play with my two favorite players...

Francesco Negro

SECTION I

INTRODUCTION

Foreword by the editor

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Pierre de Coubertin's world-famous speech, first pronounced in 1908, can be briefly reported as follows:

The important thing in the Olympic Games is not winning but taking part; the essential thing is not to have won but to have fought well[2].

The present book arises from the awareness that wood is "participating" and "fighting well" in several sports today. To name some examples, wood and its derived products are currently used to make baseball bats, basketball courts, cycling tracks, horse riding obstacles, table tennis rackets, skateboards, skis, surfboards, etc. As a matter of fact, wood has traditionally been used to make sport items and playing grounds. Throughout the ages, this has given life to fascinating stories of tradition, know-how, and innovation.

It is also true that in various sports the use of wood has today become residual or outdated, due to the rise of synthetic, high-performing materials. In many sports the replacement process is undergoing, and the future use of wood to make the equipment of some disciplines is very much in doubt. However, in several sports wood continues to be well established, and in others it is the material of choice from beginner to professional level. To sum it up, the current use of wood in sport equipment varies based on the discipline considered and can be described through an indicative four-step scale: (i) obsolete, (ii) residual or minor, (iii) well established, (iv) wood is the material of choice. Clearly, the above steps shall be seen as parts of a gradient where limits among steps are not exactly defined.

The purpose of this book is therefore to provide an overview on the use of Wood in Sport Equipment (WSE). I am confident that by leafing through the pages of this book, the myriad of uses, technical details, stories and anecdotes that characterize the use of wood in sport equipment will emerge.

I will keep this foreword short to leave the book to the readers, and for this reason I will postpone some comments to the Conclusion. Here I would like to close by finding a symbol that can represent both wood and sport. Among the possible options, I would suggest *rings* as a common symbol as they are the iconic feature of wood growth and structure, as well as the iconic symbol for both the Olympic movement and sport.

HOW THIS BOOK IS MADE

This book is not intended to be exhaustive: I actually believe this could be difficult to achieve given the vastness of the topic. Instead, this book aims to provide a broad overview of the use of wood in sport. To this purpose, Olympic and Paralympic sports have been considered, whereas other sports and games are briefly represented by some chapters in a specific section.

[2] De Coubertin's original speech was: *"Last Sunday [19th of July 1908], at the ceremony held at the Cathedral of St. Paul in honor of the athletes, the Bishop of Pennsylvania recalled this in apt terms: "In these Olympiads, the important thing is not winning, but taking part." Gentlemen, let us remember this strong statement. It applies to every endeavor and can even be taken as the basis of a serene and healthy philosophy. The important thing in life is not the triumph, but the fight; the essential thing is not to have won, but to have fought well. To spread these precepts is to help create a more valiant, stronger humanity, one that is also more scrupulous and more generous."* (IOC 2021).

Generally, an international approach has been pursued in drafting the present book. Authors of several countries have participated in writing the various chapters, mainly contributing from Universities, Polytechnics, Research Centers, and Museums. Also, sport federations and producers have been repeatedly contacted, as they represent a key part of the topic considered. The point of view is mainly wood technology, however various contributions from other research fields are present. The need for a transdisciplinary approach is in fact typical when dealing with wood and wood-based products.

As for the book's sections, a preliminary overview is given in the *Introduction*. The chapters included in this section deal with different topics that belong to various disciplines, namely architecture, history, law, philosophy, sociology, and wood technology.

In the section *Wood in sport equipment*, the use of wood in sports currently included in the Olympics and in the Paralympics is considered. Traditional and historical aspects are mentioned in the chapters, yet the main focus has been kept on the current situation.

In *Wood in non-Olympic sports and games*, some examples are reported to briefly represent the wide use of wood in non-Olympic disciplines. To this purpose, wood in billiards, bowling, and chess is considered. Bowls with weights, a traditional game once played in Italy, is included as well to represent the widespread use of wood in local, vernacular sports and games.

The book ends with the quick final considerations given in the *Conclusion*.

ADDITIONAL NOTES

Some general remarks shall be mentioned here to better frame this work:

- this book is intended as an overview, aimed at outreach and at providing a framework to students, academics and professionals. Further study of specific subjects is left to the reader, hoping that these pages can provide a useful starting point;
- "sport equipment" is used here to refer both to sport items, such as baseball bats, and to playing grounds, such as basketball courts;
- in addition to sport items and playing grounds, wood and wood-based products are widely used in sport facilities, locker rooms, benches, etc. Apart from the specific chapter on wood in sport facilities, such uses are not considered by this book;
- different sports may use similar wooden items or playing grounds. It is the case, for instance, of wooden floors on which basketball, futsal, volleyball, and other sports are played. In such cases a single sport has been selected as a representative, and the use of wood in it has been described: even if differences may exist, it has been chosen to avoid information that would be largely repetitive;
- Olympic sports in which wood is not used or is residual are not included in this book, or are briefly covered in the chapter "Other Olympic sports" (for this reason, the chapters on the historical use of wood in tennis and golf have been placed in the Introduction);
- a general outline has been used as a reference to provide some uniformity among chapters that therefore tend to have a similar structure. However, no strict formats have been fixed because this would have been limiting at best. As the editor of this book, I believe that the different approaches adopted by the authors are an added value that reflects the richness of the topic;
- each chapter is intended as a brief, self-standing overview. For this reason, for instance, the properties of some wood species are mentioned in different chapters. In such cases the values reported may vary based on the sources cited, which is due to the fact that wood properties vary depending on many factors such as provenance, portion of the trunk, etc.

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The role of wood for humankind

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INTRODUCTION

Wood has always been fundamental for humankind that has used it throughout the ages for the most diverse purposes. These have varied from combustion for heating and cooking, to using it as a material to make beams, tools, furnishings and countless other products. Clearly, the ways of using wood have varied greatly over time, mainly due to the available forest resources and the climatic, cultural and technological features of the geographical areas.

Historically, wood has often been considered the material par excellence (in the Bible, for instance, the term wood is used as a synonym of material) and has greatly contributed to the development of human civilization. The availability of wood in almost all the inhabited areas of the planet, its ease of processing, and its suitability to finishing have made it one of the most appreciated and useful materials worldwide. Advancement in the knowledge of wood, both as a raw material and as a material, have particularly occurred in Countries where wood is more abundant and constitutes a primary economic resource. In such areas, such as Nordic Countries to name an example, real "wood cultures" have developed over the centuries.

Elements for carpentry, joinery, furnishing, boatbuilding, land vehicles, as well as paper, packaging, toys, working tools and musical instruments, are some examples that can be named to illustrate how frequently we can find wood in our daily lives (Forest Products Laboratory 2021). In addition to the energetic, constructive and decorative uses, wood has always been used by humans to express their artistic vocation. The most various and surprising artistic wooden artifacts have been realized, ranging from the vernacular sphere up to cultural heritage. The relationship between humankind and this product of nature, from both natural forests and forest plantations, is indeed a close one.

Of note, many synthetic materials have been specifically developed by humans for satisfying specific needs, whereas in the case of wood, especially when solid, the opposite has often happened: humans have had to adjust to the peculiarity of the material. The proper use of wood requires in fact to consider its biological origin and its complex features deriving from the activity of living trees.

However, the great amount and variety of wood available has often made it possible to choose the most suitable type of wood for the application of interest. Thus, the choice can fall on wood that is lightweight and resistant for carpentry, durable for exterior environments, decorative for furnishing, etc. Generally, where several exceptions exist, the ensemble of the properties of wood make it valuable when decorative aspects are key, well-suited as a structural component for different constructive systems, and not particularly suited when high performance, exposition to long weathering or full incombustibility are required.

Among its countless uses, wood has always served humankind also for performing recreational and sport activities. Various traditional games indeed derive from ancient agro-pastoral rituals that were historically practiced using tools made of wood. Through the sportivization process, many games evolved into modern sports with written rules and professional approaches.

Over the ages wood has served humankind in playing the most diverse sports, whose high socio-cultural relevance is well known[3]. Suffice it to say here that the 2015 UNESCO International Charter of Physical Education, Physical Activity and Sport acknowledges that "[...] cultural diversity in physical education, physical activity and sport forms part of humanity's intangible heritage and includes physical play, recreation, dance, organized, casual, competitive, traditional and indigenous sports and games" (UNESCO 2015).

1900-2000s: DECLINE AND REDISCOVERY

During the 1900s the role of wood became more and more marginal in several sectors, construction being a relevant one. In that century wood was in fact widely replaced by other materials that were considered more reliable and performing. In many cases the interest of designers and stakeholders towards wood diminished, and wood was disregarded in educational programs. Limited knowledge of the material, misconceptions, and restrictions set by the normative framework contributed to further reduce its use. In many cases, wood was not used, used wrongly (for instance, by excessive oversizing), or chosen just for aesthetic purposes.

From the beginning of the 2000s, however, wood started to gain a renewed interest, which arose from two main factors. On the one side, the technical and scientific innovations enabled new and effective solutions, of which glulam and cross laminated timber are relevant examples [1]. On the other side, the increasing need of the modern society for renewable and sustainable materials found an ideal response in the use of wood. In this sense, several systems/regulations are of great importance to ensure the legal and sustainable provenance of wood.

Today wood has not only regained importance in many fields, but in various cases it has also gained an advantage over alternative materials. This trend is ongoing and likely to continue in the future, from which further spaces could open. Of note, the knowledge of the technological characteristics of wood and of its derived products is a key prerequisite to benefit from all the services that this natural and renewable material can provide.

AN EMBLEMATIC EXAMPLE: SWEET CHESTNUT WOOD

Sweet chestnut wood can be used as an emblematic example for the importance that wood has always had for humankind.

Over the centuries, sweet chestnut (*Castanea sativa* Mill.) has been widely diffused and cultivated by humans. Around 90% of its current distribution area is concentrated in France, Italy, Spain, Portugal, and Switzerland, where traditions of chestnut cultivation have developed (Conedera et al. 2018). The importance of sweet chestnut is such that "where the chestnut tree grew, humans arrived, and where humans stopped, the chestnut tree was sown" (Bignami and Salsotto 1983).

In the past, this species was mainly cultivated to produce chestnuts that were key to the nutrition of rural populations. However, its wood was also valuable, and used for several purposes in agriculture. In rural areas the bark of young chestnut trees was used as gutter channels, and hollow trunks as beehives. During the first half of the 1900s baskets made of split chestnut wood were commonly used. Leaves and branches were also collected and destined to the production of litter for animals. Instead, chestnut wood was not used to make dishes and food containers due to its high content in tannins that causes an acidic taste when in contact with food. Clearly, chestnut timber and scraps were also used as an energy source for domestic heating and cooking. Other relevant past uses of chestnut timber were mine supporting props and bars, and railway sleepers.

Nowadays, poles for vineyards and orchards maintain a key market outlet (Zanuttini 2020). Chestnut sawn timber is still

[3] The socio-cultural relevance of sport is covered in two specific chapters of this book, namely *Sport and games from philosophy to the ethics of sport*, and *Sport as a symbolic universe*.

used for carpentry, and over the centuries has originated relevant constructive traditions in some geographical areas. Other remarkable applications in construction include furnishing, doors and windows, floors, balconies, and staircases.

Of note, the good natural durability of sweet chestnut wood makes it suited to several applications in exterior environments, such as outdoor furnishing, fencing, and natural engineering works. Regular maintenance and, when needed, treatments shall however be considered to support its predisposition to outdoor uses.

The timber of old grafted trees at the end of their productive cycle or those attacked by pathogens, has traditionally been destined to the tannin extraction industry. This has constituted a pillar of the economy of various alpine valleys, and still maintains a considerable relevance in some areas. In addition, a more recent use of low-quality assortments is represented by wood chips to produce thermal energy in dedicated plants.

As for artistic artifacts, chestnut wood is not suited to fine engravings given its coarse texture. It is however used in sculptures, where it is appreciated for the availability of large trunks and roots, especially those coming from old fruit trees that have grain deviations and other peculiar characteristics.

WOOD IN FOLK SPORTS

As stated by the above-mentioned International Charter of UNESCO, folk sports and games are part of humanity's heritage. After long traditions, some of them have ceased being practiced nowadays (such as wooden bowls with weights, covered in a specific chapter of this book). Nonetheless, some of them are still played in their original version, at times even in structured leagues in which also young athletes participate.

Wood has always been used to make items for folk sports. To mention an example, "rebatta" is a folk sport of the Aosta Valley, Italy [2]. It consists in placing a small ball ("rebatta") on a pipe-shaped support. The player hits the support with a 100-140 cm long club, sending the ball into the air. Through another movement of the club, played in rapid sequence, the player hits the ball to launch it as far as possible. The field of play is flat, without obstacles, and divided in 15 m long sectors: the farther the ball lands, the higher the score.

The ball has a diameter of 3 cm and can be made of metal or wood. In the latter case, the ball is made of nails stuck into chestnut sphaeroblasts. These are wooden extrusions that originate from trunks or branches and usually have a spherical shape. The tangled grain provides good resistance to cracks and deformations that can originate from the high stress applied by the wooden stick. Wood is also used to make the support pipe and the clubs. Generally, club heads are made of compressed walnut wood (intended to withstand hard impact), and the handles of ash wood.

A multitude of other examples could be cited to illustrate the use of wood in folk sports. Let us briefly conclude here by mentioning the sports related to the activity of loggers. Over the ages, competitions on cutting, chopping and sawing have taken place all over the world, reflecting the widespread diffusion of such professional activities. In the last decades, some of these events have evolved up to the establishment of modern leagues with tv coverage. Different disciplines are practiced: tree felling, limbing, handsaw or chainsaw sawing, axe chopping, etc. The challenge generally consists in completing the task as quickly as possible, but in some disciplines, precision is also considered. Noteworthy, the wooden raw material (for instance poplar, spruce and pine, but also others) shall be homogeneous in terms of size, species, and characteristics to provide equal conditions to all athletes.

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[2] https://figest.it/specialita/rebatta/ [accessed on 21 March 2022].

Sport and games from philosophy to the ethics of sport

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Very often, the reaction to the many scandals that periodically rock the world of sport is simply to make urgent demands to develop a healthy sports culture. If this is the aim, I shall try to outline what the sphere of ethics and philosophy might contribute to the debate.

The ethics of sport, or sport ethics, is a discipline that on the one hand, tries to highlight the values sport specifically promotes and encourages, and on the other, explores a series of particular situations where the contrast between what sport should be and what it in fact is appears clearer. Any discussion about the strictly moral nature of sporting activity must necessarily take as its starting point the definition of sport itself. To be able to say that it is morally wrong to deliberately break the rules of a game, to fail to accept a referee's decision, or to make use of various technological aids or drugs, one must first have a clear understanding of what is meant by the concept of a game (and sport) and why these behaviors are incompatible with this activity[4].

1. WHAT IS SPORT?

As often happens, the most familiar things are hard to define precisely. To prove this, one needs only to try and answer the question: what is sport?

The word is sometimes used as an umbrella term to cover both competitive pursuits and all the various activities associated with fitness and general recreation. For instance, the European Sports Charter regards sport as any physical activity, whether organized or not, whose aim is to express or improve the performer's physical or mental condition, develop social relations, or achieve results in competitions at all levels[5].

On other occasions, the term sport is used in a more restricted sense to refer to institutionalized and rigidly rule-bound forms of competitive physical activity. From this point of view, occasional jogging in the park, attending an aerobics course or rambling in the mountains are not strictly speaking sporting activities, while all those organized by sports federations are. So how should we categorize a game of football between friends on a Thursday evening or a non-competitive running event? Or: is chess a sport or merely a game?

This is not the place to attempt a close analysis of the various positions, so I shall confine myself to outlining the main standpoints on the question[6].

1.1 Sport as play

The standard way of approaching the matter of the nature of sport is to explore its link with play, recognizing that taking part in sports involves playing in some way. From this standpoint, play is viewed as a general context, of which sport is a specific genre. This then is where we must start, and an excellent guide is the Dutch historian Johan Huizinga's *Homo Ludens*, which examines the typical features

Here, I take up and expand ideas I first introduced in two previous works: Grion, 2019; Grion, 2018a.

[4] Kretchmar, 1983.

[5] Council of Europe, 1992.

[6] There are a number of interesting publications in Italian: Ravaglioli, 1990; Isidori, Reid, 2001; Bertman, 2008; Sorgi, 2010; and in English: Holt, 2014; Reid, 2012; Conner, 2011.

of play, describing it as an act of freedom to be distinguished from "ordinary life". As such, it is in a sense superfluous, set apart in time and space; it is an activity that is an end in itself (autotelic) and is associated with feelings of tension and joy[7]. In play, a person deliberately tests himself, both in comparison with others and to experience the sense of fulfilment triggered by doing something challenging[8]. This activity cannot be imposed (otherwise it would immediately turn into something else). In other words, play is associated with carefree activities performed in one's free time, as opposed to the onerous daily demands of work. Play is superfluous, writes Huizinga, and is not a response to physical or moral needs; it is not a chore and takes place in time set aside from normal work commitments[9]. However, despite its pointlessness, play is something extremely serious, to the extent that Huizinga goes so far as to claim that human culture emerged and developed through play, as play[10]. As time passed, play became increasingly sophisticated and structured, promoting several fruitful social and cultural processes. The celebration of athletic prowess among the Greeks - at Olympia, among other sites - is a good example of this raised profile and shows how play can be a conduit for social, religious and aesthetic content.

Huizinga's definition of play has been taken up and discussed by Roger Caillois, in which the French sociologist lists the typical features of play: in his view, the term refers to a free, separate, uncertain, unproductive, rule-governed, make-believe activity[11]. Caillois stresses the importance of this last aspect in particular: play undoubtedly relies on the pleasure of overcoming an obstacle, but this obstacle is arbitrary, almost fictional, and is introduced to suit the player and is accepted by him[12]. Moreover, play does not have any single defining characteristic, but can take many forms. One of these is competitive play (*agon*), in other words an activity strictly governed by rules[13], in which participants start from a relatively evenly matched position and challenge each other in a single skill to reward excellence[14]. In this context, what we call "sport" is thus to be viewed as the most structured, formalized expression of competitive play.

As regards the nature of play in contrast to productive activity, it is worth drawing attention here to the distinction between work and play drawn by the American philosopher Bernard Suits[15]. While work represents a field in which mankind's rationality is employed in seeking the most efficient means of achieving a given goal, in play, the opposite is the case: the actors involved deliberately choose an inefficient means of achieving their aim, and this is done with the sole purpose of testing their skills[16]. Suits takes the game of golf as an example. If the aim of golf is to get little balls into a certain number of holes in the ground, we could certainly come up with more efficient methods than launching them a great distance with special clubs. But this needless complication is precisely the point of golf, and the difficulty is what makes it fun for us. We do not seek to create a product outside ourselves, but rather, we try to experience the inner satisfaction of having passed a test. This satisfaction boosts our self-esteem and

[7] See, Huizinga, 1938, pp. 3-34.
[8] See, Trabucchi, 2003; Bandura, 1997.
[9] Caillois, 1958, p.11.
[10] Huizinga, 1938, p. XXXI.
[11] Caillois, 1958, p. 26 and p. 61.
[12] *Ibid*., p. 61.
[13] Other forms that play may take include *alea* (challenging fate, as in games of chance), *mimesis* (mimicry, or role-playing) and *ilinx* (thrill-seeking and the pursuit of a sense of vertigo, or loss of control. Caillois then pinpoints two opposing extremes in each of the four macro-categories: *paidia* (unstructured, improvised, spontaneous activities) and *ludus* (controlled, rule-governed, institutionalized play).
[14] According to Caillois, *agon* serves to highlight the purest form of individual merit. See, Caillois, 1958, p. 31.
[15] See, Suits, 1988a.
[16] See, Suits, 1978, pp. 54-55.

increases our faith in our ability to impose ourselves on the outer world[17].

A game is thus play that has evolved from its spontaneous, ungoverned origins into a more sophisticated activity that is strictly controlled and rule governed. Lastly, a game turns into sport when it displays a set of distinguishing features; four, according to Suits: firstly, it needs to include an element of skill; secondly, this skill, which is tested in the game, must be of a physical nature (which is why many believe that chess, for instance, is not strictly speaking a sport, although it is definitely competitive - a point that becomes even clearer if one considers that chess can be played by email or against a computer); thirdly, the game must attract a broadly based following (in other words, it cannot be a merely private affair), and lastly it must have achieved a certain degree of stability (i.e. to be "institutionalized" in some way)[18].

1.2 Sport as a set of rules

Another way of thinking about the meaning of sport considers the pairing sport-rules. Suits himself stresses the importance of this aspect of the matter, distinguishing between *constitutive rules* (which define the aim of the game and the means that are permitted in achieving it) and *regulative rules*, which ensure its smooth performance. The former establish the boundaries circumscribing the game, with any transgression being seen as "breaking the rules" (such as when a player picks up the ball with his hands in a game of soccer and begins to run). The purpose of the latter is to encourage players to play "properly" and ignoring them does not necessarily expel the perpetrator from the game[19].

Taking its cue from Suits's observations, a wide-ranging debate has developed on the exact nature of the link between sport and rules. The connection can be interpreted in a number of ways. Firstly, sport can essentially be defined in terms of formal rules, the breaking of which then becomes the focus of ethical debate. Taking this approach prompts the discussion of questions such as whether a professional foul is morally justifiable, how many rules can be broken before a game can be said to be null and void, and whether players can agree to alter the rules to suit them. Another way to look at this matter is to concentrate instead on the *ethos* underpinning the rules of the game, i.e., respect for what we could call the spirit of the game[20]. Following this line of reasoning leads us, for instance, to consider the question of fair play and what exactly is meant by the term. Is it just a matter of playing by the rules, or are there also implicit, unwritten behavioral norms to be respected?

1.3 Sport as a social activity

Play - by which I mean a structured game, in contrast to a child absorbed by its toys - like sport, is basically a social practice. Caillois himself regarded play as a public event: in order to play properly, there must be at least two players (one can certainly play alone, but in the absence of interaction with others, a game loses much of its point). It is no accident that players in a game are called competitors and the challenge they are engaged in is known as a competition (from *cum-petere*, to strive for together, and not merely to lock horns to achieve victory). This is why play envisages a context in which *we* takes precedence over *I*. This point is brought out extremely well by Alasdair McIntyre.

[17] Bandura, 1997.
[18] See, Suits, 1988b.
[19] On these points, see also Morgan, 1987, pp. 1-20. In a certain sense, Caillois also sees sport as a rule-governed activity, leading him to make a close analysis of the role of the referee - whose job is to ensure the rules are followed and the game brought to a successful conclusion - and to conclude that *agon* begins to break down when neither referees nor the concept of independent refereeing are recognized. Caillois, 1958, p. 64.
[20] D'Agostino, 1995.

In *After Virtue*[21], the Scottish philosopher takes competitive games as an example to illustrate his concept of "social practice", a socially established, coherent and complex cooperative human activity[22]. In MacIntyre's view, every social practice promotes specific virtues and sets up its own model of excellence that acts as a benchmark for the members of the community. MacIntyre goes on to say that social practices also need institutions to uphold and protect them. Unfortunately, though, these tend to concentrate less on the values inherent in the practices themselves (the game's values), and rather more on extrinsic benefits (involving economic or political gain or providing a spectacle). So, the situation calls for great care in finding the right balance between intrinsic and extrinsic goods and in monitoring the role these institutions play with regard to the specific aims of the various practices in life. MacIntyre thus espouses a *virtues*-based ethics, which in the case of sport means eschewing single-minded attention on a single value - the importance of winning, above all - and instead nurturing the numerous other goods inherent in games: enjoying oneself, keeping active and in good health, sharing happy moments with one's teammates, delighting in friendship, fellow-feeling and shared passions, taking pleasure in the satisfaction of making it, getting on top of things, feeling up to it.

1.4 Overview

To summarize: as the etymology of the word suggests[23], sport is essentially an unregulated recreational activity performed as a kind of pastime and enjoyed for its inherent values and not for what it may produce. In this sense, it operates in quite a separate sphere from "serious things": study for children and adolescents, work for adults. Sport is also a special way of playing in which competition (the importance accorded to victory) acquires a more pronounced significance than in free, spontaneous play. It is precisely for this reason that sport strictly speaking requires sets of rules, an independent referee to ensure they are followed, and stable institutions designed to ensure they endure. When one becomes an adult, competitive sport seems to acquire a special allure that makes it more interesting not only for the participants, but also for spectators. At this point, sport - and its rationale - become interwoven with the criteria underlying spectator events, which, however, have their own characteristics that are not wholly in line with the values espoused in sport. Spectator events, and entertainment in general, put a premium on pretense, display, inventiveness and astonishing, spectacular effects; the desire for celebrity and renown they encourage means appearing becomes more important than being. While all these features are not necessarily incompatible with sport, they can generate friction and misunderstandings. As a result, sport and entertainment can share the same platform, but peaceful, unproblematic coexistence cannot be taken for granted. The key lies in establishing the governing rationale and in deciding what considerations should play a supporting, reinforcing role.

The same applies when the event has a great economic value[24]. As we know, at the highest level, sport is often a professional activity, in which the game is (also) a job. A non-productive, recreational, unconstrained activity circumscribed in time and space is thus turned into a productive, occupational, onerous activity, just like any other job. This, inevitably, is where the greatest clash of values occurs. Of course, fruitful cross-fertilization can take place between the two worlds even here, but it clearly takes considerable awareness to find the right compromise and to establish a precise set of priorities. Otherwise,

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[21] MacIntyre, 1981.
[22] *Ibid.*, p. 225.
[23] The term "sport" comes from the old French *desport*: entertainment, fun; from which are also derived the Italian *diporto* and the English *disport*: pastime, recreation.
[24] See, Piantoni, 1999.

when the predominant consideration is economic advantage, spectators attend what is only seemingly a sporting event, when what they are actually watching is workers doing what they are paid for.

Lastly: along with the fraught, though feasible interweaving of the values connected with sport, economics and entertainment, there is also the question of the relationship sport has with politics[25]. Anything that arouses people's passion and reinforces their sense of identity (whether it be a team, a flag or an activity) does not escape the notice of politics, ever ready to make use of what it thinks might help build consensus or gain approval for its short- or long-term purposes. This can occur while respecting sport's values (as when Mandela took the opportunity presented by the Rugby World Cup to help heal South Africa's racial strife) or when brazenly flouting what sport stands for and reducing it to a mere tool at the service of politics (as at the 1936 Berlin Olympics, or in cases of state-sanctioned doping)[26].

2. WHICH ETHICS SHOULD GOVERN SPORT?

The way a whole series of ethical questions regarding sport are approached depends on how one answers the question "what is sport?"[27]. Although it is always difficult to fit a large number of positions into a simplified framework, the various approaches can in the end be squeezed into four macro-paradigms: utilitarianism, deontologism, contractualism or virtue ethics. I shall try to outline the salient features in these different ethical standpoints below, but it is important to make it clear from the outset that although authors might share the same general ethical position, they can still reach divergent conclusions on specific matters, and, conversely, thinkers adhering to different moral outlooks can come to similar conclusions regarding particular questions.

2.1 The importance of consequences

Sport is synonymous with concreteness and pragmatism. What counts, in the end, are the results achieved, certainly not the good intentions of the individual sportsmen involved. Similarly, many authors believe that the numerous ethical questions connected with sport would come to nothing if we considered the consequences of our decisions, both when these lead to specific actions and when they result in new rules. Actions and rules are considered morally right when they lead to a state of the world that is at least as favorable in terms of general utility as that which might be achieved through alternative measures. In contrast, they are morally necessary when they can lead to a state of the world that is actually better than any possible alternative (where better is taken to mean providing the greatest pleasure/utility for the greatest number) [28].

According to Claudio Tamburrini, for example, Maradona's famous goal scored against England using his hand can be justified by pointing to its numerous positive consequences: increasing the rivalry (and therefore the involvement of the general public) between Argentina and England, increasing the number of television viewers, with benefits for sponsors and so on[29].

Equally, the changes in women's clothing in certain sports - now decidedly more close-fitting - might be considered right in view of the positive outcomes for a large number of people: they gratify (especially male) spectators, advertisers (through larger television audiences), sports federations (who receive more funds) and the players themselves (who reap the benefits of an economically healthier environment) [30].

[25] See, Hoberman, 1988.
[26] See, Donati, 2012.
[27] As an introduction, I recommend: Morgan, 2007; McNamee, 2010.
[28] Reichlin, 2013.

[29] See, Tamburrini, 2000.
[30] The players in the Norwegian women's beach-ball team seem not to have shared this view, since after months of protests, fines and disputes, they managed to change the rules so that they

2.2 A matter of principle

On the other hand, there are those who take issue with this kind of moral stance, pointing out that certain principles cannot be bypassed by considerations of a utilitarian nature[31]. Deliberately breaking a rule or exploiting the female body, treating it merely as a useful instrument for selling sport as a product, are things to be deplored, irrespective of their putative positive outcomes. There can be no waiver when it comes to the values associated with fair play and a sportsman's very dignity.

This deontological approach is well known to owe much of its impetus to Kant's two formulations of the categorical imperative. As applied to sport, his ethics have generated a number of fruitful lines of thought. One of the most interesting regards the attempt to block the possible liberalization of doping. Taking Kant's belief that what applies to a single person's moral actions should apply to everyone and thus have the status of a universal law[32], this approach points to the irrationality of behavior that would make the use of performance-enhancing drugs useless if they become widely available, since any advantage they give is cancelled by the opponent's drugs.

The second application of the concept of the categorical imperative requires human beings to be treated as an end and never solely as a means[33]. In the sphere of sport, this reasoning is used to show up those who do not hesitate to use their own bodies (and thus themselves) merely as a means to be exploited and overworked in the interest of attaining victory, as well as teams/federations/nations who treat athletes as tools for obtaining success, prizes and glory.

2.3 The value of a contract

What are the rules of a game based on, though? Some maintain they derive from an agreement between the participants, since a game is nothing other than a shared set of rules[34]. From this point of view, understanding what it means to do the right thing in sport means not paying too much attention to the consequences of an action or rule, as well as not giving too much importance to the principles inherent in a given practice; in this view, justice has more to do with the understanding reached by the members of a sporting community. Once the rules of the game have been established, breaking them puts the player outside the agreed bounds. Every deliberate violation, however slight, can be described as morally reprehensible cheating. However, this position clashes with the positive attitude often shown towards the "professional foul" and the systematic tactical fouls that teams resort to in basketball to stop the clock.

Contractualistic ethics applied to sport stresses formal/procedural aspects inherent in sport regulations and poses a key question: does a majority decision make a rule or behavior automatically right, or are there unwritten laws that written regulations should consider or promote? Taking once again the question of doping as an example, is the practice wrong only because it involves willfully breaking the rules? If the rules allowed it, would doping therefore become morally acceptable?[35]

2.4 Virtue ethics

The followers of an Aristotelian approach to ethics in sport place the accent on shared values, i.e., the spirit underlying sporting activities, irrespective of what is specifically allowed or forbidden by the rules. From this perspective, rules and regulations are instruments at the service of fair play but are not in

were able to wear shorts and t-shirts (as their male counterparts have always done), rather than extremely close-fitting bikini bottoms and low-necked tops.

[31] See, Fraleig, 1984; Lumpkin, Beller, Stoll, 1999.

[32] Kant, 1785, p. 79.

[33] *Ibid.*, p. 88.

[34] See, Simon, 1991 and 2004.

[35] There are those who say it would, and actually explicitly suggest that it be liberalized. See, Savulescu.

themselves sufficient to determine its boundaries. There may be practices that are not expressly prohibited but are nonetheless not ethically acceptable as they are against the spirit of the game and the many values that it would like to/should promote.

This type of stance in the ethics of sport tends also to reinforce the educational potential of sport, exemplifying as it does a number of important moral values: courage, self-control, resilience, fairness, inclusion, ability to cooperate, etc. Sport thus offers a milieu in which (good) character traits, as well as physical prowess, can be honed[36]. It is an exceptional tool at the service of the individual and the whole community that can - without too many words but through a thrilling and engaging pursuit - teach the importance of discipline and determination, develop a taste for a challenge and foster a sense of the satisfaction to be found in shared effort, friendship and togetherness. It can but is by no means certain that it will[37].

3. WHAT SPORT CAN TEACH US

Since much is made of sport as a training ground where young people's physical skills and character are molded - for which purpose the state expends considerable resources and effort - there seems good reason to consider that a virtue ethics approach provides the best framework compared with the "competition". So, what is it that sport could (and should) teach our children?

First of all, the importance of friendship, which is certainly the most precious of the ingredients in a happy life.[38] Sport helps us appreciate shared joys, the importance of being able to count on the support of colleagues in times of difficulty, and the need to accept responsibility for one's actions. Team sports offer a wealth of opportunities in this regard: a good example is rugby, where the team's strength lies in its ability to protect its weakest links. Another is volleyball, where it is impossible to win without the contribution of the other members of the team: the ball must pass from the receiver to the setter, who lifts it, and lastly the hitter, who smashes it into the opponents' court. Each player is indispensable, no-one is irreplaceable. Individual sports have similar situations. Although in these cases players cannot distribute effort and responsibility among teammates, they can nonetheless also take advantage of "team spirit" through the contribution of trainers, other players they practice with and various followers and supporters. So, sport encourages the idea that "togetherness" is the state that best suits the human condition and enables us to live our life to the full.

Sport also helps to understand the importance of targeted effort, and it does so without the need for abstract explanations but simply through experiencing the satisfaction of achieving hard-earned results, perhaps after several failures and defeats. In the process, sport reinforces a person's capacity to respond to difficulties, urging him to hang on and not to give in. "Resilience" has become a buzzword nowadays, but numerous sports clubs still recall in their very name the ancient virtue of fortitudo, the endurance required not to lose heart and to persevere in pursuit of the good even when the going gets tough. This is an invaluable virtue for it underpins the ability to aim high and the willingness to work hard to make one's dreams come true.

Another important lesson sport can teach regards the ability to handle the lure of immediate gains, learning how to deal with frustrated ambitions when a short-term advantage prevents the attainment of a longer-term, and more valuable goal. Discipline for an athlete means understanding the importance of making sacrifices and having a proper sense of priorities among the various things that attract us. The same generally applies in life: the most valuable things never come cheap; they are won through patience

[36] See, Grion, 2015a; Gough, 1997.
[37] See, Grion, 2016a; Isidori, 2009.
[38] Aristotle, *EN*, VIII-IX.

and discipline, but once obtained, they are able to repay many times over all the effort put into trying to attain them.

Again, sport can help reconcile equality and difference by encouraging us to realize we are all the same in the starting blocks, while accepting that others may be more gifted than us. In a race, for example, everyone lines up together at the start, but the different abilities are clear at the finish line. Perhaps it is no coincidence that the Olympic Games and democracy emerged together in ancient Greece, with the former just slightly ahead, as if competition in the realm of sport created a cultural climate conducive to the development of democracy, as Huizinga himself suggests.

Making the most of what sport can do for us thus entails recognizing all its educational potential and enjoying not only its role in recreation and relaxation, but also its ability to increase self-awareness and mold character. It promotes self-awareness in that when sportsmen or women accept a challenge, they inevitably come to realize their true standard, regardless of the idea they might have of themselves. It molds the character because through training and by competing, an athlete can develop a whole series of extremely important virtues that can also be applied in everyday life. Sport, then, offers an opportunity to know oneself, to discover one's limits, to test one's potential and to air one's talents. Above all, it is where one can experience the richness of relations with others and the joy of togetherness, whether in victory or defeat.

At the same time, for sport to be truly educational, the focus must be on an athlete's growth as a human being rather than on any results achieved, which means preventing other considerations (whether economic return, politics or the priorities of sport as a spectacle) from taking over. Above all, these educational purposes must be explicitly recognized and adopted as their main goals by trainers, sports directors and sports federations[39].

4. EXPLORING THE BOUNDARIES

As already mentioned, one of sport's most valuable contributions to a person's life lies in revealing one's limits and learning to accept them. Man has always brought all his intelligence and determination to bear on the attempt to overcome his physical and cognitive limits. However, it is moot whether the expression to play "beyond one's limits" really is a useful concept or whether it actually serves to conceal risks it might be better to be aware of. For example, there is a lively ongoing debate about "post-human" possibilities, i.e. the likelihood that the technological revolution will enable human beings to overcome their biological limits, giving rise to a new era in which not only will it be possible to cure every disease of the body and soul, but also to design and create new generations according to one's wishes[40]. Some see these scenarios as positive and desirable; others view them as worrying and dangerous. Once again, sport seems to offer some interesting angles. The fascinating thing about competitive sport and what makes it so exciting, is precisely the way it embodies the struggle to go beyond one's limits. But what are these limits? There are obviously certain physiological limits to any sporting activity, but there is always the chance that technology can take us beyond what is humanly possible. If the option exists, why not take it? Equally, there are a number of rules that restrict the number of technological devices that can be used to improve performance (such as hydrodynamic swimsuits); once again, why circumscribe an athlete's choice of equipment, preventing him from choosing what he feels helps him most?

We need to get a wider perspective on these points before trying to give an answer. As authors such as Huizinga and Suits have observed, competitive sport is based on rules that determine how a game is to be played. In football, for example, I cannot pick up the ball (unless I am the goalkeeper), and I cannot rugby-tackle a player or decide how long the match

[39] Grion, 2016b; Isidori, 2009; McNamee, 2010.

[40] Grion, 2012.

will last. When we engage in a sporting activity, we freely accept arbitrary limits and we do it - and this is the point - to test our real limits. The restrictions set out in the rules thus make sense to the extent that they make the game interesting.

Not all limits are a problem then, and it is not always advisable to try to overcome them. A sportsman should therefore develop the capacity to tell the difference between limits that are an obstacle to the improvement of his performance and prevent him making the most of his potential (finding out how far he can really go) and limits that define us, tracing the outlines of our true identity; whether we like it or not, these outlines describe us (regardless of what we may like). So, the former are obstacles that sport helps us confront with courage; the latter are instead an integral part of each one of us and these need to be recognized and accepted with good grace[41].

5. CONCLUSION

As we have seen, in sport the result matters: one plays to win and the more serious the game, the greater the importance of winning. Besides, the competitive spirit is nourished by the desire to come first, to prove we are better than those we are playing against and if possible, better than any other opponent (perhaps even getting our name in the record books). Even so, while these are undoubtedly important ingredients in sporting activity, we must not make the mistake of thinking they trump all others. At the end of the day, the result in itself matters less than what we can experience in trying to achieve it; if it were not so, we would not use inefficient means to achieve a given goal.

Suits's insight is crucial in this instance too: in a match, we do not seek maximum efficiency and the best possible result, but fun in pursuing them and this is provided by deliberately including a certain degree of inefficiency. This means that what really matters as we try to win a match against others is what we get out of it: self-understanding and the satisfaction of knowing we have done as well as we possible could. This is why the challenge that really counts is the inner one, rather than the contest against others. What we need to face are our own limits and fragility. Besides, this is also an extremely inclusive perspective as it enables everyone to regard themselves as a winner, regardless of the result. I can always lose a match; there is always someone more talented, in better form or luckier than me. But each of us can win the contest with himself without preventing others from doing the same.

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Sport as a symbolic universe

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A SENSATIONAL DISCOVERY

In September 2021, a ski, dating from around 700 AD and obviously made of wood, was found near the Norwegian town of Lillehammer, the site of the 1994 Winter Olympics. In 2014, a similar object was found in the same area: the seven-year wait for the progressive melting of the glacier allowed the discovery of the 'twin' ski, which occurred in 2021.

The ski found in 2021 is 187 centimeters long and 17 centimeters wide. The skis from Lillehammer are not the first pre-Viking skis to be unearthed. However, they are among the few, along with the pair found in Mänttä, Finland, which retained a component that is key for a better understanding of their use: the binding. Made of birch wood and leather, the ski binding discovered in 2021 (more complete and better preserved than that from 2014) allowed the toe of the shoe to be locked, and the heel to move relatively freely. This suggests that the technique of downhill skiing now called *telemark* was already known in Norway in the early Middle Ages. It takes little creativity to imagine scenarios not too different from those seen in the Alps in the early decades of the 20th century, when daring men slid down snow-covered mountains. What separates the medieval practice of skiing from that of the pioneers of this sport is not so much the constructional characteristics of the equipment, but the function for which it was intended.

Skis crafted and used 1300 years ago, in terms of shape, size and technology, did not differ too much from the one my grandfather portrayed in 1930 on the 'snow fields' (at that time there was no talk of slopes) of the Lanzo Valley, Italy (Figure 4.1).

Figure 4.1 Skis used in the first decades of the 1900s were still quite similar to those used during the 700s (image A. Perissinotto).

What makes twentieth-century skiing modern is the recreational dimension associated with it, as opposed to the functional dimension of pre-Viking skiing that was above all a means of movement, hunting, and therefore survival.

The journey from functionality and utilitarianism to the fun of symbolic play is common to almost all sports. The aim of this short chapter is therefore to examine the socially operated re-semanticization of activities and materials that were once part of everyday production, and now make up the symbolic universe we call 'Sport'. Rowing becomes sport when the act of rowing loses its utilitarian function and when the boat itself, becoming narrower, loses its potential as a means of transport. The rower's rowing thus becomes a gesture devoid of practical utility and rich in symbolic value, a symbol of strength and power. Riding a horse becomes horseback riding when the horse and the rider symbolically reproduce jumps and strides made during combat without the need to win a war or even to save one's life. The list could go on and on, with a number of examples all fitting into the framework of the 'socially regulated conflict' of which Simmel (1923) speaks.

We might mistakenly think that a sporting activity (e.g., rowing) becomes such only when its corresponding utilitarian activity (e.g., transport by boat) is completely exhausted, surpassed by other more modern and technologically advanced activities. In reality, this does not always happen, in fact, much more frequently, functional and symbolic activities continue in parallel. The case of the bicycle as studied by Wiebe E. Bjiker (1997) is emblematic in this sense. Immediately after conquering the world of bourgeois and popular mobility, supplanting the aristocratic horse and the even more aristocratic velocipede in urban spaces, the bicycle became an instrument of sporting competition. Its capacity to generate a mythology of sport (Perissinotto, 2019) is in direct relation to its diffusion at the functional level. Similarly, the symbolic dimension can actually constitute a memorial preservation of the functional one and can long survive the disappearance of the former. The last cavalry charge of the Italian army took place at Isbuscenskij, on the river Don, on 24 August 1942. Today, eighty years later, Italian horsemanship, often practiced by military athletes, repeats some gestures of a war technique, in a logic of 'regulated conflict' that is now out of time.

FUNCTIONAL VS. SYMBOLIC

Do functional and symbolic constitute an opposition as indicated in the title of this paragraph? Yes, they do, but this does not exclude their coexistence, just as in the case of the bicycle described above. The bicycle that took the worker to the factory in the early 1900s and the one (almost identical at the time) that led the champion to victory on the roads of the Tour de France coexisted at the same time and on the same roads. But to understand the nature of the dialectic between the functional and the symbolic in sport, we shall go much further back, even as far as the Odyssey.

We are in book VIII, Ulysses has just been shipwrecked on the land of the Phaeacians and, after narrating the sad adventures that have led him there, he bursts into tears. The king of the Phaeacians, Alcinoo, organizes running and throwing competitions (javelin, discus, etc.) to distract him; however, wiping away his guest's tears is only one of the monarch's aims, the real aim can be read between verse 95 and 105:

And straightway he spoke among the Phaeacians, lovers of the oar: "Hear me, ye leaders and counsellors of the Phaeacians, already have we satisfied our hearts with the equal banquet and with the lyre, which is the companion of the rich feast. But now let us go forth, and make trial of all manner of games, that yon stranger may tell his friends, when he returns home, how far we excel other men in boxing and wrestling and leaping and in speed of foot.

The sporting contests serve to transform the strength of the Phaeacians into a sign which, thanks to its immateriality, can cross the seas carried by the memory of Odysseus and strike fear into the other peoples of the Mediterranean. In other words, the sporting showdown, the symbolic and regulated conflict, serves as a deterrent to real conflicts, generates "effective signs", real linguistic acts and real symbols endowed with functional value. This apparent oxymoron demonstrates the possible cohabitation of the two terms in question.

On the other hand, most human activities produce functions and symbols at the same time, albeit in different proportions. The sign aspect, i.e., the communicative value of the artefact, appears in some cases as a sort of by-product, in other cases as the main product, in others still as the only real result of production. Let us explain this with a few examples. In building a house, the primary objective is to create a shelter and a space where one or more people can live. Nevertheless, that same house becomes, at the same time and almost despite itself, a sign of human presence: the value of the artefact "house" is mainly inherent in its materiality, is mainly functional, and, residually, communicative. If I build a bell tower or a minaret instead of a house, the weight of the symbolic function of my artefact increases. It is true that the materiality of the bell tower serves to support the bells and that of the minaret serves to house the muezzin who calls the faithful to pray, but their purpose is above all to mark the territory and characterize it as belonging to a certain religious community. Finally, in the case of a cross, a crescent moon or a bust of Lenin to be placed on the summit of a mountain, the functional aspect of the artefact will be irrelevant compared to the communicative one. Similarly, in sporting activities there are different balances between functionality and symbolism. A person who, in the privacy of his own room, performs exercises with continuity and application to improve the mobility of an injured limb, is performing an almost exclusively functional activity. If we transfer that same person to a gym, in contact with other individuals with similar problems, his physical effort, while remaining aimed at recovery and then action on his body, becomes an example and a stimulus for others, that is, it communicates something. At the other extreme, we have sports such as ski jumping or figure skating which communicate with the public and the jury their *raison d'être*, at least at a competitive level.

FROM FUNCTIONAL TO SYMBOLIC (ROUND TRIP): THE FATE OF WOOD

As this entire book aims to demonstrate, the destiny of wood and that of sport have been, and still are, inextricably linked. It is possible that such a link is also consolidated by the transitions that like sport, wood makes between the two polarities - functional and symbolic. Until the 1960s, wood was the preferred material for most sport equipment: skis, snowshoes, hockey or baseball sticks, etc. It is well-known that first metallic and then synthetic materials have taken over more and more space over the years. The same has happened in non-sporting activities, in civil engineering as well as in automotive, in workshop tools as well as in kitchen tools, in furniture as well as in upholstery. But just as war activities have entered the symbolic universe of sport, so too has wood, which nonetheless has retained a wide range of functional uses, being able to enter a symbolic universe and become a sign of itself. The grain of the various types of wood photographed and reproduced on the most diverse materials (plastic adhesive films, ceramic stoneware tiles, melamine cladding, PVC flooring) and on the most diverse objects (car sides and dashboards, furnishings, etc.) is evidence of a transition from functional to symbolic. The "wood effect" or the less euphemistic "fake wood", just like the sign in Peirce's sense, are something that replaces wood not in the totality of its possibilities, but according to a precise aspect, that is, through a link of similarity. When abandoned and surpassed by new technologies, wood is replaced by its own image, by the symbol. Or even, as is the case with certain types of skis, the invisible wood hidden in the core of the tool is symbolically exhibited on the outside, with the word "woodcore" prominently displayed (FIGURE 4.2). And in that symbolic permanence there remains, however, a degree of aesthetic and emotional functionality, a possibility of referring in sign form, to a universe of sensations that only wood can give.

FIGURE 4.2 The term "woodcore" is prominently displayed on this ski to highlight the presence of wood inside (image A. Perissinotto).

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Design for sports facilities with structural components in wood as evidence of a new technological challenge

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The theme of architectures designed to host sports activities is at least as broad as the number of sports disciplines that take place in indoor spaces, however, taking the specific theme of architecture for sport made with wooden structures as an analysis filter offers the opportunity to represent, albeit in a concise and non-exhaustive way, one of the most fascinating and stimulating aspects of the history of wooden constructions since the end of the twentieth century (Figure 5.1).

In fact, over the last two decades, the conditions for starting a new, completely unprecedented trajectory for wooden constructions has been determined in Europe, through a process of technological innovation in this sector.

Figure 5.1 For the Olympic Games Helsinki 1952, Alvar Aalto (Reed 2009) designed a sports center in Otaniemi (Espoo, Helsinki) - today still perfecty operational - which impresses with the simplicity and elegance of its wooden structures, representing an extraordinary example of technological innovation in wooden construction of that time. Made of thin prefabricated timber trusses (Isohauta 2013), the structural "skeleton" can be considered a demonstration of architects and engineers' ability to experiment innovative constructive systems starting from new woodprocessing industry construction products. Photograph copyright: Museum of Finnish Architecture, Heikki Havas.

Over the last twenty years, human capital in Europe, represented by the research and business system, by the world of professions and through its scientific and technological skills, has developed the functional conditions for the creation of a support network for the dissemination of completely new experimental construction and structural systems.

The experience and knowledge acquired in this sector in Europe were subsequently transferred to the international arena, resulting in a further boost in terms of innovation, particularly in North America. Architectures with wooden structural components have thus become the representation of possible new design approaches in a still completely experimental context.

Architecture, seen as the challenge of using new materials of natural origin, has thus returned to the tradition of constructing buildings and cities with wooden structural elements, but at the same time has evolved from a technological standpoint. In fact, not only do the engineered wooden components lack any apparent link with the traditional rules of good construction, but also the procedural organization into which the design and construction of a wooden building is inserted today passes through increasingly complex management tools. The transition from the mainly artisanal processing of the past to the modern-day industrialization of processes has required a capacity for organizing the flow of information, bringing elements and information from different disciplines, skills, professional figures and software tools together in a single centralized project.

In the first ten years of this century, this challenge involved the construction of new alpine shelters and the expansion of hotels in mountain settings, during a historical phase in which the primary objective at European level was the pursuit of energy efficiency of buildings.

In the following ten years this chain of skills became more specialized and dealt with new categories of architectural works such as multi-story buildings, redevelopment of the built heritage, the construction of public building structures such as schools and sports buildings in a new season no longer oriented towards the energy efficiency of the building heritage but towards environmental sustainability.

Today the timber construction sector can benefit from twenty years of European experience with very different approaches and experiences, pursuing some epochal challenges for the construction sector with respect to which engineered wood is and will certainly be the absolute protagonist, facing challenges such as decarbonization strategies, the need for innovation in the AEC sector and the industrialization of construction.

Obviously, this qualitative leap in the construction sector has been possible thanks not only to the production of new engineered components, the result of research and development, but also to the reference operational ecosystem in which the profession skills of designers, intent on developing and organizing increasingly complex processes is incorporated today.

In this framework, the buildings for sports facilities are the expression of an innovation that is appropriately expressed through very different design approaches. The case studies selected for this document contribution have different logics and approaches, all consistent within their cultural system of reference, from the prevalence of those using engineered wooden components with a view to industrializing the production processes related to construction, to those that intend to develop territorial supply chains by using solid wood components.

Architecture for sport has always had to cope with large spans but can now incorporate - also thanks to these new technological wooden components - structural and architectural concepts that are an expression of the potential of designing and building large wooden structures.

In sports facilities where the architectural concept cannot ignore the structural dimension of the project, there is no space for the rhetoric of wood as a 'natural material', on the contrary, it is assumed to be a 'structural body' which, thanks to an increasingly high performance from a mechanical point of view, meets the architectural need for lightness and tests the material to the ultimate limit of resistance. This is perhaps the condition that brings together the rigorous dialectic of structural engineers and the freer vision of architects in sports architecture, giving life to a synthesis of design ideas and cultural visions that are clearly expressed by the case studies analyzed above.

Compared to the large spans with structural components in glulam, which from the 1970s onwards were widely used in the design of swimming pool roofs and sports halls, a two-dimensional logic of the portal has been overcome and a spatial approach of more complex architectural and structural projects has been adopted.

With the case studies analyzed as part of this contribution, we intend to outline a possible geography of architecture for sport, of the underlying structural and architectural concepts that can now be documented in Europe. The analysis is not intended to be exhaustive, but representative, and is conducted by briefly setting out the specific nature of some case studies while proposing a comparative succinct reading of the different case studies characterized by using different engineered components.

The case studies are the expression of ambitious technological challenges characterized by different visions, logics and strategies which, compared to the past, enrich the specific theme of architecture and structures for sport, projecting it into a new dimension, a direct consequence of a technological innovation in the wood construction sector, the leitmotif of this publication.

SELECTED CASE STUDIES

Thirteen case studies are analyzed below, in chronological order from 1995 to 2020, using a taxonomic chart for a comparative reading of the works according to the structures and the engineered components used (FIGURE 5.2).

The chart is qualitative, and the intent is to synthetically represent the different structural and constructive conceptions of structures, using engineered components whose utilization, in some cases, is very recent. With the aim of contextualizing some of the works in more depth, seven case studies are described, which are a limited number for a matter of space, compared to those investigated.

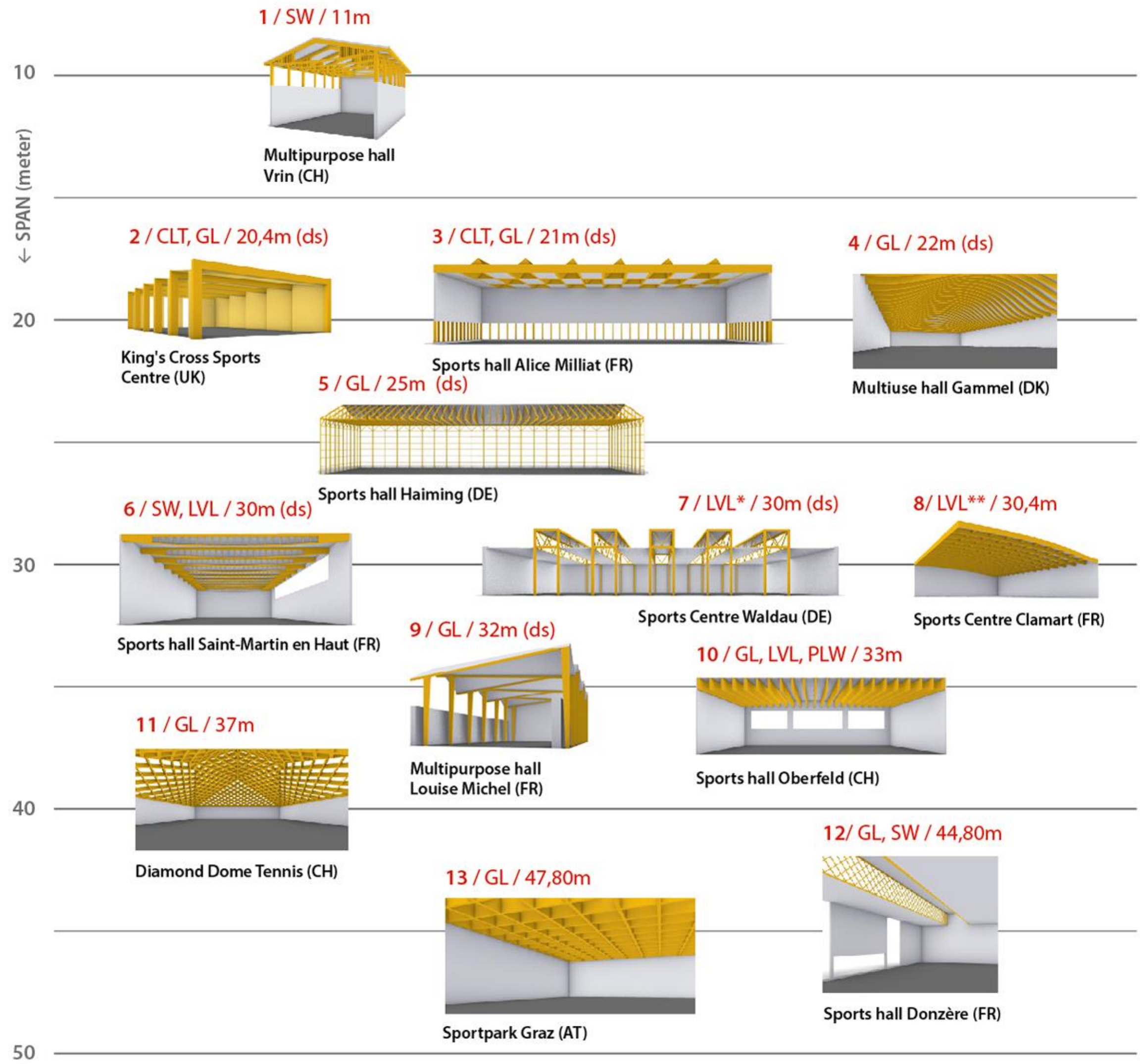


FIGURE 5.2 The comparison of thirteen case studies, including those analyzed in this article, shows the different typologies of roof structures related to the wood-based building materials and their maximum span. Original graphics: G. Callegari, P. Simeone, E. Merolla, Department of Architecture and Design, Politecnico di Torino. SW: solid wood / GL: glulam / CLT: cross laminated timber / LVL: laminated veneer lumber / LVL*: hardwood (Beech) laminated veneer lumber / LVL**: curved laminated veneer lumber / PLW: plywood / (ds): span deducted from architectural drawings available on the Internet (see also CASE STUDIES at the end).

A first case study from 1995 is the **Multipurpose Hall in Vrin (1995)**. The architect Gion Caminada together with the civil engineer Jürg Conzett designed a small work of art. both from the construction technique point of view and the wise use of non-engineered wooden structural elements. Starting from a knowledgeable understanding of traditional construction systems (Schlorhaufer 2005), the conception of the roof load-bearing structures covering the large span is a harmonious play of contrasting stresses using simple solid wooden elements - slats, struts and posts - in a binder construction designed as an understretched system (FIGURE 5.3).

Multipurpose hall
Vrin (CH) 1995
Architecture: Gion A. Caminada with civil engineer Jürg Conzett
Photography: Lucia Degonda

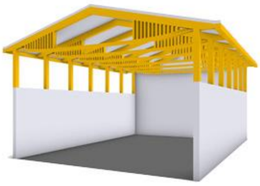


FIGURE 5.3 Multipurpose Hall Vrin; photograph copyright: Lucia Degonda; original graphics: G. Callegari, P. Simeone, E. Merolla, Department of Architecture and Design, Politecnico di Torino.

The **gymnasium and sports hall in Saint Martin en Haut (2012)** designed by the French company Tekhné architectes & urbanistes, impresses with its spatial roof design formed by an unconventional timber framework. The load-bearing structure consists of ten inverted "organic" wooden trusses - each of them divided into two parts - that support a planted 'green' roof covering a span of 30 meters: the crisscross girder trusses are made up of both engineered wood and solid timber: tensioned and compressed LVL (laminated veneer lumber) beams for the chord members and vertical and oblique solid timber bars for the latticework (FIGURE 5.4).

Sports hall gymnasium
Saint-Martin en Haut (FR), 2012
Architecture: Tekhnê Architectes
Wood structure: Arborescence
Photography: Renaud Araud

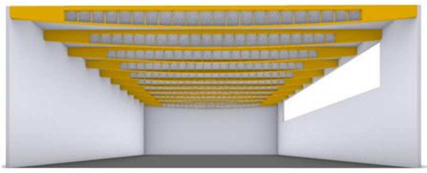
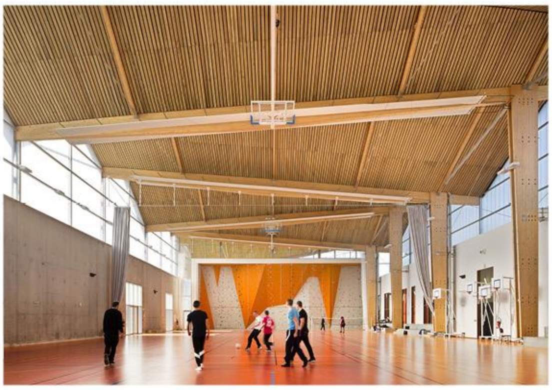


FIGURE 5.4 Sports hall gymnasium; photograph copyright: Renaud Araud; original graphics: G. Callegari, P. Simeone, E. Merolla, Department of Architecture and Design, Politecnico di Torino.

For the roof supporting structure of the new sports hall of the **Louise Michel High School in Gisors (2015),** the French architecture studio Arch5 designed an original spatial configuration of eleven non-parallel wooden portal frames made out of vertical glulam paired pillars and inclined glulam (glued laminated timber) beams and characterized by the protrusion of the load-bearing elements that cross the external wall along one side of the hall. A spectacular architectural composition that shows the will of the architects to enhance both the aesthetic and structural qualities of the apparently simple constructive system (FIGURE 5.5).



Sports hall Louise Michel high school
Gisors (FR), 2015
Architecture: archi5 Architects
Wood structure: Egis centre oust
Photography: archi5

FIGURE 5.5 Sports hall Louise Michel high school; photograph copyright: archi5; original graphics: G. Callegari, P. Simeone, E. Merolla, Department of Architecture and Design, Politecnico di Torino.

In a former industrial estate of Lyon, Dietrich I Untertrifaller architectural studio designed the **Alice Milliat Sports Hall (2016)**. For the architects, the structure of the main sports hall roof had to speak the formal language of the former factories and their shed-roofs but with a new 100% bio-based grammar. Glulam (glued laminated timber) for the long beams and straw for the thermal-acoustic insulation. The ceiling of the sports hall is impressive, with skylights in the form of truncated wooden pyramids made of CLT (cross laminated timber) panels, as an interpretation of the original industrial sheds, arranged like a chessboard to form a structure that lightly covers the long span (FIGURE 5.6).

Sports hall Alice Milliat
Lyon (FR), 2014-16
Architecture: Dietrich Untertrifaller + Tekhnê Architectes
Wood structure: Arborescence
Photography: Julien Lanoo

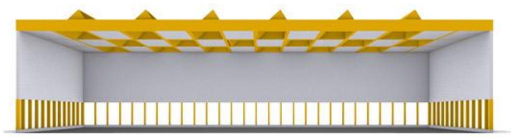


FIGURE 5.6 Sports hall Alice Milliat; photograph copyright: Julien Lanoo; original graphics: G. Callegari, P. Simeone, E. Merolla, Department of Architecture and Design, Politecnico di Torino.

The **Haiming Sports Hall (2016)** by Almannai Fischer, impresses with its simplicity and the slenderness of the structural components used for both the roof and the walls: posts, bars and diagonals with minimal resistance section create a large geometric pattern. The system of timber frame wall and narrow roof trusses includes galvanized gang nail plates: the cheapest general-purpose connector for the timber structures, demonstrating that the architects wanted to make the most of the mechanical property strength/lightness of the wooden load-bearing elements while creating a refined minimalist skeleton (FIGURE 5.7).

Sports hall Haiming
Haiming (DE), 2013-16
Architecture: Almannai Fischer Architects
+ Harald Fuchshuber Engineer
Photography: Sebastian Schels

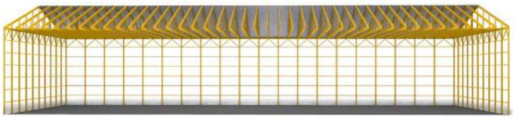


FIGURE 5.7 Sports hall Haiming; photograph copyright: Sebastian Schels; original graphics: G. Callegari, P. Simeone, E. Merolla, Department of Architecture and Design, Politecnico di Torino.

The new sports hall for the **Oberfeld school complex (2018)** - designed by Gäumann Lüdi Von Der Ropp Architekten - is characterized by a sophisticated approach to the use of wood as a building material by the Holztragwerke-Engineering & Innovations engineering company. A system of glulam beams with a 33-meter span forms the principal load-bearing element of the roof structure, which is braced by the combination of three different engineered wood components: smaller glulam beams orthogonally connected to the principal ones, external perimeter reinforcement made out of narrow LVL beams and plywood panels connected to the extrados of the beams (FIGURE 5.8).

New sports hall Oberfeld
Langnau im Emmental (CH), 2018
Architecture: Gäumann Lüdi Von Der Ropp
Wood structure: Holztragwerke Engineering
Photography: Alessandro Fabris

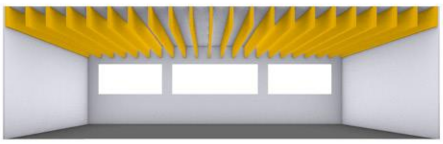


FIGURE 5.8 New sports hall Oberfeld; photograph copyright: Alessandro Fabris; original graphics: G. Callegari, P. Simeone, E. Merolla, Department of Architecture and Design, Politecnico di Torino.

The two long wooden truss beams parallel to each other positioned on the longer side of the roof are the exceptional architectural sign of the new **Donzère sports hall (2020)**, designed by the French company Tekhné architectes & urbanistes. Composed of two sections for a total length of 45 meters, the wooden lattice girders have a reticular configuration that performs both static functions and lets natural light in from the roof. The elegant constructive system consists of two glulam upper and lower oriented flat beams and a wooden truss web made of compression members and tensioned diagonal members both in solid wood (FIGURE 5.9).

Sports hall Donzère
Donzère (FR), 2020
Architecture: Tekhnê Architectes
Wood structure: Arborescence
Photography: Renaud Araud

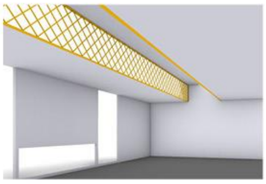


FIGURE 5.9 Sports hall Donzère; photograph copyright: Renaud Araud; original graphics: G. Callegari, P. Simeone, E. Merolla, Department of Architecture and Design, Politecnico di Torino.

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CASE STUDIES
1: Multipurpose hall, Vrin (CH) 1995, architect Gion Caminada + civil engineer Jürg Conzett / 2: King's Cross Sports Centre, London (UK), 2020, Bennetts Associates architect, Ove Arup & Partners Engineers) / 3: Sports hall Alice Milliat, Lyon (FR), 2014-16, Dietrich Untertrifaller + Tekhnê architectes, Arborescence ingénierie / 4: Multi-use hall Gammel Gymnasium, Hellerup (DK), 2013, BIG Architects / 5: Sports hall, Haiming (DE), 2016, Almannai Fischer Architects + Harald Fuchshuber Engineer / 6: Sports hall gymnasium, Saint-Martin en Haut (FR), 2012, Tekhnê architectes, Arborescence ingénierie / 7: Sports Centre Waldau, Stuttgart (DE), 2020, Glück + Partner architectes / 8: Sports Centre, Clamart (FR), 2016, Gaëtan Le Penhuel architectes / 9: Multipurpose hall Louise Michel high school, Gisors (FR), 2015, archi5 Architects, Egis centre oust /10: Sports hall Oberfeld, Langnau im Emmental (CH), 2018, Gäumann Lüdi Von Der Ropp architect, Holztragwerke Engineers / 11: Diamond Dome Tennis, Zurich (CH), 2011-17, Rüssli Architects / 12: Sports hall, Donzère (FR), 2020, Tekhnê architectes + Arch'Eco, Arborescence ingénierie / 13: Sportpark, Graz (AT), 2020, projektCC architects, Peter Lechner Engineers.

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WOOD SPECIES IN SPORT EQUIPMENT

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Wood is displayed in service (in play...) in several images within this book. This chapter aims to provide a closer look at the longitudinal surface and cross section (FIGURE 6.1) of 12 amongst the most common wood species used in wooden sport wquipment. Cross section images were taken by the XyloTron (2020).

Each species is presented by both its scientific and common name. It is quite frequent that the main species providing a certain timber differs depending on the geographic context. This is the case for instance with *Fraxinus excelsior* and *Fraxinus americana*, both sources of ash timber in Europe and the USA respectively. In such cases, we only present one species here as an example. Each description is completed by indicating whether the wood is a softwood or a hardwood and a list of *some* sports in which it is used.

Overall, this chapter is intended as a quick infographic. For detailed information on the properties and macroscopic identification of the listed wood species, please refer to the extensive amount of specific literature available (e.g., Ruffinatto and Crivellaro 2019).

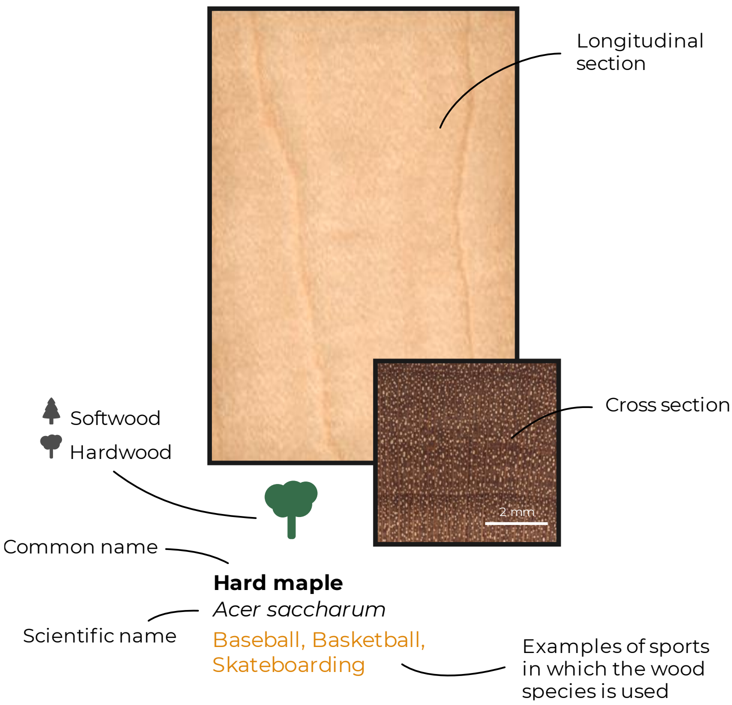

FIGURE 6.1 Information reported in the following sheets.

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Ash
Fraxinus excelsior
Archery, Ice Hockey, Skiing

Balsa
Ochroma pyramidale
Surfboarding, Table Tennis

Beech
Fagus sylvatica
Archery, Basketball, Club throw, Skateboarding

Birch
Betula pendula
Climbing, Basketball, Skateboarding

English walnut
Juglans regia
Shooting, Table Tennis

Hard maple
Acer saccharum
Baseball, Basketball, Skateboarding

Limba
Terminalia superba
Table Tennis

Paulownia
Paulownia tomentosa
Skiing, Surfboarding, Table Tennis

Poplar
Populus alba
Climbing, Ice Hockey, Skiing

Scots pine
Pinus sylvestris
Taekwondo, Track cycling

Spruce
Picea abies
Table Tennis, Taekwondo, Track cycling

Western red cedar
Thuja plicata
Surfboarding

Environmental sustainability of wooden sport equipment

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The transition to a sustainable society is a key challenge for humankind. Sustainability is a broad concept that is based on three so-called pillars: social, economic and environmental (Purvis 2019). Here, aspects related to the environmental sustainability of wood and wooden sport equipment are briefly introduced.

Improving the environmental sustainability of modern society requires adopting different strategies at the same time: increasing the use of renewable materials and energy sources, improving the efficiency of production processes, promoting socio-cultural models that reduce wastefulness of resources, etc. A common, key goal of such strategies is reducing greenhouse gas (GHGs) emissions to mitigate the undergoing climate crisis, the main cause of which is recognized as anthropogenic GHGs emissions. Atmospheric carbon dioxide (CO_2) is one of the most important GHGs, both for its global warming potential and for the impact that human activities have on its atmospheric concentration, which recently reached 417 ppm [1].

In this context, enhancing the environmental profile of materials and products is a transversal, essential challenge. Wood and its derived products typically have environmental impacts that are considerably lower compared to those of non-wooden alternatives such as steel, plastics, or carbon fiber (Bergman et al. 2014). This arises from several aspects that characterize the life cycle of wood-based products. To mention some of the most relevant:

- the extraction of the wooden raw material and its manufacturing processes are less energy-intensive compared to that of other materials;
- wooden manufacturing scraps can be destined to bio-energy production, for instance within the production processes (like the use of thermal power for steaming, drying or pressing), avoiding the use of fossil fuels;
- wood stores the carbon dioxide that has been absorbed by the living tree from the atmosphere;
- often, wood-based products can be easily reused or recycled;
- at the end-of-life stage, their destination to energy production further avoids the use of fossil fuels.

The above opportunities are also in line with the modern concept of circular economy. Overall, the number of emissions avoided by choosing a product that is made of wood instead of an alternative material can be relevant. Avoided emissions add up in large-volume structures made up of several products, such as buildings, clearly resulting in large final differences.

Evaluating the environmental impact of products has therefore become increasingly important to address sustainability issues. Life Cycle Assessment (LCA) and Environmental Product Declaration (EPD) are valuable tools to highlight and promote the use of wood-based products. Awareness of the climate crisis is actually leading to new opportunities for wood and its derived products, the demand coming both from public policies and from customers' preferences. Conversely, this also poses new challenges and the possibility of meeting the increasing demand in a sustainable way is being debated.

In fact, it must be considered that around 15-30% of timber traded on a global scale is currently estimated to be of illegal provenance

(UN Environment 2017). Illegal logging has negative impacts at environmental, social, and economic levels, which reach devastating levels in some tropical areas and have global implications as a whole. Efforts to tackle illegal logging have increased over the past decades, in which important legislative acts have been promulgated or implemented, for instance the European Timber Regulation, the US Lacey Act, and the Australian Illegal Logging Prohibition Act.

It is therefore plain that the sustainability of wood-based products necessarily starts from forests (FIGURE 7.1). When trees are harvested from sustainably managed forests, they can perpetuate over time, and wood can be truly considered a renewable material. Sustainable forest certification schemes have become more widespread over the last years, and the number of hectares of certified forests have increased constantly on a global scale. Forest certification schemes take two main areas into account. The forest management (FM) certification attests that forests are managed according to principles aimed at preserving biodiversity, respecting workers' rights, enhancing social impacts, etc. The Chain of Custody (CoC) certification instead ensures the traceability of the material along the supply chain, in order to document the provenance of wood embedded in products entering the market.

FIGURE 7.1 Sustainability of beech wood basketball floors starts with the sustainable management of the beech forest from where the wood comes from (image F. Negro).

CARBON DIOXIDE STORAGE IN WOOD-BASED PRODUCTS

Over the past decade the storage of carbon dioxide in wood-based products has gained increasing attention. Through the photosynthesis process, trees absorb carbon dioxide from the atmosphere and use it to build their tissues, and in particular wood (FIGURE 7.2). Carbon dioxide is therefore fixed in the wood of living trees as biogenic carbon. When trees are harvested, carbon dioxide remains incorporated in their trunks, and when the trunks are processed to make objects, say baseball bats, carbon dioxide remains stored in them. Carbon will be released back into the atmosphere at the end-of-life stage: if the wood is burned for energy purposes it is oxidized into carbon dioxide (it is to note that carbon dioxide is also released when wood is decomposed).

The relevance of CO_2 storage in wood-based products depends on wood density, product volume, wood fraction in the product, and service life duration (Negro and Bergman 2019). On a volume basis, the higher the density, the higher the amount of carbon stored. The role played by product volume is evident as well: everything else being equal, higher volume means a major amount of carbon stored. The wood fraction needs to be taken into account because the volume of non-wooden elements (glue or other materials) embedded in the wood-based product must be removed from the calculation. Finally, longer service life determines longer, and thus more valuable, storage periods.

In many cases wooden sport equipment has a service life limited to a few years, its replacement being due to wear or to the appearance of new, evolved models on the market. Nonetheless, some wooden sport equipment remains in use for decades or even longer, as in the case of basketball parquet floorings.

Finally, carbon dioxide stock can also extend beyond the product service life. According to the cascading use approach encouraged by the new European Forest Strategy (EU Commission 2021), wood shall be used in the following order of priorities: 1) wood-based products, 2) extending product service life, 3) re-use, 4) recycling, 5) bioenergy, 6) disposal.

Thanks to its versatility and ease of processing, wood is well-suited to "cascades" extended both in the number of steps and in usage time. Typically, the size of the wooden elements decreases alongside such cascades. For instance, the parquet strips of a basketball court wooden flooring can be reduced at the end of service life, to particles or fibers for the manufacturing of recycled panels.

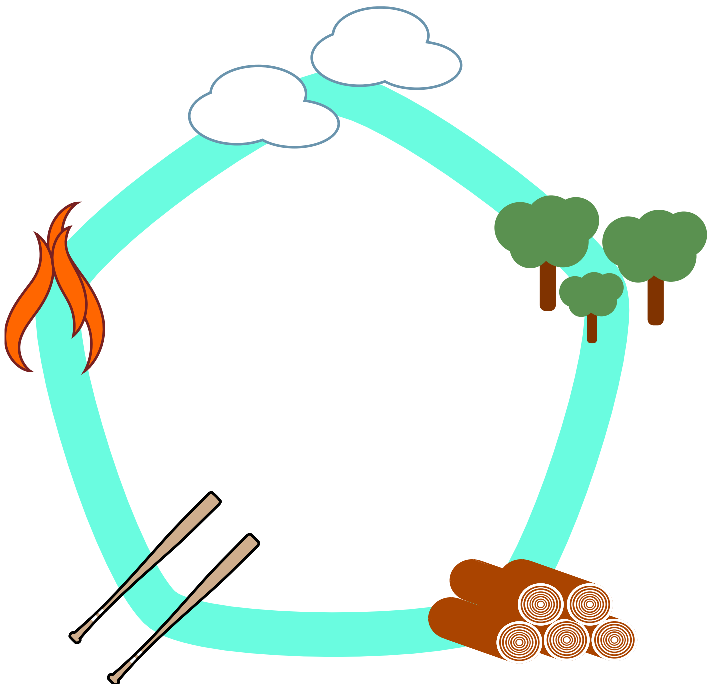

FIGURE 7.2 Outline of a multi-step carbon journey: from atmospheric CO_2, to living trees, roundwood, baseball bats and, after burning, back to the atmosphere where the cycle restarts (image F. Negro).

ENVIRONMENTAL SUSTAINABILITY OF WOODEN SPORT EQUIPMENT

The discussed environmental values of wood are valid in general terms, and therefore also apply to the specific case of wooden sport items. These can be entirely made of wood, such as baseball bats, or of composite materials, such as skis. As a rule, the higher the fraction of wood in the sport items, the lower their environmental impact.

In recent years, sustainability has been increasingly considered in the production of sport equipment. This trend is already creating new opportunities for wood that could potentially regain, also by composite products, part of the space that it has lost in some sports. At high competition levels it is clear the dominance of high-performing materials can hardly be challenged. However, at lower or recreational levels, and in some specific sports, the increased attention towards sustainability represents a relevant opportunity for wood.

Sustainability is being increasingly considered and shown by producers of sport items, also as a marketing strategy. The information provided varies from brief notes up to well-structured websites and documentations. Several sport items made with wood certified from sustainably managed forests are nowadays available on the market: for instance, table tennis rackets, snowboards and skis, basketball floors, etc. The results of Life Cycle Assessment studies are also communicated by some producers.

A key push towards sustainability in the world of sport also comes from institutions and sport federations. As regards some years ago, the International Olympic Committee started to adopt a sustainability strategy that is updated every year (IOC 2021). This strategy focuses on five, interconnected areas. Four of them are: building and operating venues; procuring goods and services and managing resources; moving people and goods; managing and helping people. The fifth area is instead addressed to the cross-cutting theme of climate issues. IOC's commitment also includes "supporting innovative low or zero carbon solutions relevant to sporting events". This approach will likely have positive cascade rebounds on international and national sport federations. Overall, the opportunities that can arise for wood in sport facilities and equipment can be easily imagined.

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INNOVATION AND RESEARCH ON WOODEN SPORT EQUIPMENT

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INTRODUCTION

Wooden sport equipment (WSE) can be replaced for a variety of reasons, the most obvious being consumption. Sport items are in fact repeatedly subjected to impacts, bending stresses, use in outdoor environments, etc., that inevitably challenge the length of their service life. In addition, WSE is often replaced not because it is exhausted, but to upgrade it. This happens for instance when one starts playing a sport with an entry-level item, whose performance becomes limiting once the player's skills have improved. Another relevant case is that of users aiming to find, within the same range of performance and costs, an item more suited to their needs, for instance with a different balancing. Assessing, testing and choosing sport items are actually often part of the pleasure of practicing a sport, by both amateur and competitive players.

Coming to the content of this chapter, entry on the market of new models with improved performance is a key reason for replacing WSE. In some cases, improvement regards minor details only; in others, major breakthroughs enter the market, making the items produced until then obsolete. Tennis rackets are a remarkable example in terms of innovation and material, namely wood, becoming obsolete for a sport item (see the relative chapter for details). In short, from the 1870s to the present day the composition of tennis rackets has evolved from solid wood to wood laminate, to composite materials, in a still undergoing search for optimal performance.

Today, wooden sport equipment is often presented by producers and retailers as a combination of tradition and innovation. Commercial claims and patented terms referring to timber technology, wood performance, wood power, wood lightness and so on are frequently used in marketing WSE. Over the past years, producers have also started to highlight novelties in terms of sustainability of the materials used.

Overall, wood sport equipment is subjected to continuous innovation that can follow different paths. Advancement can be sought by companies, especially large ones having specific Research and Development departments. In some sports, artisanal crafting can also provide a relevant contribution in technological advancement. Finally, scientific research is also carried out to understand and improve the performance of WSE, also in collaboration with producers and players.

Scientific studies on WSE can address different areas of research. To name some, researches can: focus on the specific role and characteristics of wood and wood-based products in a sport item (FIGURE 8.1); analyze the properties of the item as a whole, with no or limited reference to its wooden components; investigate the effects of WSE on players, i.e. in terms of fatigue or quality of play. Several other focus areas could be named, including sustainability, marketing, etc.

This chapter intends to briefly show some examples of scientific research in the field of wood sport equipment. To this purpose, the content of some scientific articles published in recent years is summarized herein. The aim is to give the idea of some of the aspects that can be deepened at a scientific level. In this view, the listed studies are by no means the result of an exhaustive bibliographic search, but a quick overview on this broad field of study.

FIGURE 8.1 The composition of the plywood blade, in terms of number and thickness of layers, and wood species used, is relevant to the overall performance of a table tennis racket, which can be fast, slow, stiff, etc. (image F. Negro).

EXAMPLES OF SCIENTIFIC STUDIES

Finn et al. (2019) studied the effect of wood slope of grain on the rupture of baseball bats, depending on the bat/ball speed. The research was conducted using the finite element method. Parameters considered included wood slope of grain, impact locations, impact speeds, and wood species, namely ash, maple, and yellow birch. Among the results, the authors found that 0° slope of grain is not necessarily the configuration providing the higher resistance, yet it is the most versatile.

Turcas Diaconu et al. (2019) investigated the effect of the composition of eight basketball floorings on the ball bounce height. Flooring strips were made of beech wood, had equal lengths and widths, and were 20 mm or 15 mm thick. Floorings were placed on beech timber frames made of crossing joints and noggings. Wooden and rubber shock pads were placed in different positions between the frame and the foundation. Among the results, the best bounce heights were measured for 20 mm thick strips laid on frames with wooden shock pads placed halfway between joists and nogging joints.

Manin et al. (2014) assessed the influence of blade plywood composition on the vibro-acoustic behavior of table tennis rackets. Prototype rackets with blades differing in terms of ply thickness and wood species were tested. The vibro-acoustic behavior of rackets without rubbers was measured, then rubbers were glued onto the blades and players were asked to classify the ball impact sounds. The results of the study highlight the relevance of the blade design parameters on the impact sound, and the players' sensitive classification resulted consistent with the experimental measurements.

Eberle et al. (2019) performed a multibody simulation to assess the transversal vibrations of unedged skis during schussing over slopes with random irregularities. Skis were modelled as dynamic Euler-Bernoulli beams and incorporated as flexible beams into a multibody skier model. By the Monte Carlo simulation method, runs over random slopes were performed and the ski vibrations analyzed. The results showed that irregularities on ski slopes contributed considerably to the vibration of a ski and the performance of a skier. While the ski is considered here as a whole, the results of the study can also pertain to wood as a material typically used for ski cores. Authors indicated in fact that their simulation model can also be useful to find optimal material parameters aimed at reducing ski vibrations.

Serrano et al. (2020) investigated the plantar pressures and time performance of futsal players during changes of direction on wooden and on synthetic flooring. Shock absorption and vertical deformation were taken into account. In short, the wooden flooring displayed higher shock absorption and vertical deformation compared with the synthetic flooring. Changes of direction were faster on the wooden flooring than on the synthetic flooring, whereas no differences in total test time were found. Finally, no differences in plantar pressures by playing surface were found, which could be due to player adaptation.

Willard and Loferski (2018) started from the consideration that millions of used skateboard decks are discarded every year worldwide. Therefore, they investigated the possibility of processing plywood skateboard decks into smaller panels. To this purpose, the nose and tail of decks were removed, whereas middle sections were used to make the new panels. After separation from the deck, the middle sections were further cut into strips that where then rotated by 90° (their orientation moving from facewise to edgewise) and glued to form the new composite panels. Bending strength and stiffness, moisture content, specific gravity, and moisture durability of the new panels were then determined. Their wooden species were also identified. Overall, the physico-mechanical properties of such composite panels resulted to be well-suited to several potential applications, for instance in flooring and furniture. The article finally highlights that the aesthetics of such panels could be of interest as well, as they derive from skateboard decks that typically have a great variety of colors.

Finally, a study on marketing WSE is currently being performed by the editor of this book together with some coauthors. The research - to be submitted in the near future to a scientific journal - considers various websites of relevant WSE producers in different sports. The aim is to assess some relevant parameters related to marketing WSE, such as information on the wood species used, exploitation of the aesthetics of wood, sustainability, brand awareness, etc.

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Ecological contract in sport facilities and equipment

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INTRODUCTION

This chapter is focused on the main topic of ecological contract (Pennalisco 2015) considered as an implementation tool of sustainable development. The aim is to verify whether the procedures that highlight a fulfilment of human needs, inspired by the integration of the environmental interest, are applicable to the world of sport. Therefore, we question about the effectiveness of sustainable development, starting from its best-known definition in the report of the World Commission on Environment and Development of 1987, the so-called Brundtland Report, and in the analysis of the legal changes within the institution of sports supply contracts.

SUSTAINABLE DEVELOPMENT

Over the years, the concept of environmental sustainability has been the object of a growing interest from the civil society. It is the result of a greater awareness of the exhaustibility of the resources of our planet and the increasingly need to preserve the quality of the natural heritage, aiming to promote more balanced economic and social development models than those adopted in the past. Sustainable development is a many-sided and multidisciplinary concept proposed as a value or purpose, sometimes as a reference model to strive for to overcome the "unsustainable" logic of profit and growth so far sought.

The best-known expression of the definition of sustainable development can be found in the report of the World Commission on Environment and Development of 1987, the so-called Brundtland Report, according to which "sustainable is the development which meets the needs of the present generation without compromising the ability of future generations to meet their own". If on one hand this definition wishes for an incessant need for progress towards a greater well-being, on the other it sets a boundary of sustainability with reference both to the need for environment protection and for the rationality in the use of natural resources (Pennalisco 2015).

It is appropriate to reflect on the relation between scientific progress and environment protection. On one hand, it could be argued that the respect for the environment represents an insurmountable boundary for technological progress; on the other hand, it is necessary to point out that technological progress can be an amazing ally in the process that leads to a greater respect for the environmental context. This possible antinomy could find a solution in the concept, according to which it is provided that the environmental impact assessment guarantees a high level of environmental protection, and it is ensured that plans and programs can contribute to laying down the conditions for sustainable development. This approach can be found in the Treaty on European Union and, for instance, in the Italian Environmental Code (Legislative Decree 152/2006). It can be noticed that every legally relevant act should conform to the principle of sustainability, identifying an equal relation among resources to be kept and handed down. This to the purpose that the solidarity principle aimed to improve the quality of the environment is included into the dynamics of consumption production.

SUSTAINABLE DEVELOPMENT, SPORTS EQUIPMENT AND LEGAL SYSTEM

Therefore, as happens with human behavior, also the game represents the object of study of law since it is considered as a qualified phenomenon on a social level and consequently it deserves the interest from the legal system. The sports phenomenon has become an essential element in the life of contemporary societies that identify it as one of the collective events most capable of influencing lifestyles and human values such that it constitutes a real cultural background (Porro 2008).

Sport is one of the most important markets in the world, with millions of followers everywhere. In this sector the impact of the use of sustainable materials (such as wood) cannot be underestimated. Considering its international dimension, sport represents a privileged channel to communicate sustainability, and it is exactly on this aspect that the medium and long-term plans of many sports organizations are focusing. Noteworthy are the strategies adopted by some of the most remarkable organizations world-wide, first of all, of the IOC (International Olympic Committee) that has developed a sustainability tactic based on infrastructures and natural sites. The prospect will be to make all the stadiums that host great events certified, according to one of the green building standards recognized on a national and international level. To implement sustainability, it is necessary to pay attention not only to facilities but also to playing tools.

The construction and use of the equipment used during competitions, or the training, have always drawn great attention from sportsmen. In ancient times, the most avant-garde materials were represented by metals, also used for weapons and body protections. Symmetrically to metals, and sometimes together with them, a very extensive use of wood of varied species has been made according to the needs of the various sports. If materials have become an important element in sport, there is the need to identify the ways through which it is possible to combine the theme of sustainability with that of sports performance. Therefore, the ecological contract, applied to wider contexts and by analogy also to the world of sport, acts as a driving force in the ecological management process and in the rearrangement of consumptions towards greener products (Addante 2012), as well as through the implementation of a control on the production chain aimed to guarantee the transformation process of the materials during all its steps.

ECOLOGICAL CONTRACT

By affirming that every public and private human activity must comply with the principle of sustainable development, the need to adjust negotiation activities to the requests of environmental sustainability is also highlighted in the world of sport. We are witnessing an overcoming of the traditional dogmas on which the civil law negotiation tradition is based: in other words, the principle of relativity, according to which the contract produces effects just between the parties (Perlingieri 2015). The aim of the ecological contract, intended not only as a reward contract but above all as a corrective and preventive one (Pennalisco 2015), is not so much the protection of nature itself, but rather the protection of human survival (Perlingieri 2014).

In fact, if we want to take the responsible use of natural resources in contractual matters seriously, the decisive step is precisely that of integrating the environmental interests in public and private negotiation through “green clauses” no longer optional but mandatory. Therefore, the application of the ecological contract to the world of sport is essential in the construction of the economy of sharing, in which the consumer or user does not ask for goods or services, but through those goods and services, on which the quality of present and future life depends, he/she asks to live actively, experimenting a real environmental negotiating relation.

CONCLUSIONS

The practical confirmation is, as usual, the effective implementation of the principal provisions. As already occurs in many other sectors, the solution could come from technology even in sport.

Blockchain technology could confirm the quality of the materials of professional equipment used by athletes, in compliance with sustainability as outlined so far. As is known, blockchain has a series of intrinsic characteristics which allow it to track the transactions that are carried out along a specific supply chain in a safe and immutable way. This without the need of assigning tasks of managing and transactions certification to an intermediary. Monitoring the product cycle step by step ensures a clearer and more transparent traceability of the production chain, preventing the spread of materials that contaminate the process as a whole. From this point of view, blockchain can be considered as one of the main technologies to strengthen the ability to create a system around the deepest and most consolidated values of our community of which sport is one of the best bearer.

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Wooden skis: an emblematic item of Norway's cultural heritage

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SKIS AND WOOD THROUGH NORWEGIAN HISTORY

Skiing is an important part of Norway's identity and cultural heritage and skis have historically been an important means of transportation during the winter in a society based on agriculture, hunting and fishing. The snow-covered terrain was not an obstacle but rather an aid, making it possible to move across large distances thanks to the knowledge of making skis for different purposes and terrains.

Skiing is also reflected in our language through words and expressions. The phrase "born with skis on his/her feet" is an expression many Norwegians will recognize, and points to the natural part skiing has had in people's lives throughout history.

THE OLDEST TRACES OF SKIING IN NORWAY

From prehistoric times, skis have been used as a means of transport in snow-covered areas. The historical connection between wood and skis has been inextricably linked. The connection is shown in the meaning of the word «ski» which comes from the Old Norse word «skíð» and means «split piece of wood» (Bø 1992:12).

Based on dated rock carvings, it has long been considered that the practice of skiing stretches back to around 6,000 years in time (Berg 2015: 36). A petroglyph found in Nord-Trøndelag, Norway, is considered to be the oldest reproduction of a skier in Norway (Figure 10.1). "Bølamannen" is a 147 cm long figure, standing on a 127 cm long ski with a tip.

Figure 10.1 Bølamannen was found in an area with many petroglyphs. The field has recently been dated to be from 3400-3200 years BC. Drawing Rune Flaten, The Ski Museum in Holmenkollen.

A line drawn under the figure's foot may indicate that the sole of the ski is covered with fur, held in place by cords. The figure also holds a ski pole in his hand (Flaten, 2003: 33). Other petroglyphs around "Bølamannen" tell us something about the skiers' environment. Animals such as a moose, a bear, a reindeer, and a figure that has been interpreted to represent a seabird are also depicted in the surrounding area where "Bølamannen" was discovered.

Skis are also represented in traditional storytelling and mythology through the centuries. The sagas from the Viking Age tell us that the Vikings were skilled skiers, and in Norse mythology, we encounter the ski god Ull and the ski goddess Skade. (Bø 1992:16) This indicates that skis have played a central role for several thousand years in securing the ability to survive in a snow-covered area of the world.

HISTORICAL DISCOVERIES IN NORWAY

Many prehistoric skis have been found in bogs. Due to climate change and melting glaciers, discoveries are constantly emerging. The oldest skis found in the Nordic countries are the "Kalvträsk"-skis, which were found together with a spade-shaped pole, in a bog in Sweden. The "Kalvträsk" skis are about 5600 years old, estimated to be from 3623-3110 BC. The oldest Norwegian ski, Drevjafunnet, is from Vefsn in Nordland. C-14 carbon dating of the wood has placed the ski within the period 3343-2939 BC. (Sørensen 1995:47).

There are many museums in Norway that have skis in their collections. Established in 1923, the Ski Museum in Holmenkollen is the world's oldest specialized museum for skis. The Ski Museum has several prehistoric skis in its collection of historical skis. The two oldest skis, the Alvdal-ski and the Utrovatn-ski date to the Iron Age. Like most skis found in bog areas, the Alvdal- and Utrovatn-skis are made of pinewood (Sørensen, Collegium Medievale:41). The collection of historical skis at the Ski Museum indicates that skis from the 19th century were made based on what materials were locally available. This practice would probably apply to prehistoric times. One explanation to why pine is the dominant material in prehistoric skis could be the decomposition processes within the various wood materials. Where Pinetree has a heartwood that is particularly resistant to decay, birch wood will dissolve faster (Torgersen 1999: 31).

SKIS FROM THE 19TH CENTURY

We have more knowledge from the 19th century about common practice and choice of materials in making skis. The ski was made of one piece of wood, hence the Norwegian term "helved-ski", meaning a ski from one solid piece of wood. The preferred kind of wood varied from village to village, but also from ski maker to ski maker. Inherited knowledge was one important factor, hands-on experience another. The ski maker had definite requirements for the timber; it had to be straight-growing, as free of knots as possible, and easily shaped. However, the ski maker quite often had to settle for materials of an inferior quality. He had to work with what nature offered. Coarsely speaking, it is possible to say that deciduous trees were mainly used in North and Mid-Norway. Oak was mostly common in the coastal areas from the county of Rogaland to the county of Telemark, whereas pine and ash were used more in the other regions of the south of Norway (Berg 1993:36).

For ski making, different wood has different qualities. Generally, one could say that deciduous trees are stronger than conifers. At the same time, there are different parts in the structure of the wood that is best suited for making skis. The inner heartwood is stronger and denser than the sapwood. The division between these two layers in strength and density is also reflected in the color and weight. The heartwood is darker and heavier. In spruce and pine, a so-called reaction wood called "tennar" in Norwegian, can develop, which is especially sought after for ski making. Reaction wood occurs when a tree in proximity to water, grows obliquely before it straightens up. The "tennar" is a very hard and compact wood. It allows the ski to retain its shape as it is stiff yet flexible. A ski made of "tennar" will provide glide and will not give a build-up of snow underneath the ski (Berg 1993:36). A tree with reaction wood usually provided only enough wood for one ski.

The process and work from locating a suitable piece of wood to finishing a pair of skis was a laborious process and could take up to 7 years. First, the unfinished ski had to be immersed in a bog for a year before it was laid to dry for 5-6 years, to prevent the wood from twisting (Berg 1993, 36). Understandably, a pair of "tennar"-skis was an investment for life, and something to be treasured.

TYPES OF WOOD AND SUPERSTITION

It was not just the quality of the wood that influenced what material the ski maker chose to work with. There was also some superstition linked to diverse types of wood that could make the material unsuitable. Roe and elm provided extreme glide, although not especially durable in the long run. Today, a good glide is seen as an advantage, but the hard surface of roe and elm gave an unmanageable speed to the skis and made it difficult to steer. An accident could quickly happen. Skiing on elm was considered a suicide, and if you were to perish on these kinds of skis, you were not allowed to be buried within the walls of the graveyard (Gotaas 2007:22).

BINDINGS IN WOOD AND LEATHER

Although there are few physical traces left of bindings on the very oldest skis, it is believed that prehistoric skis had a toe band made of osier or leather. The toe band is an easy way to attach the ski to the foot, as the band forms a ring you insert the foot into. The illustration "Schema xylosolearum" from 1644 is probably the oldest drawing of Norwegian skis. It shows a pair of skis with a toe band made of osier and leather straps (Berg 1993: 84). The osier is made of slender branches mainly cut from root shoots. Most often birch is used in osier bindings. The osier was first pruned, then the bark was removed before the branch was twisted into the shape of a rope. To soften the osier before shaping, the twisted branches could be soaked, heated or boiled depending on the local procedure (Berg 1993:133). The twisted osier was threaded through a hole under the footstep of the ski and fastened like a loop.

THE DEVELOPMENT OF GOOD SKI EQUIPMENT

In the 18th century, the military's use of skis stimulated both the development of ski equipment and the interest in skiing among most people. The establishment of ski-born troops patrolling the Swedish border during the winter required both equipment, knowledge and experience (Christensen, 1993:25) Training and mastering the combination of skiing and shooting were of vital importance in the military. To educate soldiers to handle weapons on skis, the military established competitions for the ski-born troops (Christensen, 1993:35). Skiing as an activity and competition also gained a ground among the bourgeoisie, and the first ski race for civilians was held in Tromsø in 1843 (Christensen, 1993:144).

The organization of skiing led to a need for establishing standards for what was considered to be decent skiing equipment. Until 1850, there had been great local variations to the shape of a ski, both in terms of design and type of wood. Separate ski exhibitions were arranged to stimulate the industry to produce better equipment and to educate potential buyers. The first ski exhibition in Norway was arranged in 1863 by «Trondhjems Vaabenøvelsesforening» (The Trondhjem Weapons Training Association). The ski exhibitions invited makers of skis and manufacturers from all over the country. By rewarding some selected skis, the exhibitions contributed to a unification of design while simultaneously contributing to the idea of an ideal ski and of Norway as a «unified national-cultural community» (Christensen 1933:151). The Association of the promotion of Skiing founded in 1883 and owner of the Ski Museum, was also an active organizer of ski exhibitions. In 1896, the Ski Association gathered 30 participants from different parts of the country at a ski exhibition in the University's Gymnasium in Christiania (Oslo). They wanted to showcase the traditional ski types from different parts of Norway to highlight and reward the good ones, and to exclude impractical designs. (Skiforeningens Årbok 1895-1896:18-20) A pair of skis from ash made by Fritz Huitfeldt, won the gold medal at the ski exhibition in 1896. The shape of the skis was based on skis from Telemark with a concave shape making sharp turns possible. The power of example through the ski exhibitions probably benefited consumers. In a letter to a Norwegian sports magazine in 1881, it was said that from 100 pieces of the finest wood you could find as few as 10 pairs of good quality skis (Norsk Idrætsblad 49/1881: 275) If that was the case, it was important to know as a consumer what qualities to look for when buying skis (FIGURE 10.2).

FIGURE 10.2 Being a good skier also requires the right technique. This is a photograph from the 1908 version of an instructional book on how to ski by Fritz Huitfeldt. The first edition was published in 1896. Photographer: Anders Beer Wilse. The Ski Museum in Holmenkollen.

LAMINATED SKIS

The demand for skis increased in the 1880s and 1890s, and ski factories entered the market. Where ski makers had previously spent years drying and preparing the ski, modern times with higher consumer demands required a faster process. Ash had been the preferred type of wood, and it was becoming difficult to get suitable specimens for the traditional "helved"-ski. Experimentation with laminated skis started in the 1890s. The base consisted of a harder wood such as ash and hickory, and the top was made from a softer type of wood such as spruce or pine. There were several reasons why the laminated ski eventually became a reality. The technological development of a strong glue was crucial for the wood to withstand snow, moisture and use. Decades of trial and error passed before the production of laminated skis started selling in the 1920s (Berg, 1993:43). The most common types of wood used for laminated skis in the 20th century were ash, birch, spruce, hickory and lignostone. Laminated skis, composed of varied materials, were the start of a new chapter in the ski-making industry, which after the 1920s still had many good years ahead. The laminated wooden skis represented a lighter ski than the "helved"-ski, a focus that is still important for the development of new skis today.

WOODEN SKIS: A POSSIBLE REVITALIZATION

The wooden ski industry in Norway flourished until synthetic fiber skis were launched on the market in the 1970s. In 1974, Magne Myrmo was the last World Cup gold medalist on wooden skis in Falun, Sweden. The interest in wooden skis was on the decline.

In recent years, a new wave of interest in wooden ski making has emerged. Increased focus on climate change and environmental considerations have put sustainable production and proximity to nature on the map. The Norwegian Ski and Ski-makers Association was founded in 2017 and is a private initiative by enthusiasts within the ski makers community. Their purpose is to "preserve Norwegian ski making tradition and convey its rich and important cultural history." Workshops and gatherings are arranged for those who want to learn both the craft behind a good ski, and to enjoy skiing on self-produced wooden skis. Together with the Norwegian Ski and Ski-makers Association, they are helping to arouse a new interest in the special knowledge that is required in making a pair of wooden skis. In a country where skis are an important leisure activity, a form of training and entertainment, it is important to preserve the knowledge behind ski making.

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WOOD LAMINATE TENNIS RACKETS: INSIDE THE MANUFACTURING OF AN ICONIC SPORT ITEM

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Wooden tennis rackets have continuously evolved from the origins of Lawn Tennis in the 1870s until they left the scene in the 1980s (ITF 2019). In the early years, tennis rackets were handmade by craftsmen who bent solid wood, mainly ash, into shape. This was particularly appreciated for its favorable mechanical properties, including its remarkable flexibility.

Rackets made of solid wood were however heavy and subjected to warping, such as twisting. This, together with other needs such as strengthening the frame and improving the aerodynamics, led to the development of wood laminate rackets. In this sense, let us remember that the wooden frames had to withstand not only the stress due to impact and swing during play, but also the permanent loads applied by the tensioned strings.

The first versions of wood laminate rackets date back to the 1930s, when they were made of small laths of wood (again, mainly ash) bent into shape and glued. Starting from the 1940s, veneers were overlaid and bonded with synthetic adhesives to obtain multiple layered frames, based on the rotary cutting and curve lamination production technology. The layered composition made of sound veneers with parallel grain (as a kind of *ante-litteram* LVL) enabled to enhance the strength of the wood and leveled out the performance of the rackets. In addition to ash, the wood of other species began to be used in those years. The International Tennis Federation (2019) reports the use of maple, sycamore and hornbeam in the main frame; hickory in the outer layer, to provide wear resistance; beech and mahogany in the throat and handle, for aesthetic purposes; obeche in the shaft, to reduce the overall weight.

The period from the 1940s to the 1960s can be considered the golden age of wood laminate rackets. Overall, wood was by far the dominant material from the 1870s to the 1960s, with minor fractions of steel or aluminum appearing here and there (Taraborrelli 2019). From the 1960s, steel, aluminum and composites began to be increasingly introduced, and their use further increased in the 1970s and in the 1980s. By the end of the 1980s, wood laminate rackets had become obsolete: composite materials began to dominate the market, their reign stretching from the 1990s to the present day. This evolution is due to the high performance and lightness of composite materials (i.e., carbon fibers), and to the technology advancements that enabled their efficient and cost-effective processing.

MANUFACTURING OF WOOD LAMINATE TENNIS RACKETS IN THE 1980s

The state of the art in the 1980s can be considered the point of arrival of a century-long evolution, and thus the most advanced level of wood laminated racket manufacturing. In those years, several companies produced a great variety of rackets worldwide. In this sense, the manufacturing process described herein can be taken as a general reference. The process was reconstructed by contacting an Italian manufacturer that supplied wood veneers to one of the main global producers of wood laminate tennis rackets at the time.

The mill bought roundwood of noble hardwoods on the market. As already mentioned, ash, beech, hickory, hornbeam and maple were among the most used and appreciated woods. The same type of raw material was also used for producing working tools handles, thanks to its elasticity and capability to withstand repeated stress (fatigue resistance).

Logs derived from the basal part of the trunk. Their quality requirements were similar to those of logs intended for the slicing of fancy veneers. Top-quality material was used, where anomalies such as large knots, end shake, fissures, and rot were not admitted. Straight grain and regular width of the growth rings were especially important. Assortments were between 4.5 and 6-8 m long to the purpose of obtaining raw pieces with multiple lengths of 150 and 200 cm, which were the lengths of the final strips. The required mid diameter of logs was at least 35 cm to ensure adequate yields.

As in the slicing process, logs were initially left for some days in tanks full of water at 65-70 °C. This was intended to "soften" the wood, to ease and make the following manufacturing phases more uniform. At the end of the immersion period, the logs were extracted from the tanks, cut to length, debarked, and rotary cut by a lathe. Veneers of different thicknesses, as a rule from 1.5 to 2 mm, were obtained.

The veneers were then dried in a tunnel dryer that reduced the moisture content up to 3-6 % in a few minutes. They were successively stored until the achievement of the equilibrium moisture content with the environmental humidity of the plant. When ready, they were cut into strips of a few centimeters wide. Each strip was visually graded, based on a specific production disciplinary to remove the unacceptable characteristics.

The flexibility of the strips was also tested. This was performed, according to the standard UNI 6483, by piling drilled disks of various diameters on a metallic planchet (FIGURE 11.1, left). The size of the testing cylinder depended on the thickness of the veneer strip to be tested. The test was considered passed when the sampled strip curved in its center, matching the cylinder's surface, without showing any beginning of rupture. Finally, strips were packed and sent to the mill's customer that carried out the further processing.

At the customer's plant, the rackets were bent into shape on apposite molds and bonded by means of thermosetting synthetic adhesives (FIGURE 11.1, right).


FIGURE 11.1 Left: device used to test the flexibility of plywood and veneers. Right: multiple-layered raw blocks were assembled, cut, and finished to obtain the final wood laminate rackets (images, not to scale, R. Zanuttini).

The shaped frames where then drilled to enable putting the strings through. The process was completed by rounding the sides, applying handles coating, painting and finishing. After the final inspection, the rackets were placed on the market through their specific commercial channels (FIGURE 11.2).

FIGURE 11.2 Wood laminated tennis rackets were produced in a wide variety of shapes and colors. Clamps were used to contrast warping during storage (image F. Negro).

Overall, wood laminate rackets can be truly considered iconic sport items, both for the diffusion that tennis has had worldwide, and for the great number of units produced over the decades. It is no surprise that nowadays they maintain a relevant interest as pieces of furniture (for instance hung on walls) and as collector's items. The Museum of Rackets located in Baldissero d'Alba, Italy [1], is a remarkable example in this sense.

The value of wood laminate rackets depends mainly on the years of production, the model, the state of preservation and the professional players that used them. Starting from a few Euros, prices can reach extremely high levels, as often happens in sport memorabilia. Furthermore, in the past years a world-renowned company placed a limited edition of a handcrafted wooden racket on the market, as a collector's item. Made of lime, walnut and balsa wood combined with graphite, it was presented as a sort of connection between tradition and innovation.

Finally, while playing tennis with wood laminate rackets has become obsolete, it is to note that wood has not entirely left tennis courts. Wooden net poles (typically made of ash wood) are in fact still used on grass courts. Other than sustaining the net and withstanding the load of the net tensioning, they have a relevant aesthetic function. Their appearance, in fact, dialogues with that of the grass, suggesting the image of a natural environment.

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Non-wooden woods, among wood

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INTRODUCTION

Modern golf is considered to have originated in Scotland, where it was already played in the fifteenth century. Its evolution unfolded over the centuries, a milestone being the first written rules set in 1744 in Leith, close to Edinburgh, Scotland. Another pivotal step is the great success registered in England and the USA around the 1900, when several golf clubs were founded (Ceron-Anaya 2010). As for the Olympic Games, golf was included in the editions in 1900 in Paris and in 1904 in St. Louis, then it took more than hundred years before it reappeared in 2016 in Rio De Janeiro, and then in 2020 in Tokyo [1].

Today golf is a global sport: in 2019 more than 38,000 golf courses existed in 209 countries; 78% of such courses were located in the top 10 golfing countries, namely the USA (by far), Japan, Canada, England, Australia, Germany, France, Republic of Korea, Sweden and Scotland (R&A 2019). Golf is also appreciated for the health benefits, including improvement of the cardiovascular system and mental well-being, it provides through the moderate physical activity required and the open-air environment (Murray et al. 2016).

The functioning of golf is well-known and straightforward. The ball is struck with a club to put it in a hole in the lowest number of shots, along rounds of 18 or fewer holes [2]. Different types of clubs are used to hit the small ball that has a dimpled surface to reduce the aerodynamic drag [3]. Drivers (or 1-woods) are used to send the ball as far as possible, and are therefore almost exclusively used for first shots from the teeing-ground. Fairway woods have smaller club heads than drivers, and are intended to strike balls that lay on the ground. ‘Rescue’ clubs are hybrid clubs whose composition is between fairway woods and long irons. Irons are intended to approach the green and to hit from the higher grass of the rough. Wedges provides high trajectory, high spin and high accuracy. The putter, finally, is intended for use on the putting green.

Wood, once the material of choice, is nowadays obsolete in golf clubs. As it happened in other sports, during the 1900s wood has been replaced by high-performing materials, and modern clubs are made of titanium, stainless steel, aluminum, carbon graphite, etc. The historical relevance of wood remains in the term “woods” that is still used to name the above listed type of clubs.

HISTORY OF WOOD IN GOLF CLUBS

Golf clubs were originally handcrafted from wood. The Professional Golfers Career College reports that in the 1500s the shafts were typically made of ash or hazel wood, whereas the club heads of tougher woods like apple, holly, beech, or pear [4].

During the 1600s wood continued to be used for club heads, and was preferred to iron also because the balls used at that time (see later) were subjected to split upon impact [5]. Of note, wooden clubs were expensive and prone to break. Actually, their high costs and the need for frequent replacing contributed to make golf substantially reserved to the higher social classes [4]. In this sense it is also to consider that until 1939 it was common to carry 20-30 clubs in the bag (the number was then reduced to the current maximum of 14 clubs) [4].

Wood continued to be largely used in the following period. In the 1800s the American hickory was the wood of choice for shafts, and by 1900 American persimmon wood became the material of choice for wooden club heads (Figure 12.1 left). Wood was widely used in golf clubs during the 1900s, when club heads also had laminated compositions (Figure 12.1 right). However, it gradually left the scene during the 1900s leaving space to the above mentioned more performing and durable materials. The full replacement of wood occurred during the 1990s, when metal definitely took over persimmon wood in club heads.

Figure 12.1 On the left: the head of this driver (1-wood) has the writing "persimmon" well on display as an element of value. On the right: the wooden head of this 5-wood clearly shows its laminated wood composition (image R. Zanuttini).

Nowadays golf clubs are still evolving in a continuous search for higher performance. Wood remains in the so called "hickory golf". In this variation, golf is played in a traditional setup using hickory shafted clubs. Societies and playing groups are present in various countries, and some producers still manufacture wooden clubs for hickory golf and as niche items.

A final remark shall go to golf balls, as wood and sap from trees have been used in the past to make them. In fact, although there is scarce evidence, the first golf balls were probably made of wood, likely beech, boxroot, and other hardwoods (Kavas and Barton 2016; [5]). From the 1500s to 1618 balls were made of a leather cover filled with cow's hair or straw ("hairy" balls), while from 1618 to 1848 the filling was of goose or chicken feathers ("feathery" balls). The 1848 saw the invention of the Gutta-Percha balls, which were made of dried sap of the sapodilla tree heated to form the ball [5]. By the 1900s rubber core balls, with a cover made of balata sap, were invented (their dimples conferred the look of the modern golf balls). By the mid-1960s the balata sap was replaced by a more resistant synthetic resin, and the evolution of golf balls continued until the present day.

WOOD IN GOLF NOWADAYS

Although it is no more used for clubs (Figure 12.3 right), wood is still present on golf courts. In fact, wood can be commonly found in course signage, starting houses, tee signs and plaques, palisades of stretches of water, boardwalks, bridges, etc. (Figure 12.2 left). A key reason for such widespread presence is that wood is in syntony with the natural environment in which golf is played (a similar situation can be found in equestrian sports, see the relative chapter).

A fascinating detail is that of some club houses having timber floors dented with the countless signs left, over the years, by the metal spikes of golf shoes. This creates a peculiar look (Figure 12.2 right) that somehow states the tradition of the club houses. In fact, since it takes decades to "obtain" floors worn this way, such floors are a tangible demonstration of the frequentation of players over the years. This can be taken as an emblematic example of how, in some applications, wood becomes even more charming by ageing and being worn out.

Finally, it is to note that today small elements of wood remain as golf playing equipment: tees made of wood or bamboo are still commonly used at all playing levels (FIGURE 12.3 left). After the shot, tees can remain in the ground or fly away on the court. In this view, compared to plastic tees, wooden tees have the remarkable advantage of being biodegradable.

FIGURE 12.2 Left: wood is widely used on golf courts for starting houses, signage, tee signs and plaques reporting the hole's description, etc. Right: wooden floors worn by countless contacts with golf shoes spikes are a peculiar and fascinating feature of historical golf club houses (images courtesy of Circolo Golf Torino - La Mandria).

FIGURE 12.3 Left: the above wooden tees are painted in white, with colored lines that indicate how much they shall be driven into the ground (image S. Delle Cave). Right: this wooden shield, exhibited at the Circolo Golf Torino - La Mandria, refers to the history of golf by displaying a wooden golf club and a cane-poled hole flag (image courtesy of Circolo Golf Torino - La Mandria).

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A good fourth place: the wooden medal

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THE WOODEN MEDAL

In the ancient Olympic games, winners received just a laurel wreath for their victories. Medals started to be awarded during the first modern Olympic games in Athens 1896, when the champions got a silver (not gold) medal and an olive branch. The tradition of awarding gold, silver, and bronze medals respectively to the first, second, and third placed athletes dates back to the games held in Sant Louis in 1904 (IOC 2019).

The well-known expression "wooden medal" is used to indicate the imaginary prize won by whoever comes fourth, hence just outside the podium. This is clearly just a way of saying, as such a medal is not awarded in the Olympic games. This medal is imaginarily made of wood as it is less precious than the iconic materials used for real medals.

It can be said that the "wooden medal" has two sides, as it is suited to a medal indeed. Its perception, in fact, depends on the way by which it is achieved. On the first side, this medal can represent a missed goal, and can be accompanied by the regret of having lost an opportunity, probably unique. This feeling is stronger when the podium is missed by a whisker: fractions of seconds, or of points, a defeat that materialized in the very last moments of the match, etc. The perspective of a wooden medal can be particularly intimidating for athletes at the peak of their career and aiming at victory. In the above cases an actual wooden medal, even if made of the most valuable wood, would hardly compensate for the missed occasion. The Olympic games are particularly challenging in this sense, as they require great sacrifices and, taking place every four years, do not give the chance for rapid redress.

On the second side, achieving fourth place can still be considered as being part of the excellence, especially in the Olympic games or in international events in which the best athletes compete. Young athletes may also be more inclined to see this positive side of the wooden medal, as it can be seen as part of a trend of improvement and can give the motivation to taking the final step onto the podium in the future. This can be particularly true in the Paralympic games, where a wooden medal, if truly available, could in fact be seen as a tangible demonstration of the athletes' determination and courage, that together with equality and inspiration constitute the four Paralympic values [1].

THE WOODEN SPOON

Another famous trophy is "the wooden spoon", ideally awarded to the last classified in a sport competition. This expression derives from the Oxford University, where the wooden spoon was granted to the student who graduated with the lowest exam marks (but graduated nonetheless [Stray 2012]). Actual spoons were realized over time, and the last was awarded in 1909. The term wooden spoon is particularly used in rugby, where it is imaginarily awarded to the team that arrives last in the Six Nations tournament.

WOOD IN MEDALS AND TROPHIES

Although medals and trophies are primarily the reign of metals, wood can actually be found there - the Davis cup being a famous example. Wood can also be found as part of artistic trophies, often as bases, and plaques, and medal boxes; noble hardwoods are often used for such applications.

In the last decade, wooden medals made of laser-cut and inscribed plywood have become more frequent. This technology enables appealing results, and such medals are appreciated also because they provide a recall to sustainability. Wooden figurines were also given to athletes during Rio 2016 instead of flowers.

An interesting case is that of the finisher medals awarded in 2021 by the Eugene marathon (Oregon, USA). Such medals were made of the timber from the steps of the dismantled grandstand of the Historic Hayward Field [2]. Thus, such medals carry relevant symbolic value, and can be taken as a small-scale example of how wood can be reutilized in a cascading use.

A final mention goes to the podiums, which are often made using wood-based panels: for instance, the Olympic and Paralympic podiums in Rio 2016 were made of wood coming from sustainably managed forests [3].

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SECTION II

WOOD IN SPORT EQUIPMENT

BEND THE WOODEN BOW, RELEASE... BULLSEYE!

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INTRODUCTION

The bow has been widely used as a weapon of war since prehistoric times. Apart from the bolas, the bow/arrow system was the first machine invented by man. It is difficult to determine with certainty when the bow appeared because bows and arrow shafts were most often made of wood, and decomposed quite quickly (Rozoy 1992). The oldest direct traces of archery are the 12680-11,590 calBP old arrows from Stellmoor, Germany and the 8000 calBP old bows from Holmegård, Denmark (Cattelain 2004). However, a Middle Stone Age date has been proposed for a single bone point from a Howiesons Poort layer dated to 61700±1500 calBP from Sibudu Cave in South Africa. Small stone segments from the same layers support the use of bow-and-arrow technology at this time, preceded by an established bone-tool manufacturing tradition in pre-Still Bay layers aged 72500±2000 to 77200±2100 calBP (Backwell et al. 2018). Amongst the ancient civilizations, the Egyptians were known to be the first great archers and used bows as their main weapon for hunting and warfare purposes.

The bow was particularly important as military equipment until modern times, around year 1500, when the arrival of the arquebus led to the gradual disappearance of the use of the bow during wars. Archery gradually turned into entertainment and then into a competitive sport. One of the first competitions took place in 1583, in Finsbury, England. Archery competitions were part of the Olympic Games in 1900, 1904, 1908 and 1920, and for women in 1904 and 1908 (Emery 1984). After that, the sport of archery was eliminated from the Olympic program because of confusion about the rules. Indeed, in previous Olympic competitions, rules created by the host country were used and there was little consistency. This is how World Archery Championships were set up in 1931 with inaugural edition held in Lwów, Poland. It is from this moment that international rules for the sport of archery began to be standardized. From 1931, world championship matches were held on either an annual or biennial basis, except during World War II. Then, after the long hiatus, archery was reintroduced to the Olympics in 1972 in Munich, Germany for both men and women and continued thereafter.

Archery is a sport of precision and concentration in which competitors attempt to shoot their arrows into the center of a target with their bow. Several disciplines exist such as indoor shooting, outdoor shooting, field shooting, nature shooting, 3D shooting, ski-arc, field and hunter course, archery run, and animal round. Sport equipment varies according to the disciplines. The use of wood for the equipment during the practice of archery in sporting activity is found in the bow, the grip for the handle, the limbs, the arrow, the quiver, the frame for the target.

TYPE OF ARCHERY BOW

Archery bows are classified into several types based on their uses and the nature of the raw materials used in their construction (FIGURE 14.1 left). The most famous types are:

Longbow (FIGURE 14.1 in the center): straight from the medieval era, the longbow is simple. It is essentially a long wooden pole with a string on both ends. Due to the lack of technological advancements, the longbow is the most difficult of these three types to handle and shoot accurately. Longbows are made from a single piece of wood or from several laminations;

The **recurve bow** (FIGURE 14.1 right): includes elements that improve the stability and accuracy of shooting: mobile arrow rest, shepherd-button, clicker, sight and stabilization rods. It is often made in three parts with a handle/riser and a pair of limbs that bolt on. The ends of its limbs are bent backwards to increase leverage. This curve stores and releases more energy into a shot more efficiently than an equivalent straight-limbed bow. The recurve bow is the only one allowed at the Olympic Games. The riser is frequently made from polymer composite, aluminum and wood. The use of wood can be found in the bow limbs which can be made from several layers of many different laminations including wood, fiberglass or carbon, making them light and efficient, and in the riser, which is often made of wood, metal and sometimes composite materials.

The **compound bow** is a technological advanced and more efficient bow. It is composed of a system of pulleys, cams, and cables, making the bow faster, easier and more accurate to shoot. We are not going to further detail this type of bow because wood is rarely used. Compound bows have aluminum, magnesium alloy or carbon fiber risers; the limbs are almost made exclusively from fiberglass-based composite or metal materials.

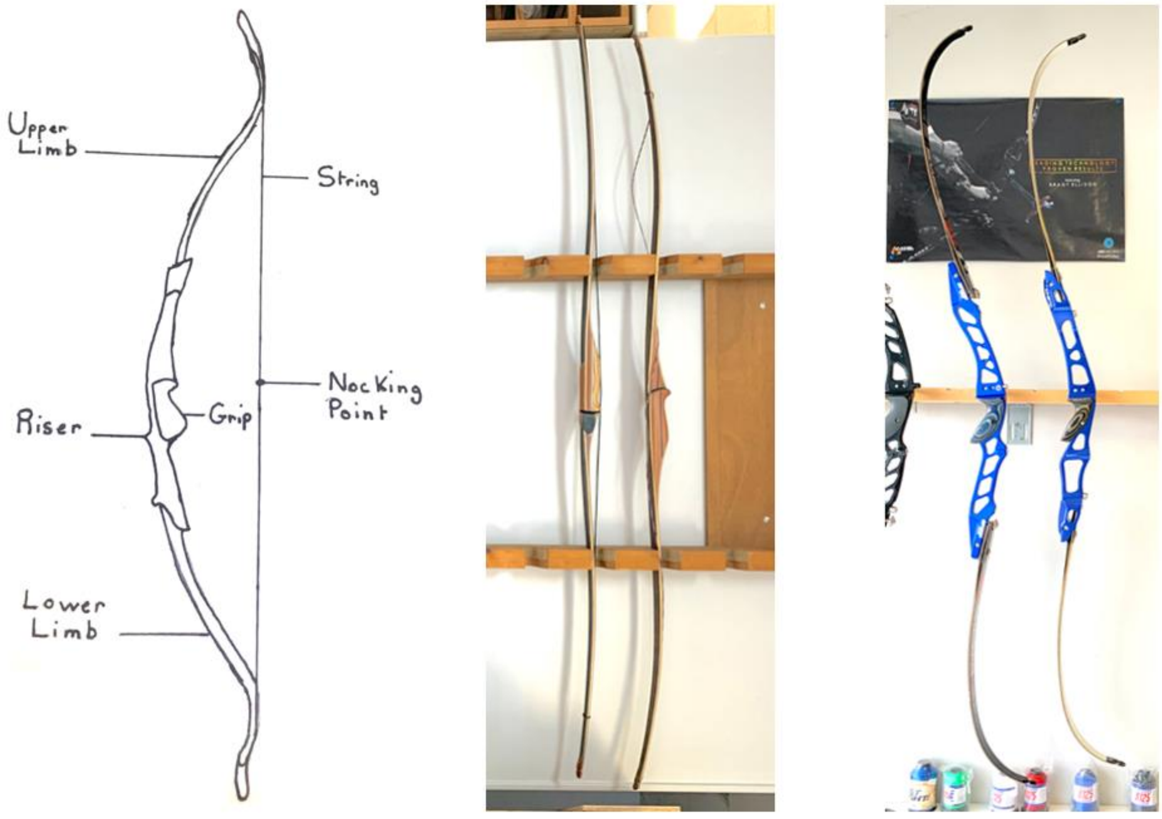

FIGURE 14.1 Left: graphical representation of a recurve bow (image T. Ramiandrisoa). In the center: longbow with limb made of laminated wood and carbon; riser made of several wood species combination. Right: recurve bow with limb made of laminated wood and carbon, riser made of aluminum, grip made of laminated wood with resin (image T. Ramananantoandro).

MAIN TECHNICAL REQUIREMENTS FOR MANUFACTURING A WOODEN BOW

This is how a bow works from a mechanical point of view: while drawing (pulling the bowstring back), the efforts of the archer make it possible to store energy in the bow limbs during bending. When the archer releases the bowstring, the bow limbs return to their initial position, the energy accumulated in the limbs is transmitted by the string to the arrow, giving it an acceleration that enables it to reach the target. After removing the load, the bow rapidly gives this energy back and returns to its original shape.

A bow is made up of limbs and a riser. It has a back and a belly. When pulling on the string, the wood of the bow is subjected to two stresses. Its back is extended, and its belly is compressed. When making the bow, the archer aims to have an optimal length and width of the branches that allow it to bend without breaking before the breaking point, with a margin of safety. This margin of safety must not be excessive because if the limbs are too long or too wide, they are given unnecessary excess weight, which will reduce the performance of the bow.

If most bows are industrially manufactured, they can also be homemade or manufactured by master-craftsman called bowers. The choice of wood species is important because the ratio between the energy put into the bow stretch and the energy transferred to the arrow depends on the properties of the wood. Wood species thus influence bow performance. The choice of wood species will be detailed in the next section. When bowers select pieces of wood, the wood used for the manufacture of the bow must meet the following criteria:

- straight grain: if the grain is twisted, the limbs would pivot in opposition to each other when pulling (arming);
- absence of knots and other defects: living knots can be accepted if there are few of them. Dead knots should be avoided to limit the risk of breakage;
- size, shape and mechanical properties adapted to compression/extension for the arch;
- tight annual rings (Martin 2003).

WOOD SPECIES IN BOW MANUFACTURE

In the old days, bows were simple and made from one solid piece of wood. Specifically, wooden archery bows were first made from yew (*Taxus baccata*). The superior strength of the yew species has the effect that a yew longbow has a greater range than bows made from other species. The mechanical performance of a bow made from yew is influenced by the juvenile-to-mature wood ratio rather than by the heartwood-to-sapwood ratio (Bjurhager et al. 2013).

Previous literature reports indicate that the best species of wood for manufacturing bows are those with the highest stiffness and yield stress in compression (Bjurhager et al. 2013). An important parameter characterizing a wood species suitable to produce bows is the amount of energy value it can accumulate in its limbs up until its destruction. Furthermore, wood species with high capabilities for accumulating energy are less vulnerable to damage. The density of wood is also important because the greater the arm mass, the greater will be the accumulation of energy which gives acceleration to the bow arms to return to their initial positions (Molinski et al. 2016).

Today, it is possible to make a bow with all wood species, providing they meet the previously mentioned constraints. Wood species commonly used for manufacturing longbows made from a single piece of wood are shown in TABLE 14.1, with their main properties at 8% moisture content.

TABLE 14.1 Wood species commonly used for manufacturing longbows made from a single piece of wood and their density (PN-77/D-04101 1977 standard) and mechanical properties (PN-77/D-04103 1977 standard) at 8% moisture content (Molinski et al. 2016).

Common name	**Scientific name**	**Density** (kg/m³)	**Bending strength** (MPa)	**Modulus of elasticity** (MPa)	**Elastic strain energy** (J)	**Work to maximum load** (J)
Yew	*Taxus baccata*	560	116	6,530	0.226	3.02
European ash	*Fraxinus excelsior*	690	147	11,557	0.247	1.96
Hickory	*Carya* sp.	880	161	9384	0.207	5.80
Ovangkol	*Guibourtia ehie*	775	198	15,910	0.382	2.64
European oak	*Quercus robur*	730	140	11,840	0.208	1.76
European birch	*Betula pubescens*	690	161	13,450	0.221	2.42
Common alder	*Alnus glutinosa*	585	121	10,319	0.252	1.45
European beech	*Fagus sylvatica*	700	130	10,511	0.159	2.16
Norway maple	*Acer platanoides*	645	148	12,392	0.257	2.29
Smooth leaved elm	*Ulmus minor*	575	128	9225	0.238	1.79

While selfbows (from one piece of wood) continue to be used in the modern day, at several points in history it was discovered that a combination of varied materials could be used for bow construction, and that these combinations could result in increased performance. Nowadays, although wood is still present, it is often replaced by fiberglass, carbon or aluminum.

Longbows are often made of different wood species in the limbs and riser, in the form of solid wood or laminates, or even combined with fiberglass or carbon fiber. It is also important to notice that while bamboo is not a tree but rather a grass, it is widely used in bow manufacturing. Due to its higher tensile strength compared to wood and its low mass for its strength, bamboo is advantageous in distance shooting. Wood and bamboo species commonly used for manufacturing multiple species longbows are shown in TABLE 14.2.

The combination of materials and species for limb manufacturing can be illustrated with the following examples: black fiberglass with a bamboo and carbon core; three laminations of bamboo surrounded by black fiberglass; bocote veneers with bamboo cores and cocobolo wedges topped by clear fiberglass; hickory back with purpleheart and ipe core and lemonwood belly; bamboo back, ipe core and lemonwood belly. It is the same for the riser, for example: cocobolo reinforced with phenolic and yew striping.

TABLE 14.2 Wood and bamboo species commonly used for manufacturing longbows made from multiple species.

Limbs		Riser	
Common name	**Scientific name**	**Common name**	**Scientific name**
Bocote	*Cordia gerascanthus*	African blackwood	*Dalbergia melanoxylon*
Cedar	*Cedrus* spp.	Amazaque	*Guibourtia ehie*
Cocobolo	*Dalbergia retusa*	Apple tree	*Malus* spp.
Hickory	*Carya* spp.	Basswood	*Tilia americana*
Ipe	*Handroanthus* sp.	Beech	*Fagus sylvatica*
Lemonwood	*Calycophyllum candidissimum*	Bocote	*Cordia elaeagnoides*
Makore	*Tieghemella heckelii*	Cherry tree	*Prunus avium*
Maple	*Acer* spp.	Chestnut	*Castanea* spp.
Mesquite	*Prosopis glandulosa*	Cocobolo	*Dalbergia retusa*
Oak	*Quercus* spp.	Indian rosewood	*Dalbergia latifolia*
Osage orange	*Maclura pomifera*	Ironwood	*Ostrya virginiana*
Pau amarello	*Euxylophora paraensis*	Makore	*Tieghemella heckelii*
Purpleheart	*Peltogyne* spp.	Maple	*Acer* spp.
Red elm	*Ulmus rubra*	Mesquite	*Prosopis glandulosa*
Tonkin bamboo	*Pseudosasa amabilis*	Oak	*Quercus* spp.
Moso bamboo	*Phyllostachys edulis*	Osage orange	*Maclura pomifera*
Hachiku bamboo	*Phyllostachys nigra var henonis*	Rosewood	*Dalbergia* spp.
Makinoi bamboo	*Phyllostachys makinoi*	Yew	*Taxus baccata*
Madake or Wangdae bamboo	*Phyllostachys bambusoides*	Yucca	*Yucca baccata*
		Zebrawood	*Microberlinia brazzavillensis*

TABLE 14.3 lists the most commonly used wood and bamboo species for the manufacture of recurve bows. The species of wood can differ depending on whether it is used for limbs or risers. Species can be used alone or mixed together in the form of solid wood, or combined in the form of laminates, or bonded to composites. For example, limbs can be made of maple core surrounded by black fiberglass or the lamination of bamboo veneer with olive tree veneer. As with longbows, the use of bamboo is widespread.

TABLE 14.3 Wood and bamboo species commonly used for manufacturing recurve bows.

Limb		Riser	
Common name	**Scientific name**	**Common name**	**Scientific name**
Hachiku	*Phyllostachys nigra* var. *henonis*	Black walnut	*Juglans nigra*
Madake or wangdae	*Phyllostachys bambusoides*	Bubinga	*Gibourtia* sp.
Makassar	*Diospyros celebica*	Cocobolo	*Dalbergia retusa*
Makinoi	*Phyllostachys makinoi*	Maple	*Acer* spp.
Maple	*Acer* spp.	Olive tree	*Olea europaea*
Moso	*Phyllostachys edulis*	White oak	*Quercus alba*
Oak	*Quercus* spp.		
Olive tree	*Olea europaea*		
Tonkin	*Pseudosasa amabilis*		
White makassar	*Diospyros virginiana*		

Wood species are either temperate species or exotic species. In some cases, wood may come from sustainably managed forests. In this case, it is specified that the bows are made with FSC (forest stewardship council) or PEFC (program for the endorsement of forest certification) certified wood. But in most cases, the source of the wood species is not specified by the manufacturer. None of the species listed in TABLE 14.2 and 14.3 are part of CITES appendices (the convention on international trade in endangered species of wild fauna and flora).

Bow makers use several types of glue to make high-end bows: animal glue, urea resin, melamine resin, polyvinyl acetate, epoxy, aliphatic resin and polyurethane. As far as treatment is concerned, after cutting the wood for its manufacture, the wood must be dried in a ventilated place, protected from humidity, light, wood boring insects and fungi. Yew wood needs three years of drying to provide wood with optimal qualities. Ash wood can be used six months after felling (Martin 2003). Once the bow is made, it must either be waxed regularly or varnished to protect it from the sun, rain and wood boring insects.

BENEFITS AND DRAWBACKS OF USING WOOD IN BOW MANUFACTURING

Wood offers physical properties suitable for the manufacture of bows. It can be cut and handled during the bow manufacturing process. Wood material is also easily available for people wanting to produce their own bows. Wood provides other benefits such as its organic origin, cheaper price, aesthetic beauty and good carbon footprint.

However, wood has several drawbacks compared with other composite, carbon or aluminum materials. The latter are dimensionally stable despite the change of environmental conditions. On the other hand, temperature and moisture changes may affect wooden bows to warp, change shape, change in bending and strength. Moreover, alternative materials are more durable, stronger, less noisy and with less deformation during the shot, which in turn translates into more precise shots and less shooter fatigue. Another drawback to wooden archery bows, especially selfbows made from one piece of wood, is the inability to replace the limbs if it breaks.

WOOD IN OTHER ARCHERY EQUIPMENT

Wood can be found in the arrow (Figure 14.2 in the center), the projectile shot from a bow. Its size and weight depend on several factors, including the draw length of the bow as well as the purpose of the projectile. Arrow shafts are typically composed of solid wood or bamboo. The disadvantage of wood is that wooden arrows are prone to warping. Arrows made from aluminum and carbon are becoming more popular due to their straightness, lighter weight, and subsequently higher speed and flatter trajectories, as well as to their resistance to damage. In the Olympic games, any material (wood, aluminum, carbon) is allowed. Nevertheless, most popular arrows at tournaments and Olympic events are made of carbon materials. Regarding wood species, the wood from which an arrow is made must be strong and robust to withstand impact and other forces without damage. In addition to strength and robustness, arrows require a high ratio of stiffness to density. Ideally, the grain should be as straight as possible, with no twisting or knots. Regardless of the species, when a number of arrows are used in the same set, they need to have uniform characteristics (same mass, dimension, form, mass distribution) for accurate shooting. Common wood species used for arrow shafts manufacturing are spruce (*Picea* sp.), cedarwood (*Cedrus* sp.), Norway pine (*Pinus resinosa*), Port Orford cedar (*Chamaecyparis lawsoniana*), Douglas fir (*Pseudotsuga menziesii*), birch (*Betula* spp.), poplar (*Populus* sp.) or ash (*Fraxinus* sp.). Arrows can be made with bamboo such as switch cane *(Arundinaria tecta*), Tonkin *(Pseudosasa amabilis)*, river cane *(Arundinaria gigantea*), Korean arrow bamboo *(Sasa coreana*) or Japanese arrow bamboo (*Pseudosasa japonica*). They can also be made with carbon tube with a wooden cover for better accuracy. As a finishing treatment, arrows can be coated with a light walnut stain for example or clear lacquer dipped or finished with polyurethane finish.

Wood is frequently employed in the frame (Figure 14.2 right), which holds and/or compresses the material that will block the arrow (high density foam or straw slats treated with M1 fire rating).

Figure 14.2 Left: graphical representation of a quiver (image T. Ramiandrisoa). In the center: wooden arrows in the front, carbon arrows in the back. Right: frame used for outdoor archery activities made of class IV autoclave-treated pin and plywood panel (image T. Ramananantoandro).

We can also find oriented strand board (OSB), plywood or medium density fiberboard (MDF), which allows optimal safety, avoiding arrow returns and splinters during arrow impacts. Worn slats can be changed by loosening the straps, and the frame can be reused. If the frame is used outdoors, it is necessary to use a naturally durable wood species or to choose a Class IV autoclave treated wood (most often the pine species) that can withstand biological agents. In addition to the autoclave treatment, wood can be stained if required.

Finally, the quiver, or namely the case used to store bow arrows (FIGURE 14.2 left), which is worn on the belt, the back, on the bow or placed on the ground, can be made of wood. The choice of species is the same as the wood used in the manufacture of arrows.

STANDARDS IN ARCHERY

The archery ASTM standards, involving wood materials are:

- F1352-91(1997)e1 Standard guide for broadhead performance and safety standards,
- F1363-91(1997)e1 Standard guide for reduction of risk of injury for archery overdraws,
- F1435-94 Standard specification for designation of the balance point location for archery arrows,
- F1436-92(1997)e1 Standard guide for center serving diameter dimensions for archery bow strings,
- F1544-99 Standard specification for determining the rating velocity of an archery bow,
- F1832-97 Standard test method for determining the force-draw and let-down curves for archery bows,
- F1880-98 Standard test method for determining the let-off percentage for archery bows,
- F1889-98 Standard guide for measuring the straightness of arrow shafts.

MYTHS AND LEGENDS

Finally, it is worth noting that archery is often mentioned in popular mythology and legends, as well as in modern literature and film. The bow and arrow often symbolize the goal to be reached and the speed to achieve it, the beauty and purity of the technical gesture, as well as self-reliance, precision and patience - the qualities of heroes. Bows used in these legends include wood or bamboo material, as, for example, in the case of the legends of Odysseus, a hero in Greek mythology. Odysseus is mentioned as being a highly skilled archer. His bow was composed of wood and horn (Sutherland 2001). One of the best-known archer legends is Robin Hood who was regarded as the best archer in England in the Middle Ages, during the reign of King Richard the Lionheart. He was famous for stealing from the rich to give to the poor. He used a longbow made from yew wood (Frost 1992). More modern stories featuring archers include The Lord of the Rings, with the main weapon of the exceptional Elf archer Legolas being a bow made of yew (Sánchez Muñoz, Raúl 2018). In the recent The Hunger Games series, the main character Katniss Everdeen uses a Hoyt Buffalo recurve bow. The core is made from maple wood surrounded by carbon, whereas the riser is made from aluminum. The popularity of this series is credited with boosting an interest in the sport of archery among female adolescents (Crookston 2018).

CONCLUSION

Unlike many other sports, wood in archery has a peculiar origin. Wood was in fact one of the materials used in the bows and arrows that were used for the subsistence of ancient peoples: for hunting or for war. Even if wood is less present today, with the preference of other materials such as fiberglass, carbon fiber and metals, it still has its place. Wood material has physical-mechanical properties that make it possible to manufacture powerful bows. It has a significant role to play in the aesthetics of the product, but also in the carbon footprint of the bows produced. Better consideration of sustainable forest management through the certification of the wood origin, will contribute to making this sector more environmentally conscious.

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Supporting the pursuit of the perfect ten

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INTRODUCTION

The history of gymnastics goes back along the millennia. In such a rich heritage, a key influence was exerted by the ancient Greece, where gymnastics was seen as a way to achieve symmetry between mind and body [1]. The term "gymnastics" derives in fact from Greek and means "to exercise naked". Modern gymnastics can be seen as the result of the evolution over the centuries in performing arts, military training, medical and education professions (Russel 2013).

Nowadays, gymnastics is part of the Olympic games as artistic, rhythmic and trampoline gymnastics. Artistic gymnastics was already present in the first Olympic games in Athens in 1986 and has been included in every edition since. Rhythmic gymnastics, a women's only event, was instead introduced in the Olympic games in Los Angeles in 1984, whereas Trampoline gymnastics appeared in 2000 in Sydney [1].

Following are listed the disciplines, for Men (M) and/or women (W), that featured in the Olympic games held in Tokyo 2020:

Artistic gymnastics: All-Around (M, W), Floor Exercise (M, W), Horizontal Bar (M), Parallel Bars (M), Pommel Horse (M), Rings (M), Team (M, W), Vault (M, W), Balance Beam (W), Uneven Bars (W).

Rhythmic gymnastics: Group All-Around (W), Individual All-Around (W).

Trampoline gymnastics (M, W).

The world of gymnastics is much wider indeed. The Fédération Internationale de Gymnastique (FIG), the governing body for gymnastics, includes also non-Olympic disciplines: gymnastics for all, acrobatic gymnastics, aerobic gymnastics, and parkour [2].

Coordination, balance, strength, and reflexes are some of the skills needed in gymnastics. The artistic value of the various and complex exercises is another fundamental part of the charm of this sport. As well-known, gymnastics is also widely recognized and appreciated as a valuable means of promoting the healthy growth of children and the development of their motor skills (Veljković et al. 2020). Enhancing the basic motor skills by practicing gymnastics can actually prove useful in several other sports.

In the last decades, gymnastics has greatly evolved towards more complex and spectacular exercises and figures. A key element has been the evolution of apparatuses that have become considerably more elastic: springy floors, vaulting boards with adjustable springs, wider and elastic vaulting tables, etc. (Russel 2013). Although the composition of such apparatuses might appear simple, they are actually the result of continuous innovation, research and fine-tuning.

Wood was once widely used in gymnastics apparatuses (Figure 15.1), whereas its use has reduced over the last decades, similarly to what has happened in various other sports. Nevertheless, the role of wood is still well established in various apparatuses that are used at all levels. Such cases are briefly considered in this chapter.

HISTORICAL USE OF WOOD IN GYMNASTICS

A multitude of examples on the use of wood in gymnastics apparatuses could be drawn from the long history of this sport. Obermann's "Atlas of tools of educative gymnastics", published in 1865, can be taken as a relevant indication. The Atlas reports 14 tables describing exercises and apparatuses: the beam, the pommel horse, rings, etc. Each of them is described by detailed illustrations that specify the dimensions, shape, constructive details, and indications on the wooden species to be used are provided. An interesting note of the Atlas regards the need for recovering apparatuses exposed in the outdoor environment to preserve them from weathering: "[...] These precautions prevent the wood from splintering, which can injure hands and damage clothes, and prevent apparatuses from becoming unusable due to sun, humidity and wind; this provides for a double purpose, safety and economy" (Obermann, 1865). It is also worth noting the connection between such text and the modern concept of service life extension within the circular economy approach.

FIGURE 15.1 Left: hoop and clubs used during the end of 1940s. Right: Baumann blocks used during the end of the 1800s (modern blocks are still made of wood) [images courtesy of Reale Società Ginnastica di Torino, established in 1844].

ARTISTIC AND RHYTHMIC FLOORS

Today, plywood is the material of choice for artistic and rhythmic gymnastics floors. These are considered apparatuses by the FIG Norms for all intents and purposes (FIG 2021a). The Norms do not expressly prescribe the constituting materials, however floors shall be approved by FIG. Their performance shall comply with the requirements set by the Norms in terms of uniformity, deflection, height of rebound, etc. (FIG 2021b).

In artistic gymnastics, the competition area is a square of 12x12 m; a border of 1 m per side determines the resulting 14x14 m floors (FIGURE 15.2 left). Such floors are made of plywood panels (i.e., 9-layer, 12 mm thick birch plywood) onto which springs are fixed. During installation, the panels are connected, for instance, through fastening sections and locking plates, to form a continuous and flat surface that is covered with an absorbing mat, which is in turn covered by the carpet on which the athletes perform (FIGURE 15.2 right). The cost of such floors is in the order of 50,000 Euro. Lanes used in training have the same composition described above, differing just in the dimensions, for instance, they can be 2 m wide x 14 m long. The elasticity of these floors is of course mainly provided by the springs, yet in such application, plywood is appreciated precisely for its elasticity other than for its light weight, dimensional stability and suitability to realize even surfaces (which are indeed some of the very typical strong points of plywood).

Plywood is also used in rhythmic gymnastics floors (models made with Oriented Strand Board are also on the market). Here the competition surface is 13x13 m; a border of 0.25 m per side determines the resulting 13.5x13.5 m floors. Minor elasticity of the competition area is required in this discipline: in these floors, plywood lays on expanded dampening blocks, e.g. in polyethylene, and is covered by the carpet. Sandwich structures made of rear wood-based panels, absorbing blocks, front wood-based panels also exist.

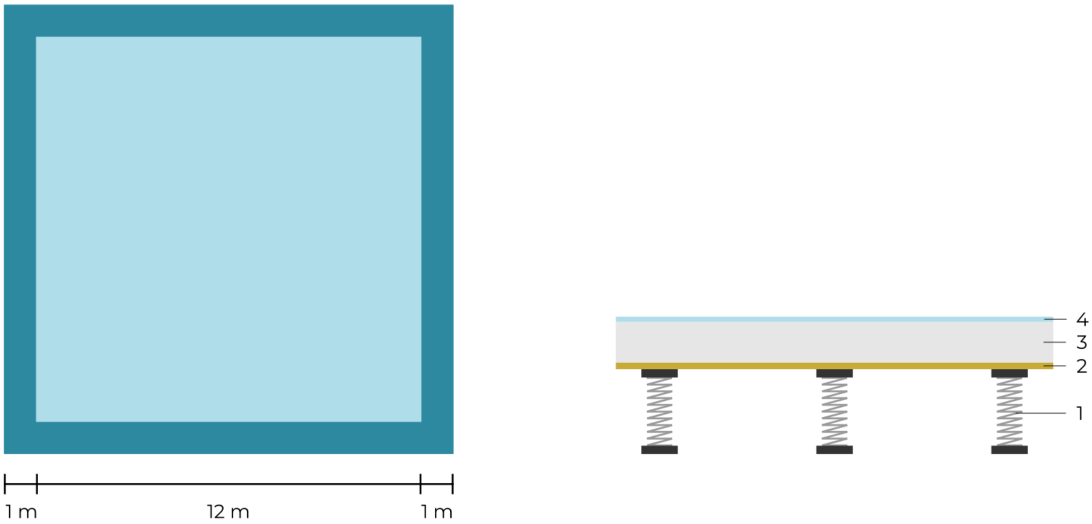

FIGURE 15.2 Left: artistic gymnastics floors are 14x14 m, where the competition surface is of 12x12 m. Right: example of a modern gymnastics floor, made of four layers: 1. springs in contact with the hall floor and fixed to the plywood; 2. plywood (10 mm thick); 3. absorbing mat (about 60 mm thick). 4. carpet (7 mm thick) [image F. Negro].

RINGS AND POMMEL HORSE

Artistic gymnastics rings have a circular profile, an inner diameter of 18 cm, and a profile diameter of 2.8 mm. Plywood, mostly made of birch but also of beech wood, is commonly used for making such rings (FIGURE 15.3 left). In fact, the FIG Apparatus norms expressly states that "The rings are made of a stiff material", and that "Rings are either made of wood or synthetic material". The reasons why wood is required are quite evident by further reading the Norms, which prescribe that the rings "[...] guarantee a sure grip and therefore must not be slippery" and, notably, that "The rings must absorb moisture content".

Grip is key for performing and for avoiding injuries, and wood provides adequate grip for the athletes' hands impregnated by magnesium powder. Looking more closely at the plywood rings, the molding of their circular profile determines that the various veneers alternatively expose their cross-section. This causes the wood pores of some veneers to be approximately perpendicular to the rings' surface in various parts of the rings, proving useful for moisture absorption purposes and to maximize the grip with hands and magnesium powder. Plywood is also suited to withstand the relevant stresses applied by the athletes' movements and holds: to this purpose, highly layered compositions are typically used.

Finally, the Norms also prescribe that "The rings retain the natural color of the material". In the case of wood (plywood), this can be reconducted to the need for avoiding surface treatments that could modify the above discussed properties. In this regard, the Norms indicate that "Except for sanding, the rings' upper surfaces receive no other treatment".

The above considerations about rings are valid for the pommel horse pommels, where in fact birch plywood is also commonly used. Pommels are elongated, with a nearly horizontal 15 cm long part and an inner vertical diameter of at least 7 cm. The FIG Norms prescribe that "In principle, they are made of stiff materials" and that "The pommels must be moisture absorbent and neutral to the use of magnesia". In this case, it is also required that the natural color of wood be retained.

The body of the pommel horse, covered with leather-like materials, is today made of metal, whereas once it was wooden.

VAULTING BOARDS

Vaulting boards are used in vaulting table events: the athlete runs, jumps on the board that provides an elastic push, and then pushes on the vaulting table that provides another elastic push. These boards are also used in some cases to help the athlete to mount the beam, the uneven bars, and the parallel bars. Depending on the elastic response, vaulting boards can be "soft" or "hard"; soft boards are generally used by women and hard boards by men.

As for other apparatuses, the FIG Norms specify the shape and dimensions of vaulting boards, but not the materials to be used. Clearly, boards must comply with the FIG requirements in terms of deflection, height of rebound, and maximum force. According to the FIG Norms, vaulting boards are 120 cm long, 60 cm wide and 20 cm high.

Different models are on the market. In general terms, they are made of a base surface that is laid on the floor, connected to a curved surface inclined at a proper angle (FIGURE 15.3 right). Metal springs are laid in between to provide adequate push upwards in response to the impact applied by the athletes. The curved surface is typically made of plywood, covered with a non-slip pad. The bendability of plywood is suited to form the curved surface and adds to its already mentioned favorable properties: lightweight, resistance and elasticity. Depending on the models, the base surface can be made of plywood, strips of plywood, metal bars, etc.

Modern boards have metal springs, while once the "springs" consisted of curved plywood strips, which is emblematic of the elasticity of plywood. Boards with this composition are still in use in several cases, such as for beginners.

A final word goes to vaulting tables, which replaced vaulting horses in the 2000s to reduce injuries and to enhance exercises. In short, the cross section of some modern vaulting tables is similar to that of artistic gymnastics floors: rear surface, springs, plywood plane, absorbing mat, covering carpet.

FIGURE 15.3 Left: detail of a gymnastics ring made of highly layered plywood. Right: vaulting board leant edgewise. The base surface, varnished red and slightly curved, and the top curved surface, onto which athletes jump, are made of plywood; the upper part of the top surface is covered with a non-slip pad, visible on its edges in the image (images courtesy of Gymnova, www.gymnova.com).

UNEVEN AND PARALLEL BARS

Uneven bars are a women's event only. The bars are 2.50 m long and their cross section is circular, with a 40 mm diameter. They are made of an inner fiberglass or carbon fiber rail, covered by a typically beech wood veneer. The inner core provides flexibility and adequate strength, also for safety reasons, whereas the wooden covering confers proper grip.

Parallel bars are a men's event only. The bars are 3.50 m long, oval shaped, with a 5 cm vertical axis and 4 cm horizontal axis. They are made of Laminated Veneer Lumber (LVL), commonly made of beech wood. Given the high stresses they need to support, such rails are reinforced by fiberglass or metal planchets that run internally along the bar length. The modern trend goes towards parallel bars with a structure similar to that of uneven bars: a fiberglass or carbon fiber bar covered by a wooden veneer.

LONG LASTING APPARATUSES AND TRAINING EQUIPMENT

The body of pommel horses and of beams is no longer made of wood. However, it is still quite frequent to find wooden pommel horses and beams in gyms for training. After all, such apparatuses can last a long time in indoor gyms and continue to perform well enough for training purposes.

Wood remains the material of choice in various items used in training, for instance Baumann blocks used for strengthening exercises (wood is again chosen for grip reasons), wall bars, and benches. Do-it-yourself items made of wood and wood-based products are also commonly realized for training purposes in gymnastics.

Finally, the FIG Norms also envisage the possible use of wood for hoops, clubs, and ribbon canes, yet other materials are preferred for these apparatuses nowadays.

ACKNOWLEDGEMENTS

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FINDING THE SWEET SPOT

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ORIGIN AND THE PRESENT OF BASEBALL

Baseball is one of the most popular sports in the United States, both, played and watched. It is called America's national pastime and has been played for centuries. Many think that it came from the British games of rounders and cricket, as early as the 1700s. Cooperstown, New York has been considered the hometown of baseball since 1839. In 1845, the rules of baseball were written by an amateur team in New York, and these rules have been changed over time. Until this day, children from all over the world play baseball and variations of this game (Rice 2012).

WHAT IS THE DIFFERENCE BETWEEN BASEBALL AND SOFTBALL?

Baseball and softball games are essentially the same game with some differences. Softball was developed from a game called indoor baseball, first played in Chicago in 1887. It is known in the United States by various names: kitten ball, mush ball, diamond ball, indoor-outdoor, and playground ball.

Even though softball started as an indoor version of baseball, these two games have evolved into two completely separate sports with different sets of rules and playing conditions. Both involve four main activities or skills: throwing, including pitching and fielding; catching; batting; and base running. The differences between the games are:

Bats - Looking almost identical, but bats used in baseball tend to be longer, have a greater diameter, and are heavier. In softball and amateur baseball, players may use bats made of wood, metal, or various composites but in Major League professional baseball (MLB), only wooden bats may be used. The differences between the games are:

Balls - Baseballs are white with red stitching and have a circumference of 9 inches[42]. Softballs are larger with a circumference of 10 or 12 inches. They are softer and yellow.

Pitching - The most obvious difference is the pitching distance. Softball is played on a smaller field; the ball is pitched from a flat pitching circle that is no more than 43 feet away from the plate. In baseball, the ball is pitched from an elevated mound that is 60-feet away from the plate.

The Playing Field - Softball fields are smaller, but they both have the same format. Softball bases are 60 feet apart, whereas baseball bases are 90 feet apart. The distance from the home plate to the outfield in softball fields is usually no more than 250 yards, but in baseball fields it is usually over 300 feet.

The act of pitching - In softball, the ball must be thrown underhand. In baseball, the pitch is almost always done overhand or sidearm (www.rulesofsport.com).

The rest of this chapter will be dedicated to the baseball bat, and everything related to it.

EVOLUTION OF THE BASEBALL BAT

The bat is a stick used by the batter to hit the ball. The earliest bats were made of tool handles, by the players themselves or local woodworkers. They were cylindrical and without rapid taper. Bats were durable, bulky and rarely broke. By about 1890, players recognized the advantages of a large barrel with a sharper taper to the handle. The handle was later modified to improve the grip. Although the rules regarding bats have scarcely changed

[42] This book uses metric units, yet baseball measures are always referenced in English units. It has therefore been chosen to use English units in this chapter (1 inch = 2.54 cm; 1 foot = 30.48 cm; 1 yard = 91.44 cm; 1 ounce = 28.35 g; 1 pound = 0.45 kg).

since 1895, the practical construction of bats has changed considerably. Players in the late 19th and early 20th centuries believed that a heavy bat could hit the ball further than a lighter one. Later on, players used much lighter bats, often made of lower-density types of wood. The theory was that bat speed, rather than weight, was the key to hitting the ball hard. Therefore, hickory wood, once a favorite bat material, because of its density and strength, has been completely abandoned as a material for bats. Different wood species were used to produce baseball bats through the years, with ever-changing explanations to justify their use.

A recent trend in bat development has been the move from ash to maple wood. Maple is supposed to be more durable than ash, and players believe that it is harder, and thus able to hit the ball further. Maple bats became controversial when they were introduced, because they tended to separate into multiple pieces when they broke, posing a risk to spectators, players, and umpires. In 2008, there were calls to ban maple bats after a series of incidents. In the same year, a team of wood scientists and technical experts partnered with the Major League Baseball (MLB), and together they tried to reduce the number of shattering bats. They understood that the "slope of grain" needed to be straighter along the bat. The straighter the grain, the less likely the bat would break into pieces. A small dot of ink was added on the face-grain on the diffuse-porous woods, such as maple bat handles, allowing the slope of the grain to be easily seen. With this improvement, there was a 50% reduction in the multi-piece failure breakage of bats (Westover 2017).

There is variation in density within each species. In the case of maple, the tricky part is to find maple with the correct density to make bats. The lower density maple, relative to maple average density, is needed for most bat models, and it is hard to find. The density of ash used in the production of bats, is more to the center of the ash density distribution and therefore easier to obtain. However, the problem with ash is its decreased availability due to tree die-off from the emerald ash borer in the US. Yellow birch is another type of wood that has gained popularity among players. It is more flexible than maple but harder than ash. Examples of typical baseball bats are shown in FIGURE 16.1.

FIGURE 16.1 Examples of unfinished maple (top) and finished ash (bottom) baseball bat (image E. Haviarova).

Aluminum and composite bats are now standard and popular in most amateur baseball and some professional leagues outside of North America. The non-wooden bats can hit the ball much harder and further than wooden bats, and many leagues are now placing restrictions on their performance (baseball-reference.com).

SHAPE AND SIZE OF BASEBALL BATS

Historically, players used to conceive their bats, and there are many creative designs out there. Some players liked heavy bats, and they would insert metal elements within their bats to add extra weight. Players even used to change the shape of their bats. Over time, shorter and lighter bats became standard for league use. Some interesting bats were also out there to help improve functionality, comfort, and the competitiveness of players, and several patents were given for bats of an unusual curve, such as the “banana bat” (1890), which caused a greater spinning motion in the ball, or the “mushroom bat” (1906), which was thicker at the base to improve grip and control. A few players used "bottle bats" that narrowed abruptly from the barrel to the handle rather than tapering gradually (Stamp 2013).

Although baseball bats have varied somewhat in length, width, and weight, they have remained approximately the same shape. Contemporary baseball bats are made of a single piece of wood, which is shaped and composed of several parts as described below and depicted in FIGURE 16.2.

Cup - The end of the bat, which is furthest from the player's hands may have a cup, which is a circular indentation that makes the bat lighter, without losing the striking surface.

Barrel - The striking surface of the bat, generally made as big as the rules will allow, extends at that diameter for about 1/3 of the length of the bat.

Sweet spot - The area of the barrel that is the ideal point for hitting the ball.

Maker's logo - The side of the bat that will be facing upward while striking, is located at about the position of the sweet spot. The brand logo helps the batter to orient the bat correctly.

Handle - The barrel of the bat gradually tapers to a narrow handle for better grip.

Knob - The handle ends in a small swelling called the knob that helps to prevent the bat from slipping out of the batter's hand while swinging. Most batters grip the bat so that the knob touches their bottom hand, or they even wrap their bottom hand around the knob.

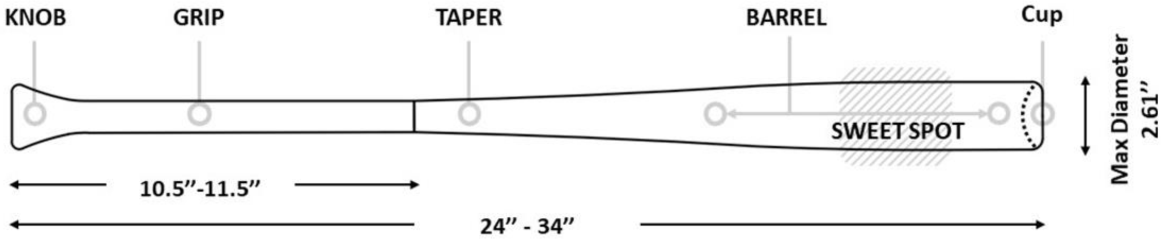
Grip - The handle of the bat is often wrapped in string or taped like an ax handle to improve grip. A coating of sticky pine tar is also used, and for many years its use was controversial, but now it is permitted (baseball-reference.com).

Drop - BAT LENGTH (in IN) - BAT WEIGHT (in OZ) = WEIGHT DROP. As a general rule of thumb, the higher the competition, or league level (meaning, from youth league up to the pros) the lesser the weight drop. Most common weight drops in various baseball leagues are -12, -10, -9, -8, -5, and -3.

Length - Bat length is measured in inches from knob to end cap. Baseball bats most commonly found are between 24-34 inches.

Weight - Bat weight will vary and is measured in ounces (oz).

Baseball measures are always referenced in English units.



Size Chart — HEIGHT/ft & in; WEIGHT/lbs

WEIGHT/lbs	3'-3'4"	3'5"-3'8"	3'9"-4	4'1"-4'4"	4'5"-4'8"	4'9"-5'	5'1"-5'4"	5'5"-5'8"	5'9"-6'	6'1"+
< 60	26"	27"	28"	28"	29"					
61-70	27"	27"	28"	28"	30"	30"				
71-80		28"	28"	28"	30"	30"	31"			
81-90		28"	29"	29"	30"	30"	31"	32"		
91-100		28"	29"	30"	30"	31"	31"	32"		
101-110		29"	29"	30"	30"	31"	31"	32"		
111-120		29"	29"	30"	30"	31"	31"	32"		
121-130		29"	30"	30"	30"	31"	32"	33"	33"	
131-140		29"	30"	30"	31"	31"	32"	33"	33"	
141-150			30"	30"	31"	31"	32"	33"	33"	
151-160			30"	31"	31"	32"	32"	33"	33"	33"
161-170				31"	31"	32"	32"	33"	33"	34"
171-180						32"	33"	33"	34"	34"
180+							33"	33"	34"	34"

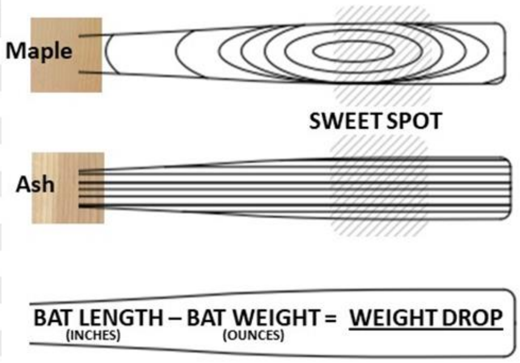


FIGURE 16.2 Contemporary baseball bat shape, parts, and size chart showing bat length options relative to players' height and weight (image E. Haviarova and J. Mo).

In terms of size and weight, always given in inches (in) and ounces (oz), the longest MLB baseball bat used in the modern era was 36 inches. This length was regularly used by Babe Ruth and Joe DiMaggio. Pete Rose and Ozzie Smith are recorded as using a 36-inch bat, but not for an extended time. The shortest MLB baseball bat used in the modern era was 32.25 inches, and it was used by Tony Gwynn. The heaviest MLB baseball bat used in the modern era was over 50 ounces and was, for example, used by Babe Ruth. Today, hitters do not usually swing bats heavier than 35 ounces. The lightest MLB bat used in the modern era was 29 ounces. Rod Carew and Ozzie Smith both used bats around this weight. Today, the majority of bats are around 34 inches and 32 ounces. The change to shorter and lighter bats over time is because hitters want faster bat speed to hit the ball harder and further. Most batters today use bats that are from 33-36 inches long and have a drop of -3, meaning that their weight in ounces is about three ounces less than their length in inches (batdigest.com).

HOW WOODEN BASEBALL BATS ARE MADE

Over the years there have been many changes to the actual production of baseball bats and there are many variations in production. Some bats are still produced by craftsmen on a high-speed lathe but as technology evolves and is more accessible, many companies are switching from bats made by hand to very precise computer designs and automated computer numerical controlled (CNC) lathe manufacturing. A change in used wood species also requires different techniques for manufacturing. Even with the CNC trend, there is still a lot of room for innovation (Springer 2018).

There are typically 5 steps associated with the production of baseball bats:

1. Turning the splits into billet - Wooden bats are made from mature trees (about 40 to 50 years old, in the case of ash), harvested, cut into 37-inch-long logs which are then split along the grain. These splits are shaped by an automatic lathe into usable shapes of 2.75-inch diameter cores called billets. The ends of the billets are painted with a protective preservative to keep the wood from splitting and rotting. The billets are bundled and then shipped to a bat manufacturer.

2. Seasoning the billets - The billets are still greenwood and must be dried through a process called seasoning. The billets are stacked in the yard and left to dry from six months to two years. Billets are also vacuum dried to reduce the drying time. This drying process helps to stabilize the wood. Billets are inspected and only those without defects and with straight grain are acceptable for further processing.

3. Shaping and sanding the billets - Once completely dried, the billets are inspected for quality. Those fulfilling the criteria are then shaped by an automatic lathe into a rough baseball bat shape. They are then sanded, inspected again, and sorted according to weight.

4. Matching the bat to the model - A bat turner (highly skilled and trained artisan) makes the specific bat based on a model. The model is identified by the baseball player who initially ordered it. Turners will select a billet from storage that fits the weight and length. If the bat is shaped manually, it is a very tedious job. A turner does this by putting the bat on a lathe and shaping the object by sanding, shaving, and comparing it with the model bat, which is placed on a rack behind the lathe. A turner will use calipers to measure the proportions along the bat, as well as weigh the bat repeatedly until it is a perfect replica of a model bat. A skilled craftsman can finish a bat in this manner in 15 minutes. However, these days, turning billets into bats occurs through using a CNC machine (CNC computer-driven lathe) and specific programs with a thousandth of an inch accuracy and a very quick manufacturing time of about 50 seconds per bat.

5. Branding, staining, and varnishing bats - The bat is then stained, varnished (to protect wood against moisture and dirt), and branded with the company trademark. The signature of the player, associated with the model, is also added to the bat. The trademark is placed one-quarter of a turn from the sweet spot (the ideal spot where the ball should strike the bat). The bats are then packed into cartons and shipped to the player or team.

Quality control - The wood species used to make bats are classified by their density and graded to account for the straightness of grain and ring structure. The structural integrity of baseball bats is monitored through repetitive impact testing. Some factories have an air cannon that shoots balls at the bat and a high-speed camera records the impact, while accelerometers measure the velocity. In other plants, a robotic arm hits the balls off oversized golf tees and an inspector collects data on the frequency of bending and how the balls travel off the bat (www.madehow.com). Some of the biggest names in baseball that produce wooden bats and composite material bats, are Louisville Slugger, DeMarini, Mizuno, Marucci, Easton, Rawlings, among a few others.

WOODEN BATS AND MOISTURE

Wooden bats should not get wet. The reason wooden baseball bats should avoid water is that they absorb unnecessary weight from the water. Wooden bats have pores and if not sealed properly, water can seep into these pores, the wood swells and the bat will gain weight. For this reason, some players "bone" their bats with hard objects to close the pores and protect their bats from water and other harmful elements. Some players keep their bats in a humidor or sawdust. Another reason why players bone their bats is that they believe it increases the hardness of the surface of the bat. This practice is not supported by any technical data, but it may have a psychological impact on players and their performance.

WHAT ARE BASEBALL BATS MADE OF?

Throughout history, the material used to produce baseball bats has evolved. These days several types of wood species are used to make bats, and each has its own characteristics. Certain wood species offer different weights, as well as more and less flex, therefore affecting the swing and the speed of the batter. Players should try to find the species and the bat that best suits their hitting style. The most popular wood species are maple, ash, birch, bamboo, and wood composite. Their performance is benchmarked in FIGURE 16.3.

COMPARING WOOD BAT MATERIAL

	MAPLE	ASH	BIRCH	COMPOSITE	BAMBOO
DENSITY & STRENGTH	●●●●● VERY DENSE SPECIFIC GRAVITY - 0.56 - 0.71 MOR 109 MPa MOE – 12.62 GPa Janka H. 6,450 N	●●●○○ DENSE & LIGHT SPECIFIC GRAVITY - 0.55 - 0.67 MOR -103.5 MPa MOE -12 GPa Janka H. – 5,870 N	●●●◐○ DENSE & STRONG SPECIFIC GRAVITY - 0.55 – 0.69 MOR 114.5 MPa MOE – 13.86 GPa Janka H.- 5,610 N	●●●◐○ DENSE, SIMILAR PERFORMANCE TO OTHER BATS SPECIFIC GRAVITY variable	●●●●● VERY DENSE SPECIFIC GRAVITY - 0.5 - 0.85 MOR 70 MPa MOE 30 GPa Janka H.- 3,500 N
DURABILITY	●●●●○ VERY DURABLE	●●●○○ LESS DURABLE THAN MAPLE	●●●●● EXTREMELY DURABLE	●●●●● EXTREMELY DURABLE	●●●●● EXTREMELY DURABLE
FLEXIBILITY	STIFFER, RIGID MORE ENERGY TRANSFER TO BALL	FLEXIBLE AND FORGIVING TRAMPOLINE EFFECT	HIGH FLEX	NOT APPLICABLE	NOT APPLICABLE
GRAIN	LESS VISIBLE	HIGHLY VISIBLE	LESS VISIBLE	VARIED BY MODEL	LAMELLAS PRESSED INTO ONE BILLET

FIGURE 16.3 Comparing baseball bats made of different wood species based on strength, durability, flexibility, and other parameters (image E. Haviarova and inspired by Dick's pro tips: dickssportinggoods.com).

White Ash - A stereotypical wooden bat would be made of ash. Players prefer ash wood bats because they like the ability to "feel" the ball while hitting. It allows them to swing the bat faster. It is easily identified by its distinctive growth rings (ring-porous species) running along the length of the bat. *Pros:* It is lightweight, strong, durable, more flexible, and more forgiving than maple. When the bat hits the ball, the bat will flex rather than break. Players believe that an ash bat allows them to “whip” the barrel through the hitting zone and contribute to the speed. It is the most forgiving of all the various types of wood and is affordable. *Cons:* Not as dense as some other bats. Low moisture content will cause grains to flake or delaminate and splinter over time. The Emerald Ash Borer (EAB) issue is taking ash off the baseball market. Bat producers no longer trust the quality of wood because of the potential degradation of physical and mechanical properties.

Maple - The most common type of wooden bats used and a clear favorite in the last 20 years. One of the best woods to be used due to its density and hardness. It is used by about 75% of MLB players. There are no visible straight lines along the bat as in ash (diffuse-porous wood species). *Pros:* Dense wood that offers a harder hitting surface, more metallic surface appearance, and stiffer flex in a bat compared to ash wood bats. The hardness of the wood also helps with the "pop" of the ball off the bat. Because of its high durability, it will hold together under high-intensity impact. *Cons:* Because of its shorter fibers, the wood is more brittle than ash and can break spectacularly under certain circumstances. Maple needs to be well-dried to be used to its full potential, but it tends to gain moisture and weight over its lifespan.

Birch - Birch is harder than ash, but not as hard as maple. It is a softer wood with more flexibility, and it may help to generate “whip-like” speed through the hitting zone. It will compress over time and resist flaking. *Pros:* Birch is very flexible, and it is less likely to break. Because of its flexibility, it will typically be the easiest to swing faster. It is more resistant to repetitive strikes in the same area, and it is approved for professional play. *Cons:* Its softness requires a ‘break-in’ period until all the grains are compressed to a higher density. It tends to dent when hitting balls and there may be less “pop” off the bat upon contact.

Hickory -The first baseball bats were made of hickory. It is the heaviest and hardest of all bat-wood species. *Pros*: It could withstand high impact. Hickory has long been known for its impact strength and is a very typical material for shovels and striking tool handles. Because it is very hard, stiff, and inflexible, it absorbs much of the energy of the ball upon impact. This very dense wood results in high exit velocity. It is durable and does not break easily. *Cons:* It is very heavy, very stiff, has no flex, no trampoline effect, and very little feel. It was used in the past and now it is not approved for play in all leagues.

Composite - These bats are made from two or more pieces of wood and incorporate a synthetic coating of resin or polymer. *Pros:* They are the most durable wooden bats. The composite bat makes a good practice bat, and it is still a useful option for players starting with wood. They have soared in popularity in recent years and are the choice for “hybrid” leagues, like the German Baseball Bundesliga, which are comprised of semi-pro teams. It is a great option for wood-bat leagues. *Cons:* They are not approved in most professional baseball for one primary reason - the players that reach this level are considered too good.

Bamboo - It is technically a grass and not the wood. It involves pressing bamboo strips into long, rectangular billets that are turned until they form the shape of a round baseball bat. *Pros:* They are very strong and durable. *Cons*: It is hard to machine bamboo because of the fast dolling of tools. Bamboo is not approved for MLB use and requires a BBCOR certification mark for organized play.

Cork - Bats are filled with cork to make them lighter, allowing a quicker swing. It is thought to cause a "trampoline effect" and make the ball travel farther but it has been found not to be true. *Cons:* Adding cork also makes the bat more susceptible to breaking. Corked bats have been illegal and frowned upon in major league baseball. Athletes will face suspension if caught using a bat with cork.

Other specialty woods used in professional baseball bats are Pine, Willow, Chestnut, Pistachio Wood, Mountain Mahogany, Lignum Vitae, and possibly others. Balsa wood is used in movies for a safe break on camera but is useless for real play. Each of these wood species offers something different to the batter (dovetailbat.com; penaltyfile.com; oldhickorybats.com).

Pine tar - It has been a widely used substance on baseball bats throughout baseball history. Pine tar is a brownish tacky substance that originates from pine trees to help batters keep a better grip on their bats. It greatly improves their game. It was controversial and illegal to use it in MLB but later on, pine tar had relaxed restrictions. Pine tar comes from the carbonization process of pine wood. It dates to Scandinavia in the Iron Age and was popular for preserving wood after being affected by harsh conditions, mostly in ships. Pine tar may not be the wood product you think of when you think of baseball, but it is another aspect of wood materials in the use of wooden baseball bats.

WOOD VERSUS ALUMINUM AND WHICH IS BETTER

MLB requires the use of wooden bats in their game because metal bats have objectionable properties influencing the game. Aluminum bats are lighter, they can be swung faster, and balls can be hit farther. However, an aluminum bat can have the trampoline effect, which causes energy from the ball to be given back at nearly 100% and leads to farther hits. While this may seem positive, the aluminum bat adds unrealistic human power. Major League games wish for the sport to reflect the power and ability of the individual player without the assistance of the bat. Wooden bats better reflect the player's abilities, and they are preserving traditions and the integrity of the game. Aluminum bats however are increasingly dominating over the use of wooden bats in the Little League and college games. This choice is frequently debated, with fears that aluminum "super bats" will eventually dominate the game.

It is important to explain that wooden bats have many benefits, including better balance, natural power, and even the potential to build more muscles. The balance that is provided with a wooden bat allows for more control when hitting. They are heavier and denser, therefore will give more power to the hitter. It is also believed that if the player starts with an aluminum bat, it is challenging to transition back to a wooden bat. If the player starts using a wooden bat at an earlier age, they can develop better swinging and hitting skills. The wooden bat also has a much smaller sweet spot, since the bat is much denser, which means the player is forced to work on the improvement of precision swinging (exploratorium.edu).

USE OF WOOD FOR BASEBALL BATS PRESCRIBED BY THE RULES OF THE SPORT

According to the Official Rules of MLB:

(a) The bat shall be a smooth, round stick not more than 2.61 inches in diameter at the thickest part and no more than 42 inches in length. The bat shall be one piece of solid wood. No laminated or experimental bats shall be used in a professional game (either championship season or exhibition games) until the manufacturer has secured approval from the Rules Committee of his design and methods of manufacture.

(b) Cupped bats, an indentation at the end of the bat up to one inch in depth is permitted and may be no wider than two inches and no less than one inch in diameter. The indentation must be curved with no foreign substance added.

(c) The bat handle, not more than 18 inches from its end, maybe covered or treated with any material or substance to improve the grip. Any such material or substance, which extends past the 18-inch limitation, shall cause the bat to be removed from the game.

(d) No colored bat may be used in a professional game unless approved by the Rules Committee (Sabr.org).

The diameter of 2.61 inches, 42-inch length, and handle restrictions came into existence because of recommendations from the technical team, and their work started in 2008. MLB had no max diameter or minimum handle diameter before then. If you could swing a smooth round tree branch 3 inches in diameter, you could do it (Spartz 2013).

PERSPECTIVE

The type of wood used to create the baseball bat has varied throughout the sport's history. The design, shape, and weight of the bats have been modified as players and manufacturers began to experiment with swing speed, and how the bat itself affects the performance of the player. Baseball as a sport and its equipment has evolved and will continue to evolve. There is a hope that wood will still play an essential role in the manufacturing of baseball bats.

ACKNOWLEDGEMENTS
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On the hardwood: more importantly, under it

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INTRODUCTION

Basketball without wood brings to mind the unforgiving and interminably slick linoleum floors of grade school gymnasiums; basketball and wooden floors go hand in hand. Basketball is a relatively young sport, originating in Massachusetts in 1891, the brain child of James Naismith. While originating in the US, basketball soon spread to other countries and was included in the Olympic Games starting in 1936.

The “baskets” in the original game were ½ bushel wooden peach baskets (Britannica 2022), so the sport has strong connections to wood, from infancy. At first, baskets had no backboards and were typically mounted on the balcony of a gymnasium. However, this resulted in fans interfering with the ball around the rim. The solution was a 1.2x1.8 meter “screen” to eliminate interference, translating eventually to a wooden backboard. Introduction of glass backboards around 1908 meant that wooden backboards were soon out of fashion (Brittanica 2021). Trees/wood contributed to the sport in many other ways through, for example, rubber used in the ball and shoes, tannins used in tanning leather for the ball, and the lumber used for gymnasium seating.

THE COURT

Wood floors for sport and dancing precede the sport of basketball, dating to around 1870 (Turcas and Fotin 2017). Generally, basketball floors are made of wood and are around 15x29 meters with some variance based on geography and level of play. Wood is clearly the preferred playing surface. In fact, wooden floors are mandatory for FIBA (International Basketball Federation) Level 1 courts. And while in North America wood is not technically required, all National Basketball Association venues have floors made of hard maple (*Acer saccharum*), except the new Boston Garden which is made of red oak (*Quercus rubra*). Beech (*Fagus sylvatica*) is commonly used in Europe. The official FIBA basketball equipment rules specify performance requirements for the court surface, providing values for both wooden and synthetic surfaces.

There are two broad categories of wood floor types used for basketball courts - permanent/fixed and portable/modular. Both categories are typically installed over a concrete subfloor. There are three common types of permanent floors - fixed/anchored, floating, and fixed/resilient. Anchored floors were the industry standard for years and involve attaching (‘anchoring’) plywood to the concrete and then nailing the hardwood tongue-and-groove (T&G) flooring to the plywood. Floating floors were developed in the 1950s and use a rubber pad (for shock absorption) between the hardwood and the plywood. The hardwood ‘floats’ in that it is not nailed or otherwise attached to the subfloor and as a result, there are some limitations in these floors due to shrink/swell stresses in the hardwood. Today’s gold standard for high-performance sports floors are the fixed-resilient floors; these are essentially a combination of the anchored and floating styles. These floors are anchored down through the concrete and involve an engineered and performance-tested design that is a combination of other materials such as plywood and non-wood materials (e.g., rubber) to allow for flexibility and absorption of shocks. There can be as many as three layers of plywood providing the foundation for the hardwood flooring. In North America this plywood is typically 4-ply CDX western fir plywood. In looking at the design of these floor systems (FIGURE 17.1), you can see why there is more wood that you do not see in these floors than in the hardwood that is plainly visible. Further, the "technology is really underneath the maple" (Gasperich 2021).

FIGURE 17.1 OSU Practice Arena (top); Robbins' Maximum Vibration Protection (MVP®) construction (bottom) [Photo Credits: Upper - Scott Leavengood; Lower - Robbins Sports Surfaces].

These advanced technology floors are nothing like your living room floor, also with respect to cost. Installed costs can be around $200/m^2 which translates to something around $100,000 just for the floor space of the court itself.

The venues for modern professional basketball, partially because of cost, are often multi-purpose which requires the basketball floor to be of the portable/modular type. If you look closely at the perimeter of the Portland Trailblazers court in FIGURE 17.2, you can see that the floor is produced from modular elements. A venue might host a basketball game one night and a hockey game the next. In fact, the Staples Center in Los Angeles is home to the LA Lakers, LA Clippers, LA Sparks (WNBA) and the LA Kings (hockey). In 2012, the Lakers, Clippers, and Kings were each in the playoffs which required multiple changes to accommodate six games within four days. Such fast changes require specialized designs and systems. An NBA court might be built and taken down as many as 70 times in a season. The hockey ice is in place for a full season and the basketball court(s) are assembled on top of the ice. Hundreds of sheets of insulated plywood are first laid over the ice, then the sections of basketball court are assembled on this base. Transitioning from one court to another (or to ice) can take as little as 90 minutes (with a large crew), to all day. The Denver Nuggets court is made up of 285 pieces that weigh nearly 85 kilograms each (Wonderopolis 2021).

At least some readers may be reminded at this point of a floor in a multi-purpose venue made famous in the 1946 movie, It's a Wonderful Life. In the movie, a group of high school students are dancing on a gymnasium floor until a couple pranksters discover they can open the floor to reveal the swimming pool beneath it (FIGURE 17.3) - at which point of course, the dance party turns into a pool party. That floor was designed and constructed in 1939 as the Swim Gym at California's Beverly Hills High School; the floor, and pool, are still in use after over eight decades, although a new floor was installed in 2016.

Basketball is a popular sport in nearly every corner of the globe. As a result, there are courts everywhere, even in places where availability of flat, dry ground is a significant challenge. Among the list of the world's most amazing basketball courts is the floating court on Lake Tonle in the village of Chong Khneas, Cambodia. In looking at photos of this court, the floor surface does indeed appear to be wood!

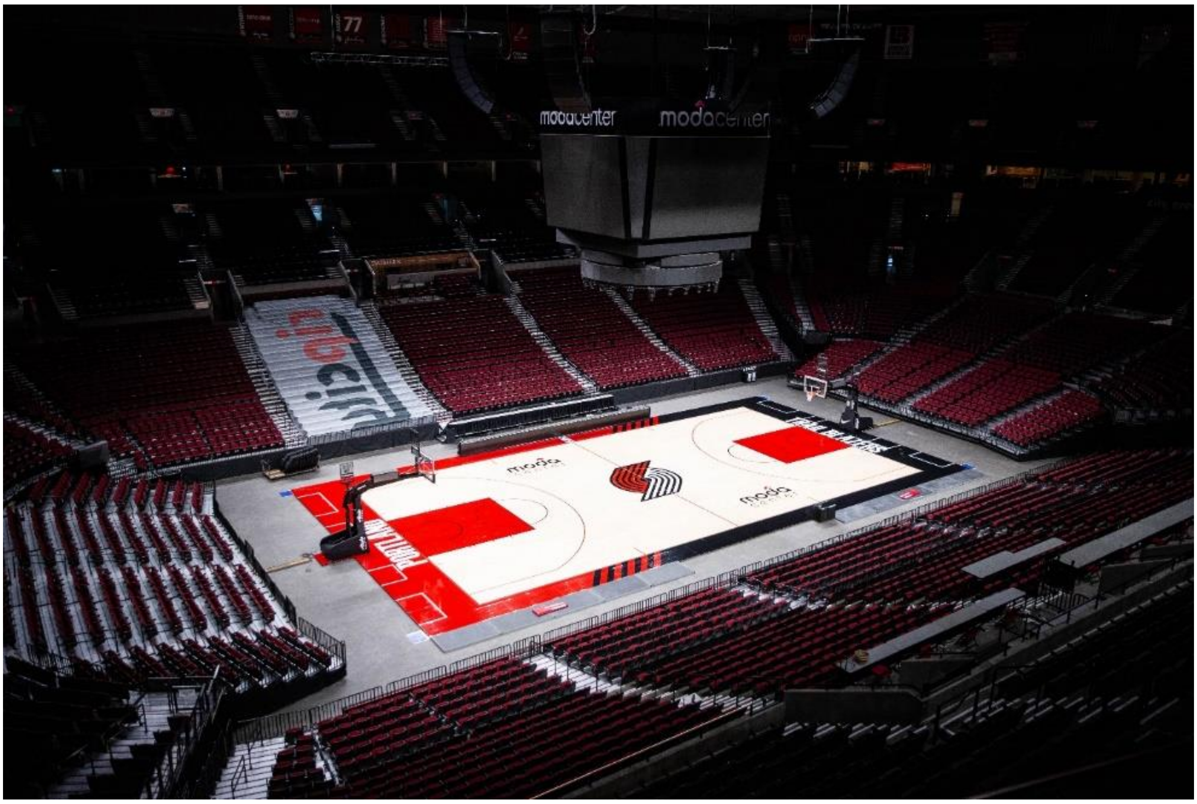

FIGURE 17.2 Moda Center, Portland, OR USA (Photo Credit: Portland Trail Blazers).

FIGURE 17.3 Beverly Hills High School, Beverly Hills, CA USA. (Photo Credit: Robbins Sport Surfaces).

PERFORMANCE REQUIREMENTS

As stated above, in North America, there are no regulations that require that floors be made of wood or even to conform to specific performance standards (Elliott 2017; Gasperich 2021). However, not only are FIBA Level 1 basketball floors[43] required to be made of wood, but the performance of these floors is regulated as well. While there are specifications for some aspects of court performance, an overriding principle is uniformity in performance. In other words, the ball should bounce the same amount/way on all parts of the court. Sometimes home court advantage is partially knowing where the "dead spots" are on the floor and when on defense funneling the opposing dribbler into those areas.

There are numerous international standards that specify the performance requirements of sports floors. Some well-known examples include the German standard DIN 18032-2, the integrated European standard EN 14904, ASTM F2772, and the Maple Flooring Manufacturers Association Performance & Uniformity Rating standards for sports floors (MFMA 2021). Many of these standards emphasize similar criteria and even levels of performance. As one example, the specific performance criteria for FIBA Level 1 mobile floors involve conforming to standards related to force reduction, vertical deformation, ball rebound, slip resistance, resistance to wear, specular (mirror-like) gloss and rolling load (FIBA, 2020). See Annex 17.1 for the specific criteria and standard test methods.

Looking at just one criterion, how is force reduction/shock absorption measured? ASTM F2569 (ASTM 2019) stipulates, via the use of a specially designed device, "...a mass of 20 kg is allowed to fall onto an anvil, which transmits the load via a spring to a test foot resting on the surface. The foot is fitted with a force

[43] FIBA rules allow for backboards for Level 2 courts to be made of wood, glass, acrylic, fiberglass, steel or aluminum.

transducer that enables the peak force during the impact event to be recorded. The peak force is compared with the result obtained on a rigid floor, and the percentage of force reduction calculated for the test surface." The specified rigid surface is concrete (minimum 15 cm thickness) with a 10 mm thick steel plate fully glued to the concrete. The 'specially designed device' described above is often a so-called 'artificial athlete' as shown in FIGURE 17.4 below.

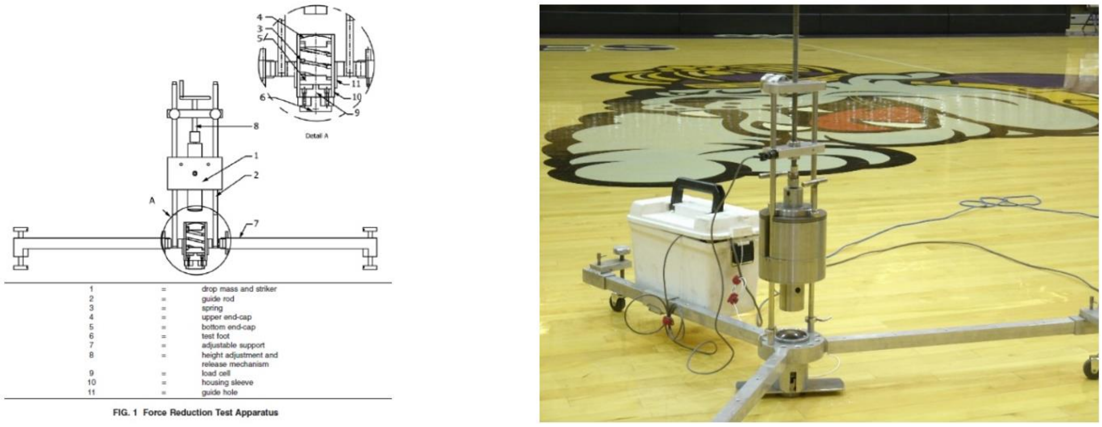

FIGURE 17.4 Left, outline of the device (image credit: ASTM 2019). Right: device (Artificial Athlete) used for testing force reduction (image credit: P. Elliott, ASET Services).

People familiar with wood flooring may be surprised to learn that hardness (either Janka or Brinell) is not directly measured to assess suitability of basketball flooring. The simple fact is, the hardness of species like sugar (hard) maple and European beech is well-established, and these species have a long track record of performing well for sports surfaces. Any new species wishing to vie for consideration would almost certainly need to be of similar hardness as maple and beech. In particular though, the standards address performance of the flooring system rather than material properties (such as hardness) of the individual floor components. As such, force reduction is a more important measure in this regard than is the hardness of the wood. Tradition plays a huge role in maintaining hard maple as the predominant species used in high-level basketball courts as well. Part of that tradition is the light color which helps brighten the venue (Newcomb 2015) for both players and fans. Typically, floors are specified by an architect that will likely reference a particular standard, most likely in consultation with one of the key manufacturers. Maple is the traditional species, so this is naturally what architects tend to specify (noting regional differences).

HARDWOOD - THE FINER POINTS

As mentioned previously, maple, beech, and oak, are the dominant species used for basketball floors around the globe. But of course, there are a lot of details for hardwood flooring beyond just species. Such details include things like the grade of the lumber, grain orientation, and dimensions.

Starting with grades, the higher quality boards sawn from the outer perimeter of a log are used for high-value uses like furniture and cabinetry. Boards for flooring come from the lower-quality interior of the log; the lowest-quality material is used for pallets. One US flooring manufacturer stated that they typically purchase 2A and 3A grade (which are National Hardwood Lumber Association grades) hard maple, process it to flooring, and then regrade it according to MFMA rules. MFMA provides rules for four grades of maple, beech and birch. Details of these grades are provided in ANNEX 17.2. In addition, to be considered on-grade, material must be kiln-dried to between six and eight percent moisture content.

Of course, the grade of the lumber is a key factor influencing the cost of a floor. For the consumer, grade often manifests itself in terms of uniformity, color uniformity in particular. If the architect specifies a very light and uniform color floor, then First grade lumber will be used. If more color contrast is acceptable, lower grades can be used. And of course, combinations of grades are often used. For example, First grade lumber could be used in the center and Third grade around the perimeter to give a picture-frame appearance (Evans 2021).

With respect to grain orientation, MFMA rules require 'edge-grain' flooring which is defined as flooring for which the annual growth rings range from 30 degrees horizontal to 90 degrees vertical. In other words, the wood must be somewhere between rift sawn and quartersawn. Given the relatively small size of the logs and hence variation in grain orientation within an individual board, the rules will be deemed to be met if 75 percent of each piece's grain orientation falls within the range mentioned above (MFMA 2020).

Flooring is typically 13, 20, or 26 mm thick and widths vary from 39 to 83 mm; 20x57 mm is the most common dimension used in the industry. However, one manufacturer noted that they were seeing a trend to increase width to 64 mm as one way to increase efficiency of installation. As this person noted, this apparently minor change results in about a 12% increase in width for each plank. Given the large dimensions of basketball courts, this can result in a significant decrease in installation time.

FINISHING, CARE AND MAINTENANCE

FIBA rules (Annex 17.1) regulate the gloss level of floors and the MFMA provides detailed industry recommendations for sanding, sealing, court lining, and finishing floors. For example, these guidelines stipulate sanding three times (coarse, medium, then fine) with the final sand using a screen and disk sander. The floor should then be vacuumed to remove dust and grit prior to application of the recommended four-coats of sealer and finish. These four coats are applied as either "1-3" (one coat of sealer plus three coats of finish) or "2-2" (two coats of sealer followed by two coats of finish). The paint for game lines and markings is applied between the sealer and the first layer of finish. Staff at Oregon State University's Athletics Department state that they sand the finish (but not paint) off every year and add three coats of finish. The courts are sanded down to bare wood every three to five years. It costs $25,000 to $30,000 to resurface a floor and double that when going down to bare wood and repainting (Bucher and Bartholomae 2021).

In addition, MFMA finishing and care guidelines emphasize to never use water to clean floors. People familiar with wood products in general will be well aware of issues related to hygroscopicity - the fact that wood adsorbs and desorbs moisture and swells and shrinks as a result. Moisture may be from water that has been directly applied (i.e., in liquid form) or simply due to changes in ambient relative humidity. For this reason, upon delivery of a new floor system, manufacturers tell their customers to store the floor systems indoors in areas with temperature and humidity control; ensure the concrete slab is below 85% moisture content; building HVAC system is installed and maintaining temperatures between 10º to 27 ºC prior, during and after, installation of the floor system; and the relative humidity remains between 35% and 50%. Further, storage areas for portable floor panels should maintain these conditions as well. Of course, problems with HVAC systems do occur and therefore professional installers know to allow for movement by including an expansion gap. This gap may be between 38 and 51mm adjacent to walls (Gasperich 2021). One manufacturer reported a 'horror story' related to water where the fire suppression (sprinkler) system was tested immediately after a brand new floor was installed. And then, another brand new floor needed to be installed!

As you can imagine, basketball floors endure significant wear and tear. In the case of portable floors, a court might be built and taken down as many as 70 times in a season. While the industry expects a floor to last about 50 to 70 years (Evans 2021), the frequent assembly and disassembly, combined with normal wear and tear, lead the NBA to require that courts be replaced every 10 years (Newcomb 2015).

INNOVATION ON/UNDER THE HARDWOOD

There has been significant innovation in floor systems (such as shown in FIGURE 17.1), including a patented secondary compression nub to allow for expansion, owned by Robbins, Inc. Still, some of the most important process innovations in the industry are said to simply be better measurement and control systems. This means measurement of the moisture content of the concrete and assuring it is at an acceptable level before ever installing the floor, inclusion of vapor barriers, use of data loggers, and better monitoring and control of the inside environment of the venue to assure steady conditions. In that regard, when asked about new performance requirements on the horizon, a representative of MFMA (Evans 2021) stated that there were ongoing tests to evaluate the performance integrity of floors following moisture damage. At the time of this writing, MFMA has ongoing tests involving flooding floors for a specific time period, drying the floors, and then, assessing the integrity of fasteners as well as the efficacy of standard repair methods used in the industry.

With respect to raw materials, recent (2021) price instability of panel products in North America have altered the thinking of manufacturers with respect to what panel products may be used in the substructure under the hardwood flooring. However, with respect to the hardwood surface itself, manufacturers seem to have little concern over adequate supply or quality of flooring materials (Evans 2021; Gasperich 2021, Anonymous 2021). They also are not especially concerned about substitutes for their products. While there are significant inroads at the low end of the market by high-performance synthetics and there is some use of engineered wood flooring, wood flooring manufacturers do not see these materials as a competitive threat to solid wood flooring systems. First, substitutes cannot effectively compete on performance. Perhaps more importantly substitutes are hard pressed to enter what was referred to as the ecosystem around maple sports floors.

Last but not least, in the spirit of a circular economy, when a professional basketball court is retired it quite likely enters a new life cycle as sports memorabilia. Pioneer Millworks of Portland, Oregon marketed the retired Portland Trailblazers court. As the court was mounted on plywood, the typical 4x8 foot plywood sheet size was offered, as well as smaller off-cuts.

Annex 17.1

FIBA Level 1 Performance Criteria (FIBA 2020)

Criteria	Performance/Uniformity	Test Method
Force Reduction	≥50% - ≤75% ±5% from average	EN 14808 - Surfaces for sports areas - Determination of shock absorption
Vertical Deformation	≥1.5 mm - ≤5.0 mm ±0.7 mm from average	EN 14809 - Surfaces for sports areas - Determination of vertical deformation
Ball Rebound	≥93% ±3% from average	EN 12235 - Surfaces for sports areas - Determination of vertical ball behaviour
Slip Resistance	Average: ≥80 - ≤110	EN 13036 - Method for measurement of slip/skid resistance of a surface: The pendulum test
Resistance to Wear	≤80 mg	EN 5470- Determination of abrasion resistance: Part 1: Taber abrader
Specular Gloss	≤45%* ≤10-unit variance	
Rolling Load	Permanent indentation of ≤0.5 mm	EN 1569 - Surfaces for sports areas - Determination of the behaviour under a rolling load

*Recommended value to minimize playing court glare for player's vision and TV production. High-gloss alternatives may be used when lighting is positioned as such to avoid unwanted playing court glare.

Annex 17.2

MFMA Grade Rules (MFMA 2020)

First - one face should basically be perfect; with variations in natural color of wood allowed.
Second - tight, sound knots (except on edges or ends) and other slight imperfections allowed; must be possible to lay flooring without waste.
Third - may contain all visual features common to hard maple, beech, and birch; but any voids over 10-mm in diameter are not permitted; must permit proper laying of floor and provide a serviceable floor; few restrictions on imperfections; must be possible to lay flooring properly.
Fourth - may contain all visual features, but must be possible to lay a serviceable floor, with some cutting.

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Appendix - Floors for other sports

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In addition to basketball, discussed above, many sports are played on wooden floors. Among these are, for instance, futsal, roller hockey, volleyball, wheelchair rugby, etc. Wooden floors can also be intended for multi-sport purposes, with marking related to multiple sports (Figure 17.5).

In general terms, high-level floors that serve sports where jumping are a significant component can be considered somewhat similar: a sophisticated sub-floor that helps minimize repetition injuries. The subfloor can be viewed as less critical in case of floors specifically designed for roller sports.

Requirements of wooden sport floors vary depending on the intended sport. Each sport, in fact, requires specific performance for optimal play and for minimizing athletes' injuries. For instance, playing basketball on a floor with excessive shock absorption can lead to poor play and quicker fatigue. Properties often considered in wooden sport floorings are shock absorption, vertical deflection, area of deflection, ball bounce level, surface friction, and uniformity. Comparison tables exist to verify the suitability of a wooden flooring to the practice of different sports (MFMA 2022).

Figure 17.5 Oak wood floor with marking related to multiple sports (image courtesy of Dalla Riva Sportfloors).

Overall, the basketball chapter can be taken as a general reference on wooden sport floors (cycling track and bowling are treated in specific chapters as they are markedly different situations). Discussing floors of other sports is avoided within the present book, since it would be largely repetition. Addressing specific details is therefore left to the reader, in line with the general approach of the book.

Moving from courts to their perimeters, it is finally worth mentioning that solid timber and wood-based products are also used to delimit recreational playing courts (FIGURE 17.6). The design of such facilities, and the type of wooden elements included, is based on several factors (playability, safety, maintenance, appearance, costs, etc.), resulting in a virtually unlimited range of possible solutions.

FIGURE 17.6 Timber elements of this outdoor, multi-purpose playing field (Oulx, Italy) perform different functions at the same time: they delimit the playing area, withstand the repeated impacts of the ball, and are key to determine the aesthetic appearance of the facility (image F. Negro).

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POINTING AND THROWING WOOD IN PARALYMPIC DISCIPLINES

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INTRODUCTION

The word "Paralympic", composed of "para" (beside) and "Olympic", means that Paralympic and Olympic movements exist side-by-side [1]. Paralympic games have taken place every four years since their first edition in Rome in 1960 and have greatly evolved over the years [2]. The back-to-back comparison between the Paralympic games held in Tokyo 1964 and in 2020 is impressive indeed. Suffice it to say that participating countries increased from 21 to 162, the disciplines from 9 to 22, and attending athletes from less than 400 to more than 4,400 [3]. Nowadays the Paralympic games are a spectacular, global event with a worldwide TV coverage.

The International Paralympic Committee (IPC) was founded in 1989. Its grounds are well represented by the Paralympic symbol and Motto. As reported by IPC, "The Paralympic symbols are three "*agitos*" (Latin for "*I move*") [...]. The symbol also reflects the Paralympic Motto, *Spirit in Motion*, representing the strong will of every Paralympian. The Paralympic Symbol emphasizes the fact that Paralympic athletes constantly inspire and excite the world with their performances: always moving forward and never giving up" [4]. The four Paralympic values set by IPC are determination, equality, inspiration and courage [5]. To deepen into this valuable topic the reader can refer to the large amount of specific literature available (for instance, Ogura 2020).

Coming to wood equipment, sports in which it is the same in the Paralympic and Olympic versions are not covered in this chapter. This is to avoid information that would be largely repetitive, in line with the general approach of this book. Similarly, cases in which wood equipment used in Paralympic and Olympic sports is substantially similar - for instance when the difference consists in modifications of handles - are not taken into account here.

This chapter contains instead a brief focus on the wooden ramps and clubs used respectively in boccia and club throw, as sports that are included in the Paralympic and not in the Olympic games.

BOCCIA

Boccia is similar to bowls and *pétanque* and consists in throwing or rolling colored balls as close as possible to a white target ball. Boccia is played individually, in pairs or teams of athletes with impairments that affect motor skills [6].

Ramps (FIGURE 18.1) are used by athletes in the BC3 Division [7], who are assisted by ramp operators that adjust the ramp under their direction. In short, the ramp is oriented toward the desired direction, and the ball is released from different heights on the ramp. The Rules of the Boccia International Sports Federation (BISFed 2022) prescribe a maximum size for ramps which, laid on their side, fit into a 2.5x1 m area. The Rules indicate other requirements, for instance devices to propel the ball are not accepted, however a wide choice remains for materials and constructive details.

In practice, such ramps can be divided into do-it-yourself (DIY) and commercial models. As for the do-it-yourself ones, plywood and timber boards are frequently used. Among the different materials, wood and wood-based products are often chosen here for the typical reasons that make them appreciated in DIY. They are in fact affordable, lightweight, easy to work, and enable the realization of accurate and well-finished manufacts, even with simple tools.

Commercial ramps available on the market are typically made of various assemblable parts to ease their transport. Models with different constructive details are available, made of a variety of materials such as polycarbonate, steel, and plywood. The latter is often used to make the sides of the ramp. Here, the choice of plywood can be ascribed to its good dimensional stability and to its relative light weight (on the other hand, heavier weight also provides for stabler and thus more accurate ramps). Wood can also be found in other components: in some models, several parts of the supporting structure are made of plywood; in some cases, thin plywood is used to make the curved rolling flat surface, due to its flexibility; finally, wooden movable ball holders are also used in some models.

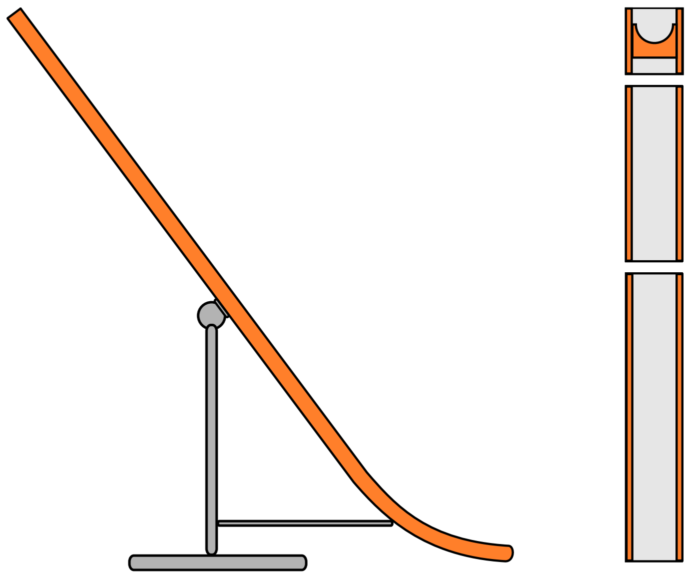

FIGURE 18.1 Outline of a boccia ramp with orange sides made of plywood (although realistic, proportions of the drawing are not to scale). The side view on the left shows the curved shape of the ramp slide, sustained by a supporting structure (dark grey) made of a vertical bar, a horizontal bar and a larger base. The front view on the right is divided into three parts, as ramps are often composed of assemblable parts. The drawing shows a semicircular, wooden ball holder (orange), the plywood sides (orange), and the polycarbonate flat rolling surface (light grey) [image F. Negro].

CLUB THROW

Club throw consists in throwing a wooden club as far as possible and can be considered as the Paralympic equivalent of the Olympic hammer throw. Club throw is intended for athletes with significant hand impairments and is played by athletes in the F31, F32 and F51 Classes [8]. They compete seated and any style is accepted, including facing away from the club landing area and throwing from behind [9]. The Rules and Regulations of the World Para Athletics expressly prescribe that the club shall be made of wood (FIGURE 18.2), but no specific wood species is imposed.

The aforementioned Rules specify club composition: “The Club shall consist of four main parts: a head, a neck, a body and an end. The head, neck and body shall be solid and made of wood to constitute a fixed and integrated whole. The body shall be fixed to a cylindrical end constructed of metal [...] The surface of the head, neck and body shall be smooth [...]. The head shall be spherical or cylindrical in shape and immediately taper towards the neck. [...]. The club shall taper regularly towards the neck and slightly towards the metal end.” (World Para Athletics 2020). According to the Rules, clubs shall be between 350 and 390 mm long, have a diameter of the widest part of the body between 50 and 60 mm, and a diameter of the neck between 18 and 20 mm.

As reported above, the Rules prescribe that the minimum weight of such clubs shall be 397 g. Notably however, the Rules specifically indicate a range of supply for competition from 402 to 420 g to manufacturers. This specification is intended to leave a small allowance that can compensate for limited weight losses, which can be caused by club wear or by limited reductions in the moisture content of the wood they are made of. This could occur, for instance, because of the relative humidity of the environment in which clubs are stored. The weight of wooden clubs is indeed checked by officials before each competition. In case of limited weight losses, the above allowance would still enable the clubs to comply with the minimum weight required, allowing their use and thus the homologation of competitions and records. This detail can be taken as an example of how wood can be suited to the most different applications, provided it is used according to proper knowledge of its characteristics and behavior.

In general terms, the role of wood in clubs for club throw is quite straightforward: to provide a solid and robust item with an appropriate weight. The wood density shall of course be suited to realize clubs with adequate weights; beech and ash wood are used for instance.

Nowadays, clubs for club throw are realized by Computer Numerical Control lathe cutting, which also enables smooth and splinter-free surfaces to be achieved. Even if these clubs appear as simple objects, their shape is the result of a specific design. They are in fact intended to enable different kinds of hold: athletes can in fact grasp the club handle with the palm or they can place the thinner part between their fingers.

FIGURE 18.2 Wooden clubs with cylindrical and spherical heads used in club throw (image M. Poletti).

ACKNOWLEDGEMENTS
Mario Poletti is thanked for the useful information provided about club throw and the Paralympic movement.

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FAST AND FLOATING

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The common element between canoe & kayak and rowing is just the use of a kind of boat. In fact, there are several differences between paddlers (canoe & kayak users) and rowers. While rowers use long oars fixed on special oarlocks and proceed in the opposite direction to where they are facing, paddlers use paddles - not tied to the boat - which can be single-blade (canoe) or two-blade (kayak) and proceed in the direction they are facing. In any case, the origin of these boats is ancient and due to the needs for transporting people and materials; over time, sports disciplines and related competitions have developed. Historically, it is not known where the origins are, but it is possible they are not unique, considering that boats have been used all over the world wherever there is water. In fact, it is probable that ancient canoes and boats were born from tree trunks moved by using long branches as poles. Then, they evolved into ever more manageable, fast and safe boats. Over the centuries, the search for new solutions has substantially divided rowing boats from those moved by paddles, depending on the needs. In fact, rowing boats are generally faster than canoes and kayaks, but also heavier and less maneuverable, considering also that rowing normally requires a coxswain, because rowers cannot see where they are going. Having clarified these differences, firstly we can proceed to briefly explore the history, and then the role of wood in the past, present and future of sports derived from these means of transportation.

CANOE & KAYAK

Canoe is a term that encompasses a wide range of boats, united by their small size and a long and tapered shape. The origin of the term is Caribbean: "canaoa", which means "hollowed trunk". Nowadays, canoe usually means the sport that includes two main types of boats, the kayak and the Canadian canoe. The latter is of Canadian origin, was built with the characteristic raised bow using chestnut, fir, walnut and birch wood, then waterproofed with pine resin. It was used for transportation and specifically for hunting. Paddlers used a single-blade paddle. Boats similar to those in Canada have been found in Etruscan and Egyptian excavations, in some African and Oceanian regions, where pirogues -conceptually similar to Canadian canoes- are used. The kayak, on the other hand, derives from the typical hunting and fishing boat used by Eskimos, who built it with a frame of salvaged wood, which they covered with sealskins. The paddler is seated in the kayak and uses a two-blade paddle. At a sporting level, modern canoeing includes two specialties within the Olympic program: historic canoe flatwater, which made its appearance as a demonstration sport in 1924 and then definitively in 1936, and canoe slalom, scheduled since 1992. The world of canoeing also includes many other specialties and disciplines, such as canoe polo and canoe marathon, which are not included in the Olympics, but which still respond to the International Canoe Federation (ICF). In canoe flatwater, the only Olympic canoeing discipline that is linked to wood, boats can have 1, 2 or 4 seats for both kayaking and canoeing; in the first case it is identified with the letter 'K', in the second with the letter 'C', in both cases followed by the number of rowers provided. For example, with K1 a single-seater kayak is identified, with C4 a Canadian canoe with 4 paddlers.

ROWING

The technical gesture of rowing is typical of the homonym sport, which consists in propelling a boat as fast as possible using oars as a lever. According to some studies, the first rowing boats were already built in the Paleolithic era, and over the millennia they distinguished themselves from canoes and similar boats for the size they reached. In fact, polyreme ships have navigated across seas for both trade and war reasons for many centuries, moved by a variable number of rowers. As for competitions, the first ones were already reported in ancient Rome, but it was in the nineteenth century in England that modern rowing was born. In modern rowing, single, double, quadruple and octuple boats exist. These can be sculling boats, when each rower uses two oars, or sweep boats, when each rower uses one oar. Furthermore, boats can have a coxswain or not. While the first boats had a fixed seat, now the rower sits on a mobile trolley that slides on a special track to optimize the levers and maximize the speed.

THE USE OF WOOD IN CANOE & KAYAK AND ROWING

Regarding competitions, the first material used for boat construction was wood, and it has been the main material used until the Forties, with the advent of composite materials. At the beginning, the clinker technique was the most used in wooden boat construction. It is characteristic because the hull is made from a series of overlapping planks fixed to light frames. In this way, the hull is not linear, but has a stepped profile (FIGURE 19.1).

FIGURE 19.1 Example of clinker technique in an old rowing boat (image G. Goli/A. Laschi).

Thanks to this technique, it was easier to guarantee adequate watertightness, as well as giving stability to the boat. The wood species used were different; mainly lime and ash wood for planks. In this kind of boat, the deck could be open, as in rowing boats, or covered by a canvas, as in kayaks. Wooden decks were more common when the construction method of wooden boats changed from the clinker to the carvel technique in the thirties. In fact, this technique allowed producers to obtain a smooth surface on the hull, using a thick sheet of wood (a 5 mm basswood sheet in the first boats built in Lakefield Ontario) mounted on a lightweight frame. The first hulls were made by cold-pressed laminated timber. Over time, the production processes increased in level, including the possibility to make the hull from plywood through a hot-molded process. In this way, a very light and rigid wooden shell was obtained, creating high-performance boats (FIGURE 19.2).

FIGURE 19.2 Example of the carvel technique applied in a rowing boat (left) and a kayak (right) [image G. Goli/A. Laschi].

For example, the official dimensional standards establish the minimum weight for canoes and kayaks (e.g., 12 kg for K1 and 30 kg for K4) and it is important to maintain the weight close to this value. The main tree species used are mahogany (generally Honduras mahogany), cedar and obeche. In the world of racing boats, wood was the main material used until the 1980s. Then, the competition with composite materials including glass, kevlar and carbon fibers decreased the appeal of wood on the market, especially when sandwich construction started guaranteeing high performance in terms of stiffness and weight. Beyond their performance, modern materials proved to be particularly easier to work with, reducing production costs. Moreover, composite synthetic fibers were easier to manage in terms of maintenance and repair. This revolution in materials involved not only boats, but also paddles and oars; their evolution in terms of material was faster than for boats, because kevlar and carbon guarantee high stiffness and lightness that wood cannot guarantee (paddles were normally made from ash or fir wood), including the possibility to obtain new forms of wooden blades that were more efficient than standard ones. Despite the described difficulties, the manufacturers of wooden canoes & kayaks remained at the forefront for many years, developing innovative and competitive models, in some cases copied by other producers. Despite the higher number of canoes and kayaks made with synthetic materials in comparison with wood among practitioners, wooden canoes resisted at the highest level until the 1996 Olympics in Atlanta. In fact, comparing the number of kayaks that participated in the men's K1 Olympic finals (in both 500 and 1,000 m) in “Barcelona 1992”, 7 out of 9 finalists were in wooden kayaks, including the winners, in “Atlanta 1996” 4 out of 9 finalists were in wooden kayaks, again including the winners, while in “Sidney 2000” there were no wooden kayaks in the finals. This disappearance of wooden canoes was partly due to new models that "circumvented" the minimum width limit of the hulls (51 cm, a limit officially abolished in 2002) eliminating the classic enlargement in the back part of the boat behind the paddler, adding the so-called “horns” on the deck to reach the minimum width. In flatwater canoe & kayak this change marked a revolution in hulls, causing the substantial disappearance of wooden boats from competition fields at all levels. Furthermore, in those years the price difference between a wooden canoe and a fiber one was significant, a factor that favored the replacement process. Nowadays, it is possible to find some instruments made from wood in carbon fiber boats and the like, such as the seat and footrest, both normally made from plywood, without no recognized standard applied. To date, the use of wooden canoes & kayaks is mainly linked to amateurs and former athletes who do not give up the charm of a wooden canoe. If in a race at all levels it is quite impossible to find wooden boats, in rowing clubs it is easy to find a large number of wooden boats, and many rowers and paddlers use them. Considering aesthetics, most paddlers agree on the superiority of wood, and many of them dream of having a wooden boat to show off in their rowing clubs. In recent years, the historic manufacturer of wooden canoes Struer has signed an agreement with one of the largest producers of composite canoes in the world, and new models have been developed. The new wooden hulls seem to be competitive in the modern racing world (FIGURE 19.3).

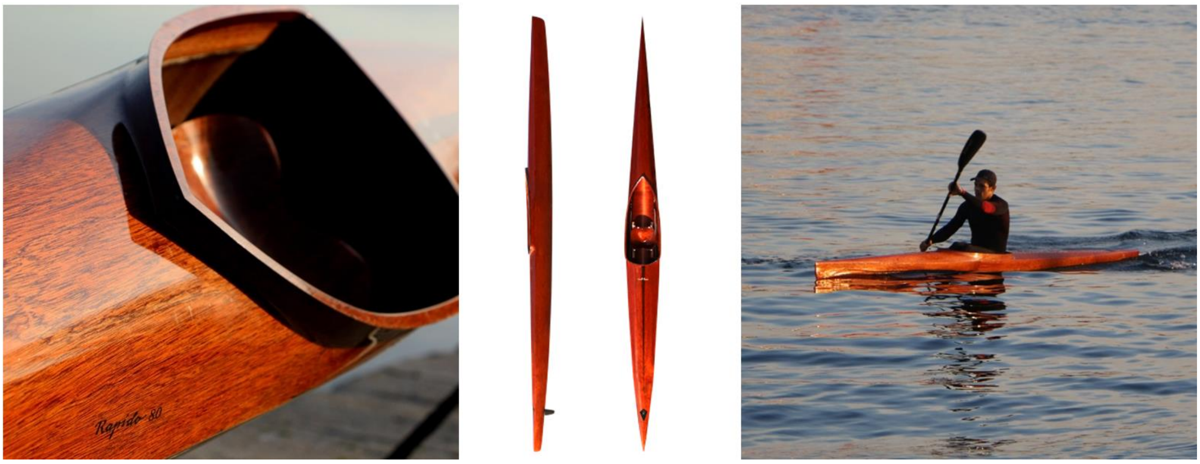

FIGURE 19.3 Example of a modern wooden K1 (image courtesy of Struer Kayaks & Nelo Kayaks).

As cited in the text, the production process of wooden kayaks has changed over time. As a reference, the modern kayak in FIGURE 19.3 is made of 4 wooden layers in the hull and 5 layers in the deck. Regarding the hull, the internal layer is 0.6 mm thick mahogany, as is the third one; between these two equal layers is a thicker 1.8 mm layer of obeche, while the external layer is again 0.9 mm thick mahogany. Looking at the deck, it is composed of four 0.6 thick mahogany layers, and an external layer of 0.9 thick mahogany. In the opinion of the writers, this meeting between wood tradition and technical innovation could lead within a few years to a new advent of wood in the world of competitions. Moreover, considering the increasing prices of composite materials in recent years, the cost of a wooden canoe could become competitive again. As an indication, a wooden K1 today costs around 5,000-5,500 euros, while a carbon fiber one costs around 4,000 Euro.

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Facing wood on the path

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THE WORLD OF CYCLING

Cycling is a vast world. To date, the disciplines encompassed by the Union Cycliste Internationale (UCI) are bicycle moto cross (BMX) freestyle (Olympic discipline since 2020), BMX racing (2008), cyclo-cross, cycling esport, cross-country Olympic mountain bike (MTB, 1996), mountain bike (cross-country marathon and eliminator, downhill, four-cross, enduro, snowbike), indoor cycling (artistic cycling and cycle-ball), para cycling (Paralympic discipline since 1984), road cycling (1896), track cycling (1896), trials; also, cycling is part of the triathlon (2000) [1,2]. The fact that track and road cycling were already present in the first Games of the modern era (Athens 1986) is evidence of the great tradition of the sport of cycling.

In addition, cycling is eco-friendly, a widespread means of transport, and in many senses a lifestyle. The benefits of including cycling in one's daily life are well known (Oja et al. 2011), and cover life expectancy, cardiorespiratory fitness, sleep quality, etc. In this regard it is emblematic that the World Health Organization explicitly mentions cycling in the flyer *Global recommendations on physical activity for health* (WHO 2011)[44].

Wood contributes in several ways to the realization of cycling tracks and arenas, as it is used to make boardwalks, obstacles, curbs, jumps, ramps, etc. The great variety of such possibilities is outlined as follows, whereas track cycling is covered in a specific chapter of this book.

ROOTS, OBSTACLES, BOARDWALKS JUMPS, RAMPS... AND COUNTING

Let us start this quick overview with the roots of standing trees that can be found for instance in downhill and cross-country MTB tracks. Extended wooden root systems are particularly challenging as their irregular shape makes an unpredictable surface even more complicated if they are slippery. Root systems can be intimidating indeed, and downhill competitive riders hop right over them when possible.

Apart from roots, wood is present in cycling tracks and arenas in the form of stumps, logs, timber beams, boards and panels. The MTB UCI Regulations (UCI 2022a) explicitly envisage the presence of "Obstacles such as trees, stairs (up/down), drops, bridges or wooden constructions" as well as "tree stumps" and "tree trunks". Logs or sequences of logs are for instance horizontally embedded in the ground in MTB tracks to create irregular, bumpy surfaces. Logs are also used as curbs to delimit and sustain the tracks.

Boardwalks and timber bridges are frequent in cross-country MTB, downhill, cyclo-cross and trials. Boardwalks are typically made of timber boards (or wood-based panels) fixed onto metal or wooden frames (Figure 20.1). Their surface can be plane, laterally curved as in parabolic curves, or made by one or more bumps. Their path can take different lines: straight, snaked, zigzag, two-split, etc.

[44] In a book dealing with sport, this seems like a proper place to mention that the World Health Organization recommends that all healthy adults aged 18-64 *"[...] should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week or an equivalent combination of moderate - and vigorous-intensity activity"* (WHO 2011).

In cyclo-cross, wooden planks are placed edgewise as obstacles. The cyclo-cross UCI Regulations (UCI 2021) prescribe that "[...] This obstacle must consist of two planks placed minimum 4 meters and maximum 6 meters apart and placed on a straight section. The planks must be solid for their entire height, without sharp edges and not made of metal. They must have a maximum height of 40 cm and extend the entire width of the course". Riders clear plank obstacles on foot or by "bunny hopping" them.

A typical image of cyclo-cross is also that of athletes facing steps made of rough sawn timber. Again, the obstacle is cleared in the saddle or on foot, depending on the course and on the depth of the steps.

FIGURE 20.1 Left: timber boardwalk installed in a downhill track in a mountain larch wood (image F. Negro). Right: jump in a downhill track, made of timber boards mounted on a frame fixed to horizontal logs (image F. Negro).

In trials, wood is largely used to make obstacles: stumps, logs, boardwalks and bridges are mixed to arrange the competition areas. According to the UCI building guide (2022b), the most commonly used wooden elements are: logs (straight, with wide branches, or fork-shaped, approx. 1.5-3 m long, 20-50 cm wide); railway sleepers (approx. 2 m long, 2-5 cm wide, 15 cm high); wooden spools (approx. 0.5-2 m high, 1 m wide); wooden structures (approx. 0.5-2 m high, 1 m wide), wooden alphabet letters (approx. 1-2 m height, 1 m wide). Their aesthetics is also considered by the above UCI guide that reports various examples of logs inventively painted and sculpted as animals, vegetables or crayons. The use of wooden wedges and battens is also envisaged to safely fix superimposed elements; wooden platforms can also be used to delimit the "neutral zones" in the competition area.

In BMX racing, the inclined plane of starting hills can be made of plywood panels, generally supported by metal scaffolding. Such structures are quite imposing indeed: according to the UCI regulations (2022c), starting hills shall accommodate tracks at least 10 m wide, must be at least 12 m long, and their height can reach 8 m in World Cup events. Smaller-sized inclines, just a few meters wide and long, are used as starting points of time trials in road cycling. As for the BMX racing tracks, the UCI regulations admit wooden surfaces for indoor events.

In BMX freestyle, ramps and the ground surface must be made of hard, even surfaces such as concrete or plywood, whereas the supporting structure can be made of metal or wood (UCI 2019). Thanks to its flexibility and mechanical performance, plywood (often painted) is in fact well suited for making the curved surfaces of ramps. The entire structure must be solid since it must withstand the force applied by bike landings. Thin metal sheets at the bottom of wooden ramps are recommended for smooth connection with the riding surface on which the ramps are mounted, and to prevent damage to wooden panels. Just to give the idea of the relevant dimensions, BMX freestyle parks can be 25 m wide and 40 m long, and even larger; some basic obstacles like “jump boxes” and “half pipes” are around 1.5 m high and 1-4 m wide. Wood is also used in “hitching posts”, elevated bars placed atop ramps to enable additional bike maneuvers. Portable and easy to assemble ramps, bumps and other difficulties are also available on the market. There are various models and shapes, an example being those made of plywood with grip resin finishing.

Finally, a quick mention of bicycles with wooden frames: many types are available on the market, from pedal-free for kids to various models for adults that are often presented as design objects.

CONSIDERATIONS ON WOODEN STRUCTURES IN CYCLING

The structures listed above vary from permanent, to temporary, and even to portable. They can be realized at different levels: by producers that place them on the market (i.e., in the case of prefabricated boardwalks or ramps), by professionals, or by amateurs. Several wood species are used, softwood timber being quite common; noteworthy is the possibility of using timber directly from the forests in which the tracks unfold.

In general terms, the choice of wood to make the cited structures is an affordable solution also considering that the extension of the tracks/arenas can be remarkable. Aesthetics has to be mentioned here as well, as timber elements fit well in the woodlands and fields in which cycling competitions take place.

It is worth noting that some of the cited wooden structures can be permanently installed in outdoor environments. Their service conditions can correspond to the Use Classes 3.1 and 3.2 of EN 335 (exterior, with wood above ground and exposed to the weather with limited or prolonged wet conditions), and/or to the Use Class 4 of EN 335 (exterior, with wood in contact with ground and/or fresh water). Such challenging conditions require to pay particular attention to preserve the structures from biodegradation, which of course is also relevant to assure the riders’ safety. Following are some of the main, general rules to be adopted in such cases.

First, wood with adequate natural durability or with modified, improved durability shall be used. Several design details are pivotal: for instance, regular maintenance and inspections need to be planned, as well as the possibility to easily replace the deteriorated parts. In this sense, the use of “sacrifice” elements is an effective way to preserve the main structure. Adequate slopes are necessary to avoid water stagnation, and drainage systems must also be realized. Parts in contact with the ground must be made of wood with suited natural durability, otherwise contact with the ground can be avoided by using metallic supports (zinc-coated or stainless fasteners and hardware are generally recommended for such structures). However, this is just a quick reference to the large theme of the design approach to wooden structures in exterior environments.

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The art of jumping wood

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EQUESTRIAN DISCIPLINES AND THEIR ORIGIN

Equestrian debuted in the Olympic Games in 1900. Three disciplines are now included in the Olympic program: dressage, eventing and jumping.

The origin of *dressage* goes back to Ancient Greece when it was practiced to enhance the cooperation between horse and rider, which was vital for their mutual survival in battle [1]. In dressage, horse and rider execute a series of movements that involve different horse gaits like trot and canter. Freestyle dressage is performed to the rhythm of music: it was added in the 1996 Olympic program and has had great success ever since. Horse docility and ductility are especially needed to perform dressage with precision.

Jumping originates from fox hunting, as riders had to jump the fences that were typically found in the English countryside [1]. In jumping, horse and rider must jump a series of obstacles without knocking them down or refusing the jump; the time needed to complete the track is also taken into consideration. Agility, accuracy and timing are key in this discipline.

Eventing has a military background, as it was intended to prepare officers and horses to the challenges they could likely encounter on their path [1]. It comprises three disciplines: dressage, cross-country and jumping, and is thus also referred to as the "equestrian triathlon". In *cross-country*, horse and rider go through the countryside facing various obstacles like tree trunks, fences and water stretches. The time required to complete the track, and jump refusals are considered in this discipline that requires both agility and stamina. Overall, eventing is the most complete discipline as it requires all the different skills needed in dressage, cross-contry and jumping.

In addition to their specific requirements, the above disciplines are based on a common element, which makes equestrian so fascinating: the harmony between horse and rider. The relationship between horse and man has a rich history indeed. The benefits that humans receive from dealing with horses are numerous and well-known, and include anxiety relieve, self-esteem enhancement, and hyperactivity reduction (Othani et al. 2017).

THE SURROUNDING ENVIRONMENT

This book focuses on sport items and playing grounds, yet a quick mention about the environment that surrounds equestrian sports is needed here. Equestrian sports are in fact played in a context in which the use of wood is particularly abundant. Wood can be typically found in fencing, judging boxes, stands, horse stables, etc. Wood shavings are often used as bedding for sport horses: compared to straw bedding, wood shavings are less dusty and irritating to horses that can suffer from allergies to straw dust. In addition to the technical reasons, the frequent use of wood is also due to the fact that it is in syntony with the natural environment in which the equestrian competitions take place.

A particular mention shall go to the use of timber in horse stables. Other than to their aesthetics, timber boards are popular for constructing stables because they can withstand powerful horse kicks. Wood also has good thermo-insulating properties that come from its porous structure. The use of timber boards and panels enables therefore to realize affordable stables with indoor conditions that contribute to the horses' wellness. Here it is easy to find a link with the psycho-physical effects that wooden indoor environments have on humans, a field of study of wood technology that is raising increasing interest (Alapieti et al. 2020).

DRESSAGE

Dressage competitions take place in rectangular, flat areas that are 20 m wide and 60 m long and are delimited by low white fences approximately 30 cm high (FEI 2022a). These are commonly made of timber boards, often of white painted softwood, that are laid edgewise and placed on white triangular supports made of plastic or wood. The above setup is the most frequent, however variations are possible: for instance the low fence may comprise two rows of boards, whereas the supporting elements can be short poles.

In dressage, as in jumping, wood can also be found on the terrain of the arenas in the form of shavings, often being softwood, that can be mixed with sand and stone meal. Limited dimensions of wood shavings are required to make sure they are harmless to the horses' feet.

CROSS-COUNTRY

Obstacles to be faced in cross-country originate from those that can actually be found in the countryside: mainly logs, fences, walls and stretches of water. Overall, wooden obstacles constitute the large majority of them. According to the rules of the Fédération Equestre Internationale (FEI 2022b), cross-country obstacles "must be fixed and imposing in appearance", and their height can reach 1.20 m in the Olympic Games.

Tree trunks and logs can arguably be defined as the most classic cross-country obstacles. It is indicative that they are often the first ones that horse and rider learn to jump. Large trunks and logs are placed horizontally along courses, directly on the terrain or on supports that are often made of timber. A great variety of sizes and shapes are possible, particularly when branches and roots are present (FIGURE 21.1).

FIGURE 21.1 Trunks with branches and roots are imposing cross-country obstacles (image G. Della Chiesa).

Given that cross-country is practiced worldwide, the wood species used to make its obstacles are typically those that grow in the geographical area of the course. Eucalyptus, pine, sweet chestnut and oak are some of the wood species most commonly used. Cross-country obstacles are traditionally built on site, but transportable and recoverable structures have become more frequent over the past years. Other than easing the preparation of the courses, they have the advantage of enabling proper maintenance. This is relevant since cross-country obstacles are exposed to outdoor conditions and can have parts in contact with the ground[45].

The shape and size of the obstacles used in cross-country are indeed boundless. As said, logs, fences, and walls are the most classic, however a great variety of typologies exist. Typical elements include pole stacks, natural engineering cribs, embankments enclosed by timber boards, and water stretches delimited by timber palisades (Austen 2021). Laurel hedges are also frequent. In this case wood can be found in its most primary form: still in the living plant. Artificial hedges are also created by putting sorghum brushes atop artificial obstacles.

Stones and small walls are other obstacles that derive from real countryside elements. Noteworthy, their top part has to be somehow covered with wood, for instance through the installation of a board. This is to safeguard horses, as impacts with wood are less traumatic than that with stone and bricks, which are harder and can provoke cuts more easily.

As for aesthetics, timber is generally shown in its natural form, and trunks and logs are displayed with bark (that clearly tends to crumble over the years). However, in recent years colors and fluorescent markers have been added more regularly. This is for aesthetic reasons and also because contrast in lightness helps horses in reading the obstacles (Paul and Stevens 2020). Overall, in addition to the previously listed typologies, modern courses also display several types of artificial wooden obstacles that have a great variety of colors and shapes. Just to name some: tables, benches, boats, sculptures, giant horseshoes, reproductions of traditional houses or castles, pole sequences, and so on (FIGURE 21.2). The decorative aspect regards not only the strictly intended obstacle, but also the elements that can be laid at its sides with aesthetic purposes.

FIGURE 21.2 Artistic obstacles are becoming more frequent in cross-country and contribute to conferring a pleasant aspect to the course (image G. Della Chiesa).

[45] The importance of a correct design of wooden structures for exterior environments has already been mentioned in the chapter on cycling, to which the reader can refer.

JUMPING

Wood is the material of choice for the different types of obstacles used in jumping. To name some of them, *oxers* are made of poles piled on two separate rails, placed at some width from one another; *rails* are made of stacked wood poles; *walls* consist of stacked blocks, where often wood is decorated in the form of bricks; *planks* are made of rows of timber boards placed edgewise and overlaid.

The poles used in jumping are obtained by lathe cutting and are commonly made of softwood. They are painted with alternating contrasting colors, both for aesthetic reasons and for providing a better readability to horses. The lateral supporting structures are generally made of wood as well, but synthetic materials have gained more space in recent years.

The density of wood is considered by track designers and obstacle producers. Lighter elements tend to fall easier and thus increase the difficulty of the obstacle, whereas heavier elements are steadier but also determine harder impacts. As for horse safety, the significant advantage of wooden poles over other materials is that they do not tend to break in case of impact, which could cause injuries to horses' legs. Their hardness and weight are also suited to avoid injures. Such aspects are considered by the rules of jumping of the Fédération Equestre Internationale: "Both the obstacles themselves and their constituent parts must be such that they can be knocked down, while not being so light that they fall at the slightest touch or so heavy that they may cause horses to fall or be injured" (FEI 2022c).

Great attention is paid to aesthetics, which is expressly considered by the FEI jumping rules: "The obstacles must be inviting in their overall shape and appearance, varied and match their surroundings" (FEI 2022c). Jumping obstacles have therefore lateral decorative components, typically made of wood or wood-based panels, that can take the most different colors and shapes: from classical fences up to artistic reproductions of vegetables, trees, toys, lighthouses, towers, cultural symbols, etc. (Figure 21.3).

Finally, jumping obstacles are made to be disassembled and stored after competitions, to avoid their exposure to exterior weathering. Winter days dedicated to repainting wooden obstacles are actually a familiar image in equestrian clubs.

FIGURE 21.3 Jumping obstacles are often characterized by large and colored decorative elements (image G. Della Chiesa).

WOODEN SADDLE TREES

The saddle tree is the supporting frame of the saddle. It must provide adequate resistance, fit both horse and rider, and distribute the rider's weight on a wide surface of the horse's back. Sport saddle trees are today made of different materials, including carbon fiber, plastics, fiberglass, and wood.

Wood is the material originally used for crafting saddle trees: indeed, the etymological meaning of "tree" in this term is "made of wood" [1]. Over recent decades alternative materials have emerged, nonetheless wood has maintained a role in the manufacturing of saddle trees. Wood is in fact relatively lightweight and suited to withstand - along with metal strengthening and reinforcement coatings - the relevant mechanical stresses applied to the saddle during riding and jumping. Bending loads are due to the rider's bumping on the saddle, whereas torsional forces derive from the horse's gait that warps the saddle. The flexibility of wood enables the absorption of adequate amounts of energy, thus minimizing the loads on the horse's back. In addition to the above aspects, wood is also appreciated for traditional reasons, and it is not rare that customers expressly require saddles with saddle trees made of wood.

The structure of wooden saddle trees can be divided into three parts (FIGURE 21.4): the arch is the front part that shall fit the horse's shoulders; the twist, in the middle, is made of separate elements to keep the horse's vertebrae free; the cantle is the rear part, wider to adequately support the rider.

Wooden saddle trees are typically handcrafted through articulated processes, which originates a multitude of possible shapes and constructive details. Several wood species are used based on the preferences and expertise of the artisans: beech, European nettle, poplar, and sycamore to name some. Layered compositions (i.e., pine and birch plywood) are often used to provide additional resistance and stability. Saddle trees are finished by applying a covering (i.e., rawhide or resin-coated dressing) and then embedded into the saddle.

Overall, saddles are valuable items whose cost ranges from around 500 € up to 2,000-4,000 € and more. The length of the service life of a saddle that clearly depends on the frequency and intensity of use, can extend to 10-20 years and more.

FIGURE 21.4 "Spring saddle trees" are made of a wooden frame reinforced with spring steel bars. The three-part structure is shown in this image: the arch is the curved part on the left; the twist is the hollow section in the middle; the cantle is the wider part on the right (image courtesy of Selleria Pariani).

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STILL FLEXING ON THE ICE

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INTRODUCTION

Wood plays important roles in many sports including ice hockey[46]. Hockey is believed to have originated with the First Nations Mi'kmaq tribe in the Maritime Provinces of Eastern Canada (Bennett 2018; Wu et al. 2003). The name hockey is believed to be derived from the French word "hoquet" or shepherd's stick and was later anglicized to hockey. The first organised hockey game reportedly took place in 1855 between British soldiers from Halifax, Nova Scotia and Kingston, Ontario, Canada. The first game with specific rules was reported in 1875 between students at McGill University in Montreal, Canada. Many other amateur teams emerged across the country and Lord Stanley of Preston the Governor General of Canada initiated the Dominion Challenge Cup which later evolved to become the Stanley cup. Originally given to the best amateur hockey team, it later shifted to the best professional team with the advent of the National Hockey League in 1917. Organized ice hockey is now played on every continent except Antarctica, but remains a national passion in Canada closely followed by the unique "sport" of curling.

The game incorporates elements of lacrosse, field hockey and, to a lesser extent soccer (football) except that it takes place with players wearing ice skates. The objective is to place a hardened rubber disk (or puck) into the opposing team's goal. Each team has six skaters on the ice at a time. One, the goalie, stays near that team's end of the ice and protects the goal. Three of the remaining five skaters are forwards and are expected to advance the puck to the other goal while the other two players are on defense. However, players (except for the goalie who can go no further than the center of the ice rink) can move anywhere on the ice. The player with the puck can be physically discouraged or "checked" by the opposing team. The game is fast moving and graceful at its best, but can also be violent as a result of the checking.

The most critical piece of equipment in hockey is the stick which the players use to advance the puck along the ice and shoot it past the opposing goalie (Hoerner 1989). Hockey sticks consist of a long shaft with a flattened blade at the bottom. The first hockey sticks were made of a single piece of timber which was hand carved and shaped. Historically, the first sticks were made by the Mi'kmaq, but the demand was soon too great and others began to manufacture sticks. Hockey sticks continued to be one piece until the early 1950's when the blade was created separately from the shaft. This made it easier to source materials and also allowed materials with different properties and grain orientations to be used for each element. The original blades were relatively straight, but three players (Stan Makita, Bobby Hull and Andy Bathgate) are credited with using heat to curve the wood blades which allowed for better control when taking shots, especially the slap shot. The trade-off with curving the blade is some loss of puck control but curved blades changed the game. The degree of curvature in the blade is limited (NHL 2021). While the blade can play a key role in puck feel when stickhandling, there are

[46] In line with the general approach of this book, field hockey is not considered here: even if differences with ice hockey exist, it has been chosen to avoid information that would be largely repetitive.

far fewer studies of this element of the stick (Gerbé 2017).

In the 1970's fibreglass overlays were used to both reinforce the wood and reduce weight and laminated veneers became more common for the shaft (Wu 2002). These advances resulted in more uniform sticks. At the same time, other innovations began to emerge with materials. Carbon fibres and aluminum began to be substituted for wood in the shaft to reduce weight and produce more uniform material properties. The NHL rules specify dimensions of the shaft and blade but not materials, leaving the field wide open for material innovation (NHL 2021).

At present, aluminum hockey sticks have taken over in the professional leagues, carbon fibre composites are commonly used, but wood is still widely used at the amateur levels. There remains considerable debate about the best material for hockey sticks. Several studies have compared the performance of wood, carbon fibre and aluminium sticks. A number of factors affect the quality of a shot including the velocity of the lower part of the stick as it strikes the puck, preloading of the stick (i.e. flexure related to stiffness), and puck contact time with the stick (Behrmann et al. 2014; Laliberte 2009; Pearsall et al. 1999, Vellaseñor et al. 2006; Worobets et al. 2006). Aluminum and carbon fibre are stiffer than wood in tension and torsion meaning that they have the potential to return more energy to the puck. Aluminum, however, has poor damping characteristics meaning that it transfers more vibration to the player, making it harder to "feel" the puck as the player stick handles. This property is important because a skilled player does not continuously look at the puck otherwise they risk being checked by the opposing defense. There is a definite "feel" to a good stick which likely reflects both its material properties and how closely they match the player skills. Composite and wood sticks have similar but better damping characteristics. Underlying these factors, however, is the skill of the player. A number of studies found no significant differences in performance of wood, composite, or aluminium sticks when player skill level was accounted for (Kays and Smith 2014, 2017; Roy and Dore 1979; Hannon et al., 2011; Hateni et al. 2001; Marino 1998; Marino and VanNeck 1992; Wu et al. 2003). The main disadvantage of wood over the other two materials was variability. Wood is inherently variable and this characteristic transfers into performance as a hockey stick. This is no doubt that some wood sticks are better than others in terms of feel and ability to return energy into the shot as the junior author sadly remembers when one of his favourite sticks broke.

Composite and aluminum sticks are far more uniform allowing sticks to be tailored for specific player attributes. This is more difficult with wood sticks. Aluminum sticks also allow the blade to be changed when it breaks.

The primary advantage of wood sticks remains lower cost, which is particularly important for newer players who are less able to take advantage of the performance attributes of composite or aluminum sticks. It is telling, however, that nearly all professional players now use either aluminum or composite sticks.

It is helpful to examine the attributes of a desirable material for a hockey stick. The shaft must be reasonably light but capable of flexing without failing when the player is shooting. There are two primary shots used in hockey, the wrist shot and the slap shot. The wrist shot involves the player moving the puck on the blade and flexing their arms to propel the push forward and, hopefully towards the net. The puck velocity on a wrist shot reaches approximately 20 m/s (70 kph), depending on the skill of the shooter. In this case, the shaft flexes back as the stick moves forward and the shooter flicks their wrist at the point of release to transfer the energy in the shaft to the puck. The more popular approach is the slap shot where the player draws their stick upwards and behind them and brings it down to the ice to propel the puck forward. Slapshots introduce more energy from the shaft to the puck and result in velocities of ~30 m/s (110kph). Stiffness becomes an important factor in a slap shot since the goal is to transfer as much energy as possible form the deflecting stick to the puck (Laliberte 2009; Pearsall et al. 1999; Villaseñor et al. 2006). Wrist shots tend to be more accurate while slapshots are less predictable and make it more difficult for the goalie to identify the pathway. Slapshots are also more exciting for spectators.

While wood hockey sticks can be composed of virtually any material, a number of factors make a given timber species more suitable for this use. Commonly used timber species in North America include ash, birch, maple, aspen, and willow (TABLE 22.1).

TABLE 22.1 Properties of timber species used to manufacture wooden hockey sticks at 12% moisture content (FPL 2010).

Common name	**Latin name**	**Specific Gravity**	**Modulus of Elasticity** (MPa)
Aspen	*Populus deltoides*	0.38	8,100
Willow	*Salix* spp.	0.39	7,000
Ash (white)	*Fraxinus americana*	0.60	12,000
Birch (Paper)	*Betula papyrifera*	0.55	11,000
Maple (Red)	*Acer rubra*	0.54	11,300
Maple (Sugar)	*Acer saccharum*	0.63	12,600

The latter two species tend to be used in composite sticks owing to their lower density. Their use in the shaft core is analogous to the use of lower density species in the cores of many wood-based composites that use stronger timbers on the outer tension and compression faces. A number of studies indicate that the most important properties for a good stick relate to the ability of the wood to efficiently transfer energy from the stick to puck to produce maximum velocity. Thus, stick flexibility, rather than composition, should be the key mechanical consideration since more flexible sticks can enhance both stick deflection and strain energy storage which is then released as the puck is driven off the stick (FIGURE 22.1).

As a result, the species commonly used for traditional wood sticks have similar densities and moduli of elasticities (where two groups can be distinguished: aspen and willow to provide low density, and other species). It is also interesting to note that most studies comparing wood sticks with either composites or aluminum sticks do not identify the wood species. This makes it difficult to determine if the variations noted between sticks reflect the inherent range within a species or differences between species.

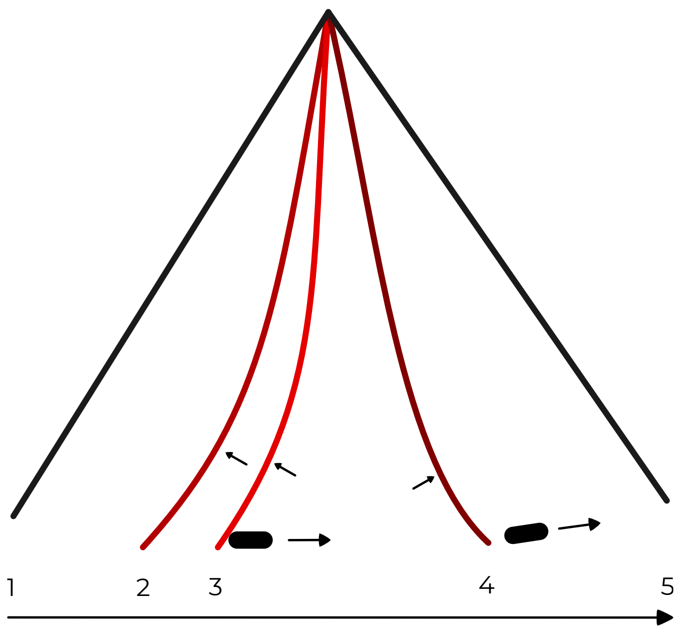

FIGURE 22.1 Representation of the deflection of a hockey stick as it is driven downwards towards the puck (1), strikes the puck (3) and transfers the energy in the stick to the puck to propel it towards the goal (image F. Negro).

FUTURE OF WOOD HOCKEY STICKS

The relatively lower cost of wood sticks makes it likely that we will continue to see wood used in this sport at the non-professional levels. However, aluminium appears to be here to stay in the professional ranks. One possible negative influence on continued use of wood will be the effects of the emerald ash borer (*Agrilus planipennis*) on supplies of ash. This invasive beetle has devastated ash stands through the South, Midwest and Northeast of the United States and extending upwards into Canada. This beetle threatens the continued availability of this resource for hockey sticks and other sporting equipment, notably baseball bats. Fortunately, for beginning hockey players, other species with similar attributes remain available meaning that future Wayne Gretzky's and Mario Lemieux's will have wood sticks to learn to play what is arguably the most amazing game on ice.

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Residual and minor uses of wood in sport equipment: a brief outline

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As mentioned in the Introduction, the current use of wood in sport equipment varies based on the discipline considered and can be described through an indicative four-step scale: (i) obsolete, (ii) residual or minor, (iii) well established, (iv) wood is the material of choice. Clearly, the above steps shall be seen as parts of a gradient where limits among steps are not exactly defined.

This book mainly deals with the upper part of the above gradient: sports in which the use of wood is well established, or wood is the material of choice. Sports in which wood has become obsolete are not considered by this book, save for some historical notes here and there, and for the chapters in the Introduction, on wooden tennis rackets and on golf.

The present chapter, instead, intends to take a look at the mid-lower part of the gradient. To this purpose, some cases in which the use of wood can be considered as residual or somewhat minor are presented.

ATHLETICS

Wood was common in athletics equipment until the 1940s-1960s, when other materials started to come on the scene. For instance, pole vaulting athletes, back to the modern origins of this sport in the 1850s, used ash or hickory poles with iron spikes in the end [1] (heaps of sawdust were used for the landing areas). Bamboo poles were used later, then steel appeared in the 1940s until fiberglass in the 1960s and later carbon fiber poles revolutionized pole vaulting. Similarly, at the beginning of the 1900s, javelins were mainly made of birch wood, and Nordic countries led their manufacturing (Borgström 2000). During the first decades of the 1900s, javelins started to be made of other materials that gradually replaced wood, as was the case in several other sports.

Today, the technical rules of World Athletics[47] envisage the use of wood for various equipment (World Athletics 2020, from which the following text is taken in quotes). The most relevant case is arguably that of wood in indoor tracks, although in this case wood is not directly visible. The Technical rules state that "The foundation on which the synthetic surface of the tracks, runways and take-off areas is laid shall be either solid e.g., concrete or, if of suspended construction (such as wooden boards or plywood sheets mounted on joists), without any special sprung sections [...]". Wooden foundations are indeed a common solution for indoor tracks, and in this case the use of wood can be considered not only minor, but indeed well established.

As for steeplechase hurdles, "The top bars shall be made of wood or other suitable material [...]". Bars made of laminated timber, typically softwood, are today available on the market (Figure 23.1). According to the Technical rules, such bars must have square sections of 127x127 cm and 3.94 m minimum length. Also, the thin top bar of hurdles (i.e., 400 m hurdles) can be made "of wood or other non-metallic suitable material [...]". However, in this case wood has been replaced by synthetic materials.

[47] Until 2019 the International Association of Athletics Federations - IAAF.

FIGURE 23.1 The shabby painting of this steeplechase hurdle clearly shows the laminate timber structure of the bar and is also a reminder of the need for regular maintenance of wood exposed to outdoor environments (image F. Negro).

The relay baton "shall be a smooth hollow tube, circular in section, made of wood, metal or any other rigid material in one piece [...]". Batons made of wood can be found on the market, and in some cases, they are eloquently described as "splinter free".

As for the discus, its body "[...] may be solid or hollow and shall be made of wood, or other suitable material, with a metal rim [...]". Discuses with a wooden body were common until the 1960s, and today some models made with a plywood body are still available on the market. Of note, overweight wooden discuses are sometimes used for training: they weigh up to 4 kg, whereas the weight of a competition discus is 1 kg for women and 2 kg for men.

The use of wood is also envisaged on the ground of athletics fields. Wood can be found in the take-off boards of horizontal jumps. These "shall be rectangular, made of wood or other suitable rigid material in which the spikes of an athlete's shoe will grip". Also, in case plasticine is used to determine null jumps, the plasticine supporting board can be made of wood.

Wood can also appear on the emplacements of throwing events. The rim of the throwing circle "[...] shall be made of band iron, steel or other suitable material [...]. The ground surrounding the circle may be concrete, synthetic, asphalt, wood or any other suitable material [...]. A white line 50mm wide shall be drawn from the top of the rim [...] painted or made of wood or other suitable material". In the javelin throw runaway "the throw shall be made from behind an arc of a circle [...] made of wood or a suitable noncorrodible material like plastic". Finally, in the shot put "the stop board shall be white and made of wood or other suitable material in the shape of an arc". Also, plywood throwing platforms are commonly used in indoor events.

A QUICK GLANCE AT OTHER SPORTS

Scrum machines used for training in rugby have padded stands that fit athletes shoulders allowing them to push, thus reproducing the scrum effort. The supporting structure of these machines is commonly made of steel, yet some types have a timber frame. Such machines can also have a rear platform, often made of timber boards or wood-based panels. The platform can be loaded to increase the overall weight that athletes must move. Do-it-yourself machines are also realized in practice, frequently using timber and pallets. Of note, rugby fields are also typically delimited by a fence, often made of timber, which separates the field of play from the spectator area.

In boxing, the supporting structure of rings is commonly made of a horizontal plywood platform screwed to a steel frame. The plywood platform (some producers indicate 18 mm thick) is covered with padding that is in turn overlaid with canvas. In such composition, plywood ensures a levelled, homogeneous and resistant structure, which is needed due to the loads applied by the athletes' weight and movement.

As for winter sports, bobsleighs, luges and skeleton sleds used in competitions are nowadays made of high performing materials such as fiberglass and carbon fiber. However, wooden sleds are still widespread in the market as recreational items, especially in some countries. Such sleds are typically made of ash wood, bent to shape to form the runners. Their shape can be traditional or modern, depending on the various models available.

The decks (inruns) of ski jumping trampolines were once made with timber boards (FIGURE 23.2). Timber in trampolines is nowadays obsolete, also due to the dimensional variations to which it is subjected. Modern trampolines have ceramic rails with integrated cooling systems that maintain a uniform layer of ice. The high precision achievable by this system is also relevant for safety purposes. Nowadays, wood in ski jumping can still be found in judge's towers. In fact, wood is still present in various winter sports, if not as sport equipment, then in the surroundings of the competition field. For instance, timber is used in the above-mentioned judge's towers, in alpine ski starting gates, in roofing and external coverings of bob tracks, and in similar applications. In such cases, wood is often used because it is in syntony with the open-air environment in which the events take place, as is the case in golf and equestrian (see the relative chapters).

Other examples could be mentioned about minor or residual uses of wood in sport equipment, however, it is not the purpose of this chapter to provide an exhaustive list which, leaving aside the challenge of covering all uses, would result repetitive.

FIGURE 23.2 The ski jumping trampoline of Cortina d'Ampezzo, Italy, used during the 1956 winter Olympics. The inrun was covered by timber boards, in turn covered with snow and ice. Disused since 1990, today it remains a relevant historical monument (image courtesy of Servizi Ampezzo Unipersonale S.r.l.).

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Aiming for victory

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INTRODUCTION

Shooting is amongst the original nine disciplines of Athens 1896 and since then with the only exceptions of St Louis 1904 and Amsterdam 1928, it has always been featured at the Summer Olympics. The sport, governed by the International Shooting Sport Federation (ISSF), consists of aiming at a target with a man-portable gun. Three weapons are featured in the Olympics (Figure 24.1): rifle, pistol, and shotgun, for a total of fifteen different events, each one defined by a specific set of rules. The first two are indoor disciplines and involve shooting at stationary targets, while the third one is performed outdoors, and targets are thrown in the air.

Figure 24.1 Wooden and non-wooden materials are assembled to produce rifles with optimized performance in terms of accuracy, maneuverability, ergonomics, balance, etc. (image courtesy of Armi Perazzi).

A BRIEF HISTORY OF FIREARMS

The first weapons resembling modern guns appeared in China during the 10th century and underwent further evolution in the 15th century, when the first small arms were introduced, up to the 16th century, when the pistol appeared. Thanks to its effectiveness, this rather light, compact, and easily to handle weapon, became one of the best-known firearms, and underwent numerous evolutions over the centuries, including the introduction of semi-automatic pistols at the end of the 19th century.

Wood accompanied the history of firearms, representing the material of choice for stocks and grips at least until the mid-1960s when Chet Brown created the first fiberglass stock. After the establishment in the 1980s of Fibermark, the first synthetic-stocked rifle factory, many mixtures of graphite, boron, fiberglass, urethane, plastic, and other materials called “composites” have been introduced. Although these alternatives have earned the favor of many, traditional wooden stocks are still valued by several collectors and professional shooters who prefer wood to more recent but cold synthetic materials.

Shooting demands precision and focus. Sport weapons not only differ from firearms regarding their intrinsic ballistic qualities but above all because they must be equipped with a customized butt. This component, also called a stock, represents the link between man and weapon and is essential to improve performance, settings, and balance. It allows the shooter to feel the weapon as an extension of his own body and is also critical in cushioning the weapon recoil.

WEAPONS IN OLYMPIC SPORTS

Shooting

Shooting is a centuries-old sport that enjoys great popularity in many countries. After the foundation in 1859 of the English National Rifle Association, and in 1871 of the USA National Rifle Association, in 1896 the sport was featured in the first edition of the Modern Olympic Games in Athens. The Olympic format currently includes four different disciplines in which athletes must fire at stationary targets at different distances and with various rifles or pistols, depending on the specialty. In detail, the events are 50 m rifle 3 positions (kneeling, prone and standing; men and women), 10 m air rifle (men, women and mixed), 25 m rapid fire pistol (men and women), 10 m air pistol (men, women and mixed), for a total of ten events.

Trap and Skeet shooting

These two disciplines differ from the previous one in that athletes must shoot moving targets and the weapon is a shotgun. The origin of trap shooting dates to the 19th century as a practice for bird hunting and it consists in hitting targets traveling away from the athlete, shot in the air at varying angles that are unknown to the shooter. Skeet shooting is instead a more recent sport, developed at the beginning of the 20th century to better simulate real bird flight and it consists in hitting two targets crossing one other. A third discipline called double trap, where two targets are launched at the same time, was featured from 1996 to 2016 but was removed prior to Tokyo 2020. Five events are therefore currently featured: trap (men, women and mixed), and skeet (men and women).

Biathlon

The use of a weapon characterizes a winter Olympic sport too - the biathlon, which is in fact composed of two specialties: rifle shooting and cross-country skiing. This discipline, the origin of which traces back to 1797 amongst Norwegian and Swedish troops, made its first appearance at the 1960 Winter Olympics held in Squaw Valley (CA, USA) as a successor of another Olympic discipline, the Military patrol, which was a combination of cross-country skiing, ski mountaineering, and rifle shooting. Military patrol was actually part of the official Olympic program only once, in 1924 (Chamonix, France), while it was featured as a demonstration sport in 1928, 1936, and 1948.

Nowadays five disciplines are included in the Olympic program: individual (men 20 km and women 15 km), sprint (men 10 km and women 7.5 km), pursuit (men 12.5 km and women 10 km), mass start (men 15 km and women 12.5 km), and relay (4 x 7.5 km men, 4 x 6 km women, 4 x 6 km mixed), for a total of eleven events.

WOODEN RIFLE AND GUN STOCKS

In the vast field of firearms, and more specifically of sporting weapons, identifying the most appropriate woods is not so obvious. Although it can be a matter of personal tastes, a few characteristics are undeniably desirable for a high-grade gunstock: resistance, great dimensional stability, and appropriate weight and grain direction. Moreover, it must also have little to no fissility, as well as smooth and homogeneous surfaces showing a pleasant color and grain (TABLE 24.1). Traditionally, quarter-sawn blanks are preferred since they guarantee the same figure on both sides of the stock.

Walnut is, without doubt, the most popular gunstock wood ever (FIGURE 24.2), more precisely, the two closely related species *Juglans regia* (European or English walnut) and *Juglans nigra* (American or black walnut). The former is considered easier to work and to finish than the latter and can present highly decorative and sought after marblecake assortments, so called because of their characteristic dark striped figure. The latter has a more variable color, often with red, yellow, green, or purple hues, it is harder and has the tendency to make short, broken curls when planed (Shifley 2004).

FIGURE 24.2 Rifle stocks are made starting from pieces of solid wood that often have particular figures to confer a unique aesthetic appearance to the rifle (image courtesy of Armi Perazzi).

Amongst the numerous other temperate types of wood able to guarantee durable stocks are: oak (*Quercus* spp.), olive (*Olea europaea*), boxwood (*Buxus sempervirens*), elm (*Ulmus* spp.), chestnut (*Castanea sativa*), juniper (*Juniperis communis*), yew (*Taxus baccata*), cypress (*Cupressus sempervires*), larch (*Larix* spp.), cedar (*Cedrus* spp.) (Benson 1960). Other ones considered of medium duration are fir (*Abies* spp.), pine (*Pinus* spp.), douglas fir (*Pseudotsuga menziesii*), thuja (*Thuja* spp.), cherry (*Prunus* spp.), ash (*Fraxinus* spp.), hornbeam (*Carpinus* spp.), mulberry (*Morus* spp.), black locust (*Robinia pseudoacacia*). Finally, fewer durable types of wood are found too, such as maple (*Acer* spp.), alder (*Alnus* spp.), beech (*Fagus sylvatica*), plane tree (*Platanus* spp.), horse chestnut (*Aesculus* spp.), lime (*Tilia* spp.), willow (*Salix* spp.), birch (*Betula* spp.).

TABLE 24.1 Mechanical properties of wood used in the production of stocks for firearms.

Wood Species	**Mean density** (kg/m³)	**MOR$_{Longitudinal}$** (N/mm²)	**Janka Hardness** (N)	**Shrinkage** (%)			**Wood durability** (EN 350)	
				Tangential	Radial	T/R ratio	Fungi	Beetles
E. walnut*	650	111	5,410	7.5	5.5	1.4	3	D
B. walnut**	610	100	4,490	7.8	5.5	1.4	3	n/a
Bubinga*	920	137	10,930	7.9	5.5	1.4	2	D
B. Cherry*	620	95	4,630	7.1	3.7	1.9	5	ND
E. Beech*	730	111	5,900	11.6	5.7	2.0	5	ND

* Ruffinatto and Cantarutti 2021; ** AA.VV. 2016; n/a = insufficient data available.

Several tropical woods are used as well, some of them being very heavy and fairly expensive. One notable example is bubinga (*Guibourtia tessmannii*), a stunning African timber with exceptional working properties and dimensional stability.

Even if a timber's aptness to produce stocks does not rely on its mechanical properties exclusively, it is of undeniable importance to choose it according to the weapon cartridge power. For instance, while most timbers are suitable for kicking guns equipped with 0.22 Long Rifle or 0.22 WRFM cartridges, it may not be advisable to use a relatively low-density wood such as American black walnut in presence of cartridges more powerful than a 0.243 Winchester or, at most, a 7x57. However, it should be noted that wood species with higher breaking loads than American and European walnut, such as beech, ash, and oak, may still show less service life duration than expected due to fissility.

INNOVATION IN WOODEN STOCK PRODUCTION

Although many companies specialized in the production of wooden stocks are at an artisanal level, a wide range of CNC machines intended to produce firearm parts are nowadays available, an utterly qualified field of application for this type of technology indeed. Modern numerical control technologies cover every stage of the production, from the first processing of raw wood pieces to the milling of mechanics' seats and the final customization and turning of the external surfaces. Pieces produced with this type of technology, whether they are rifle butts or sculpted parts, are already perfect in every detail and ready for the last finishing touches such as sanding and finishing. On the other hand, many people still prefer the feel and look of handcrafted custom-made wooden stocks. A recent innovation is represented by wood-aluminum stocks, which, thanks to their good adaptability to each shooter characteristics, are meeting the favor of a growing number of people.

CONCLUDING REMARKS

Within the vast array of sport firearms employed in the different shooting disciplines, each one being characterized by specific characteristics and purposes, wood is undeniably amongst the most featured materials. Whether manually handcrafted or built with the aid of modern CNC technology, wooden stocks are still preferred by many professional athletes to ensure the best feeling of the weapon, as well as an unmatched aesthetic appeal. This is the reason why after centuries, wood still represents a material of choice in the production of not only sport weapons but firearms at large.

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Keeping feet on the wood

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ABSTRACT

Skateboarding has been around since the 1960s and has always been a popular alternative sport. With its inclusion in the Olympic Games, there is new focus on this sport and the production of skateboards. Among many materials, wood is an excellent choice because it has a suitable compromise between energy absorption, flexural strength and weight, making it a resilient, light and strong material that is sustainable and recyclable at the same time. In this chapter the history and the physical, mechanical and aesthetic properties of wood in the construction of skateboards are presented.

INTRODUCTION

This chapter is a review of the wood properties related to the skateboard, as of some of its characteristics, such as physical, mechanical, and aesthetic appearance, which are featured in skateboard manufacturing. The inclusion of skateboarding in the Olympic Games in Tokyo by the International Olympic Committee in 2016 legitimized skateboarding culture among the values shared by the high Olympic competition (Batuev and Robinson 2017). The article of Forbes (2019) cites that the global skateboard market is expected to reach a value of 2.4 billion USD by 2025, with an estimation of 100,000 boards being made per month, showing the importance of this sport for the wood industry.

The species typically used for the manufacturing of skateboards are *Acer saccharum*, *Fagus sylvatica* and *Betula pendula*, but there are alternative woods that have the potential to also be used in a sustainable way (Fotin et al. 2016, Liu et al. 2018, Sýkora 2021). Table 25.1 shows the most common materials used in skateboard production, highlighting their technical advantages and limitations as sustainable materials, and comments on their "pop" (the striking of the tail of the board against the ground to propel it upwards to do tricks). In general terms, wood is becoming more and more relevant thanks to the growing attention towards sustainability and recyclability, although the Olympic rules do not have material limitations (World Skateboarding Commission 2021). Reinforced composites with carbon or glass fibers improve the specific strength and stiffness and give higher durability to the skateboard (Endruweit and Ermanni 2002).

A skateboard is a well-researched device, used in competitive sporting events, with the recent Olympic Games as a prime example. Models on the current market are based on how the skateboard was created in its early days, as a simple wooden board with 4 wheels made of clay. Nowadays, they are usually manufactured from a deck of plywood and 4 steel wheels. The standard length is about 70 to 82 cm, and the structure can be divided into three parts: the front (also called nose), the wheelbase (the part between the trucks in the board) and the rear (tail of the skate), as shown in Figure 25.1. The deck structure could look like a simple remanufacture, but it must meet physical-mechanical requirements to support the weight of the skater and the skater's jumps during the typical maneuvers of a competition.

TABLE 25.1 Common skateboard materials (adapted from Waterman and Crease 1978).

Material	Advantages	Limitations
Wood laminates	Good compromise between strength and tailored construction. Recyclable. Relatively cheap.	Delamination. Heavy. Less durable pop.
Carbon fiber or glass fiber	Very-good compromise between strength and tailored construction. Durable. Light. Durable and quicker pop. Moisture proof.	Reduction in sustainability and recyclability. Expensive.
Reinforced wood laminate (carbon fiber, glass fiber, metal)	Good compromise between strength and tailored construction. Durable. Longer durable pop.	Some reinforced parts need longer time for biodegradation as a sustainable recyclable material. Relatively expensive.

Thus, it is necessary to develop an engineered structure that prevents deck failures or deformations: this is why the use of high-quality wood, and a proper design is required. Among the challenges of deck design, a relevant one is finding a suitable compromise between energy absorption, flexural strength and weight. In other terms, the deck must be resilient, light and strong at the same time. It cannot be too heavy, because this would limit the skater's maneuvers and would not be able to cushion the jump impact; neither too flexible, because in this case it would destabilize the skater during jump maneuvers. To meet such characteristics, the chosen wooden species, such as for example *Acer saccharum* (Ansell 2015), must give the skateboard a lightweight, compliant and impact tolerant structure.

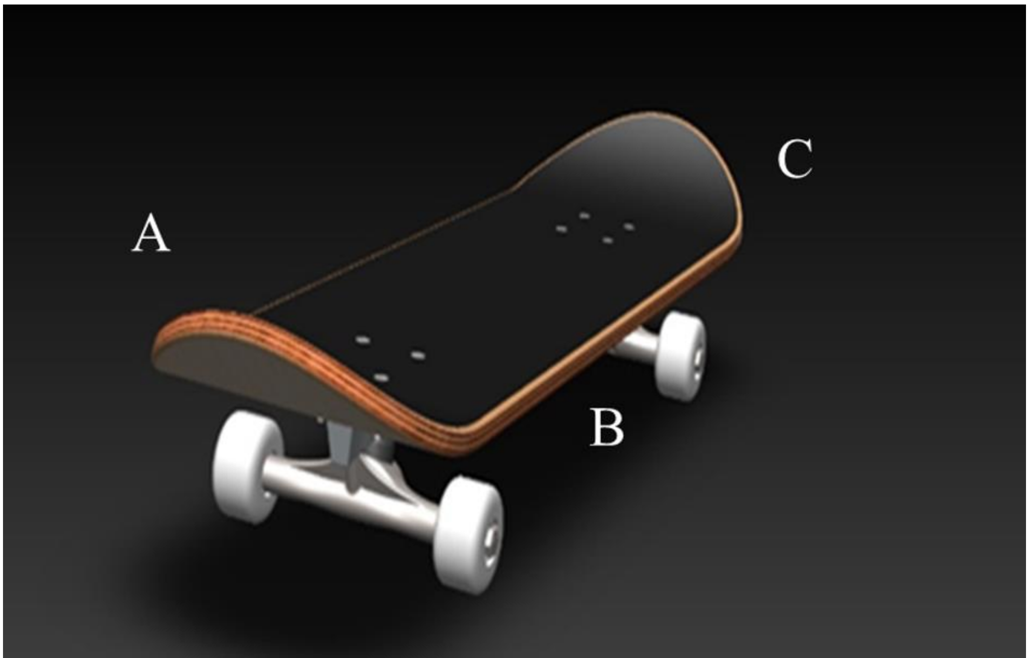

FIGURE 25.1 Example of a standard skateboard available on the market. A: Front part (nose). B: Wheelbase. C: Tail end (rear of the skateboard) [image J.A. Torres-Mella].

Color and graphics are also key to a good skateboard deck. A quality spray finish improves the aesthetic appeal, as does well-executed artwork intended to make skateboards look good (Waterman and Crease 1978). The shape will be slightly different depending on the envisaged use: for tricks or for cruising in the streets. Overall, a well-designed deck will be strong and incorporate a quality finish. Decks made of wood are manufactured with veneers, two for both faces of the deck (top and bottom), and the remaining for the core of the skate. Clearly, veneers that constitute the bottom and the top of the skateboard deck are important in terms of aesthetic appearance (Willard and Loferski 2018).

Last but not least, from a circular economy perspective the wooden components of skateboards that have been damaged or are at the end of their life cycle are well-suited for cascading usage and could be recycled for manufacturing new plywood products (Willard and Loferski 2018).

WOOD AND ENGINEERED WOOD-BASED PRODUCTS FOR SKATEBOARDS

Since the early 60s, wood has been an important material for the construction of skateboard decks. The first manufacturers used a solid flat wooden board. However, solid wood is not an ideal material for this purpose due to its rigidity/flexibility and, moreover, its use results in excessively thick and heavy decks. During the 1970s, innovation occurred in the construction of skateboard decks: the maple laminated construction enabled easy manufacture granting weight reduction, greater rigidity, strength, lightness and durability (Borden 2019).

At present, the skateboard deck is an engineered wood product that has evolved considerably over the years. To make a skateboard deck, layers of thinly cut wooden (known as veneers) are used based on the plywood technology. This involves the use of crossed veneers, which means the orientation of the veneer between layers alternates in order for the product to have sufficient strength in both directions of the plane. Any type of veneer would be suited for the manufacturing of a skateboard deck, however the best one for this application and the most used is the rotary cut veneer (Sýkora 2021).

The wood used to make skateboards requires certain important properties such as flexibility and strength because during use the deck is subjected to deformations and stress, mainly bending strains. Sugar maple (*Acer saccharum*) wood is the most used to manufacture skateboard decks: its hardness, lightness, density, and the possibility of obtaining veneers free from knots or defects make it especially suitable for skateboarding. According to Fotin et al. (2016), it is also possible to use beech and birch plywood for manufacturing skateboards, and the plywood of these species could even replace sugar maple wood. Marangon (2018) evaluated the quality of ten types of commercial skateboard decks with different combinations of wood, adhesive and reinforcement. The deck of seven sugar maple veneers with epoxy adhesive showed the best performance. An alternative is to use bamboo plywood, which is interesting due to its elasticity and hardness. Because it is very brittle, it needs fiberglass reinforcement or to be combined with sugar maple veneers (Linke 2011, Fotin et al. 2016).

A report by Liu et al. (2018) indicated that an ideal material for a skateboard deck shall have a fracture toughness of 5 MPa/m^2, a minimum lifetime of 10,000 cycles and must not experience brittle fracture, while maintaining an ideal weight.

Skateboard decks are mainly subjected to bending strain: whether they are made of plywood or other wood-based materials, the determination of the modulus of rupture (MOR) and modulus of elasticity (MOE) is recommended (Fotin et al. 2016) to test them. Some physical-mechanical properties of the most used wood species in skateboard manufacturing are given in Table 25.2.

TABLE 25.2 Physical and mechanical properties of wood species commonly used in skateboards (wood at 12% moisture content).

Wood species	**Density** (kg/m^3)	**MOE** (GPa)	**MOR** (MPa)
Acer saccharum	597[1]-700[2]	10.7[1]-12.4[2]	113.2[1]-123.6[2]
Fagus sylvatica	608[3]-632[4]	9.7[3]-10.9[4]	56.2[3]-104.3[4]
Betula pendula	512[3]-799[5]	9.6[3]-14.5[5]	58[3]-114[5]

[1]Duchesne et al. (2016). [2]Uzcategui et al. (2020). [3]Fotin et al. (2016). [4]Papadopoulus (2008). [5]Heräjärvi (2004).

CONSTRUCTIVE DETAILS OF WOODEN SKATEBOARDS DECKS

Veneers are commonly used to make plywood skateboard decks. For the manufacture of a skateboard deck, seven veneers of approximately 1.6 mm thick are used in most cases. Typically, three types of veneers can be distinguished: face (top and bottom of the deck), longitudinal, and perpendicular. The importance of the seven-layer composition is related to the strength it provides thanks to the orientation of the fibers of each veneer. Face and longitudinal veneers are oriented in the wood grain direction from nose to tail, where the face veneer is also selected based on the aesthetic qualities of the wood and is usually of a high-quality grade. The perpendicular veneers have, as the name suggests, perpendicular grain orientation, so they support the deck to uphold its concavity (Willard and Loferski 2018). Veneers are therefore layered in the following sequence: face (top), longitudinal, perpendicular, longitudinal, perpendicular, longitudinal, and face (bottom). There are five sheets oriented along the longitudinal direction: this is due to the fact that such direction has to withstand the greatest loads during use, particularly the bending stresses (Willard and Loferski 2018). The above composition helps to strengthen the board, which in turn prevents it from twisting. The main glue types used for the manufacturing of decks are polyvinyl acetate, polyurethane, and epoxy resin (Sýkora 2021).

PRODUCTION OF SKATEBOARDS

The deck flexibility varies, along with the wheels and their truck mountings, to adapt to the end use of the skateboard. To make it more stable and speedier, the deck is made stiffer; to use the skateboard for slalom, the board is usually made more flexible. The maneuverability, speed and stability of the skateboard, while retaining these properties when it is being used, will depend on the precise construction and processing of the components used to produce the deck (Waterman and Crease 1978).

To manufacture a deck, the universal constant is the pressing and forming of laminated veneers to generate what is called a deck blank (Linke 2011). Typically, the direct pressure (hydraulic system) is used. Molds are used to obtain the form of any kind of skateboard (longboards, cruiser boards or street decks), and to generate the characteristic upswept nose, tail, and the concavity of the skateboard. The molds are usually made from wood, concrete, metal (aluminum) or plastic. They can also be made utilizing computer numerical control machines utilizing a 3D model sketch to produce precise molds (Sýkora 2021). Vacuum mold compression is an alternative way to produce decks. It uses a foam mold made from high density foam, in which the veneer is placed and glued on top. A plastic sleeve is placed over the mold and the veneer, so that a vacuum pump can remove the air to compress the veneer over the mold (Linke 2011).

After producing and curing the blank deck, the truck holes are drilled (they vary depending to the final form of the skateboard), followed by cutting it to the final form, routing the edge, sanding the surfaces, lacquering, painting and staining (if desired). Finally, the deck is taped and assembled (Linke 2011, Sýkora 2021).

Failures of skateboard decks can be separated into three categories: focused, in which the fracture occurs when the board breaks right in the middle; delamination, which occurs when the sheets of wood detach from each other weakening the structure of the board. That can be caused by bumps on the edge of the board, the wear on the ends of the board due to excessive friction against the concrete, or fatigue from use; and shaft fracture, caused by the consumption of the material due to the constant use of the skateboard (Contreras et al. 2016).

COSTS

Liu et al. (2018) indicates that a price of $300 USD for a deck using alternative materials (carbon fiber) should be the limit, while Linke (2011) mentions that the average price of a wood skateboard is 70$ USD. Online resources mention that longboards can cost between $60 to $500 USD, classic cruiser skateboards between $60 to $400 USD and street skateboards (used mostly for tricks) cost from $70 to $200 USD. These prices can be taken as a rough reference when producing skateboard parts with alternative materials.

SKATEPARKS

Skateparks are built using a variety of materials, ranging from concrete, steel, phenolic wood fiber composite or wood. For our interests, we will focus on the skateparks made only from wooden materials. Usually, it is feasible to build a halfpipe, a ramp or a pyramid out of wood. The biggest advantage of using wood is that it is easier, faster and cheaper to build, but the maintenance cost of a wooden skatepark is higher than the other materials (Pender 2010); it can be relocated and adjusted, thus is mostly used for home and mobile skateparks (FIGURE 25.2).

FIGURE 25.2 Skateparks in a public open space of Santiago city (Chile), with a mobile fast ramp manufactured by radiata pine plywood (picture with permission of Castro-Aedo, 2021).

CONCLUSIONS

Wood in skateboarding has become relevant because it is the material chosen by skaters for competing in the recent Olympic Games of Tokyo 2020. Some physical-mechanical characteristics of wood, as well as its aesthetic appearance are relevant in skateboard manufacturing. The species that have usually been used for the manufacture of skateboards are *Accer saccharum*, *Fagus sylvatica* and *Betula pendula*, since they can provide the best compromise among the aesthetic quality, physical-mechanical properties and sustainability.

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Two wooden planks and a passion

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SKIS: AMONG THE OLDEST WOODEN OBJECTS EVER FOUND

Modern skis and snowboards are highly engineered, multi-material products[48]. Merriam-Webster defines the word ski as coming from the Old Norse word skíð, which means "cleft wood", or also "stick of wood", or simply "ski". The English language kept the original Norwegian spelling ski, with only the pronunciation being modified. In German, the spellings Ski and Schi are in use. Other languages use "ski" in a similar way. Historically originating from geometrically simple slats of wood, the shape as well as material utilization and composition have changed drastically since a suggested first recording of skis dating back to 8,000 BC, from the Altay region, China (Dresbeck, 1967; Truong et al., 2020). However, the earliest well documented traces on skis come from northern Russia. They were discovered in the 1960s by Grigoriy Burow, a Ukrainian archaeologist, at an excavation site called Vis. The ski fragments found dated back to 6,000 BC, belonging to the Mesolithic era. The fragments found are among the oldest wood objects ever to be found (Huntfort 2008). The Salla ski, named after the municipality in Finland, as one of the first well documented objects used for skiing, dates to over 3,000 years B.C and was made entirely - apart from the strapping mechanism- from pine wood (*Pinus sylvestris* L.) and did not feature any camber or curved tips. A later object from Mantta, Finland, dated to about 542 AD, was also constructed from pine and featured relief carvings on the top that induced the upward curving of the tips, thereby facilitating the ability of the ski to float on the snow as opposed to diving beneath the surface (Formenti et al., 2005).

Several centuries thereafter saw the use of an asymmetrical setup (Figure 26.1), with one ski serving as the main gliding portion and the other shorter one as the means to propel the skier forward by pushing. This necessitated a stronger grip against the snow on the underside, which was achieved by animal skin, therefore establishing a first "multi-material".

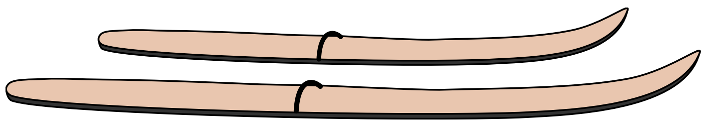

Figure 26.1 Asymmetrical skis, as those outlined here, were used by the Saami people of Northern Scandinavia, who are widely credited with being major inventors of skis, known since the Early Middle Ages: the Saami people were known as the "ski going people" (image F. Negro/R. Wimmer).

WHY USE WOOD?

Wood is highly anisotropic, and it exhibits good strength and flexibility in uniaxial tension but has rather poor torsion strength. Wood is also sensitive to humidity and absorbs moisture, which increases the weight and reduces strength, causing potential distortions. However, wood continues to be an important material in ski making because of its specific modulus, i.e., modulus/density, which is comparable with steel, aluminum and titanium. Like most natural structural materials,

[48] This chapter mainly focuses on alpine skis. Other types of skis are not considered, and snowboards are briefly treated in the Appendix: even if differences exist, it has been chosen to avoid information that would be largely repetitive, in line with the general approach of this book.

wood has a cellular structure providing low density and high strength properties. To this day, no synthetic material can match the sensitivity of wood when used in skies. In former times, wood needed no wax in midwinter conditions, and different wood species were able to cope with the harsh conditions. For example, the Norwegian explorer Roald Amundsen (1872-1928) used hickory for his skis, as to his knowledge this species was the best material performing at low temperatures.

As mentioned, the great drawback of wood is the sensitivity against moisture, which required protection against water rising from snow (Huntford 2018). Historically, pine pitch was the first ski wax, which was used until the 20th century. The convex shape of skis was crucial for good performance, especially when the snow became wind compacted. Compression wood was used, formed on the lower side of leaning and twisted tree stems of conifers. The specific inclusion of compression wood made the planks naturally bent, with the wood also being tougher, hard wearing, but also more brittle. For that purpose, pine has frequently been used in early ski making. Later, wood species such as birch, ash, beech, basswood, or spruce were used, among others (Petutschnigg et al. 2013).

BECOMING A MULTI-MATERIAL PRODUCT

The end of the 19th century saw rapid development in competitive and recreational skiing and correspondingly advancements in technology. With the international popularization of the telemark ski by Sondre Norheim in Norway around 1870, which instead of being of uniform width, featured a curved profile, thus enabling the telemark technique, requirements for even tougher timbers grew. Hickory from North America was imported, and thinner, more flexible skis could be manufactured. In 1893 H.M. Christiansen constructed the first two-layer wood laminate utilizing light species such as basswood or alder for weight reduction, and hickory for strength and abrasive resistance, bonded together by hide (animal) glue. This was further improved by the more water-resistant casein glue, and a 3-layer build-up with a core of vertically oriented, laminated wood strips for further stabilization (Masia, 2003). Alternative materials started gradually replacing wood. In 1928, Austrian born Rudolf Lettner used steel edges and improved the grip and wear resistance of ski edges in the steep alpine terrain (Fry, 2008). Further improvement of the gliding portion of the ski was made possible by the utilization of polymers, such as Bakelite (a phenolic resin) or cellulose-based plastics (marketed as *Cellulix*) that were slicker and less permeable to water than wood, as well as being better substrates for waxes. Introduced in 1962, the gliding layer, which represents the modern state-of-the-art technology, is made of high-molecular weight polyethylene. The introduction of the composite sandwich construction and the advent of synthetic adhesives further replaced wood.

In 1945, Vought Aircraft, USA, introduced the first laminated ski made from aluminum and a wooden core. In 1946, Gomme Ltd., UK presented the first plastic-laminated ski that had a high modulus of elasticity surface layers, and a wood core. Further development even eliminated wood, as in 1947 by Howard Head, USA, with an aluminum sandwich construction and a resin-impregnated honeycomb core. Or the Alu 60, a two-layer hollow ski construction, made by TEY Manufacturing (Masia, 2004). With fiberglass, carbon, ceramic or Kevlar reinforced resins becoming available throughout the second half of the 20th century, classical wooden skis with a monolithic structure vanished from the market.

MODERN SKIS AND THE ROLE OF WOOD

Contemporary ski constructions and material compositions have been subdued to various technological advancements that propelled a gradual decline of the importance of wood as the main structural component of a ski. However, wood has retained some of that ground lost to different materials with most manufacturers nowadays, relying on wood in high quality alpine skis as a core material (Gstöttenmayr, 2003). So, modern alpine skis as well as snowboards are composed of different materials, with each component facilitating different desired properties (FIGURE 26.2).

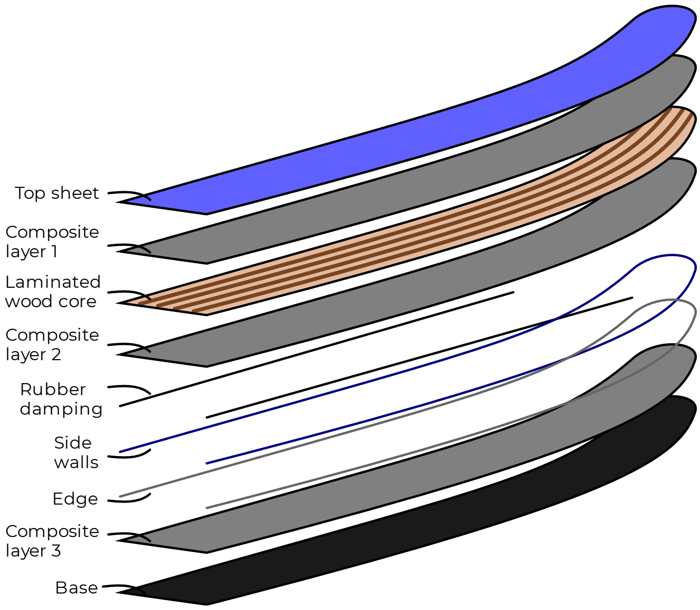

FIGURE 26.2 Typical lay of an alpine ski (image F. Negro/R. Wimmer).

The composition of today's ski layup is derived from the stresses imposed on the ski when used, which typically result in conflicting requirements. On the one hand, a ski needs to provide adequate rigidity (i.e., torsional stiffness); on the other hand, it should also be longitudinally flexible enough to conform to the terrain (Casey, 2001). In most ski types this is achieved by a sandwich construction as depicted in FIGURE 26.3. The core, from a static point of view, is responsible for holding the surface layers at a desired distance from one another. It thereby directly influences the overall mechanical performance since the bending mode induces the highest forces in the outermost part of the laminate, with the stiffness increasing quadratically with the distance from the center (Zenkert, 1997). Wood is suitable in this configuration since it exhibits good strength and flexibility values when subdued to uniaxial stress. When compared to a foam core - nowadays, a widely used material in skis- a higher stiffness and failure stress can be attributed (Atas and Sevim, 2010). **In summary, wood provides a lively feel when skiing, with good vibration-damping properties, ski shape retention, and provides fairly low resonances. In essence, the use of wood in skis helps to achieve the perfect balance between weight, strength, and flexibility.**

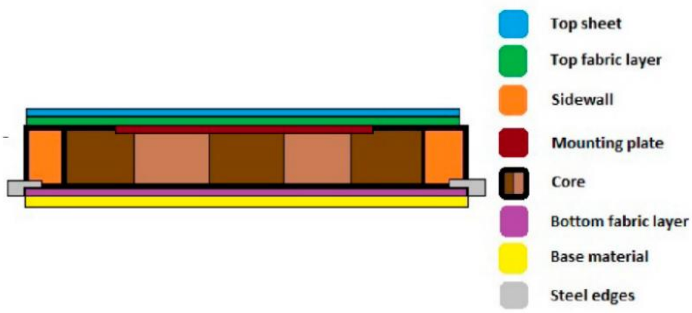

FIGURE 26.3 Schematic cross section of an alpine ski (image courtesy of Borenius et al. 2020).

So, less desired properties of wood are compensated by the sandwich layup as the wood core is isolated from moisture and is reinforced by the adhered composite belts that provide for the ski's torsional rigidity (Casey, 2001; Gstöttenmayr, 2003). Important wood species used by manufacturers are ash (*Fraxinus* sp.), beech (*Fagus sylvatica* L.), poplar (*Populus* sp.), maple (*Acer* sp.), alder (*Alnus* sp.) and kiri (*Paulownia* sp.), but also tropical species such as okoume (*Aucoumea klaineana* Pierre), abachi (*Triplochiton scleroxylon* K. Schum.; ayous, samba, wawa), or balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) (Borenius et al., 2020). Maple and ash are among the stiffest and most durable materials, making them suitable for standard alpine skis. Poplar and aspen are lighter species, and they often get mixed with other species used in alpine skis. Touring skis take advantage of very light wood species such as paulownia or balsa.

PROCESSING WOOD FOR HIGH-QUALITY SKI CORES

The wood is usually sawn into lamellas then glued together in a vertical position. In this regard, the ski's stiffness and hence the response can be varied not only by the thickness of the wood core but also by laminating different wood species together (Gstöttenmayr, 2003). Thus, the varying densities can be used to easily engineer the desired properties but are also needed to facilitate resistance against compressive forces while the laminations are being pressed together during manufacturing. In addition to the favorable physical-static properties, wood is also valued by manufacturers for its dynamic properties. The properties achievable by the sandwich layup seem to conform quite well to the requirements. This relates to the specific properties of wood, which makes wood comparable to other high-performance materials such as steel. The density also seems to contribute to this context, since skis with lighter cores were easy to maneuver but lacked stability while riding (Masia, 2004). In this regard there seems to be the indication that the optimal compromise regarding mass for a ski with good performance has been achieved throughout the past decades (Truong et al., 2020). As mentioned, a ski in use is subjected to a variety of forces, particularly the inherent stiffness that is acting as a dampened mass- spring system and can be set into oscillatory motion through the wind resistance at the curved tips or lateral skidding over the snow (Gosselin et al., 2021). Cheaper foam cores typically prove to be inferior and experience fatigue earlier, especially at lower temperatures (Lackner, 2003).

As for manufacturing, wood is dried to a moisture content between 7 and 10%, before core strips are cut, which are then glued together. The glued core panels are then planed and sanded. Soft (light) and hard (heavier) species are joined together in a core. The harder strips also have the role of supporting the load when the ski gets pressed together during manufacturing, while the softer strips have more of a space-holder function. It is worth mentioning that wooden cores are found more in expensive skis, while cheaper skis have polyurethane (PUR) cores. The reason is the significantly better vibration-damping properties of wooden cores, providing better skiing performances. PUR cores tend to shrink slightly with time, making the running surface of the ski slightly concave, with the consequent higher grip at the ski edges, at the cost of its glideability.

The use of wood can be seen as a signature component by Austrian-based ski manufacturers, which are world-famous due to the lasting success of Austrian racing skiers (FIGURE 26.4). There is no doubt that wood in skis continues to make strong contributions to high-performance ski equipment.

FIGURE 26.4 Austrian Franz Klammer winning Olympic downhill gold in 1976 at Patscherkofel in Innsbruck, which expedited the success of the still Austrian-owned ski manufacturer Fischer (Ried, Upper Austria), which was the world's largest ski manufacturer at the time (image Fischersports, CC BY-SA 3.0 DE, https://commons.wikimedia.org/wiki/File:Fischer_Sports_franz-klammer_1976.jpg, accessed on 12 May 2022).

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Appendix - Wood in snowboarding

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Snowboarding is relatively recent, having been developed during the 1960s in the USA. This sport was successful from the very beginning: by the 1980s-1990s it was already affirmed, so much that in 1998 it debuted in the Nagano winter Olympic games [1].

As a rule, the principles of the layered composition discussed above for skis are also valid for snowboards (thus, this appendix remains brief). Clearly, the one-piece structure and the position of the snowboarder determine differences in mechanics and applied loads (Caillaud 2019).

Wood is extensively appreciated to make the core of snowboards, where the species already cited for skis are commonly used. The core of a snowboard is basically made of wooden strips oriented parallel to the main axis of the snowboard. In addition, perpendicularly oriented strips and end-grain wood can be used in specific areas. Mixed compositions, in terms of wood species and strip orientation, aim at creating zones of the core that provide different properties, such as pop, mechanical strength, and lightness.

Of note, in some models a properly finished wooden top sheet is used for aesthetic purposes (this is also valid for skis and recalls once again the relevant aesthetic value of wood). The most various graphics are realized, where wood is alternated with drawings, writings and logos (Figure 26.5).

A final mention goes to wooden obstacles (jumps, rails, steps, etc.) used in snow parks for snowboarding and freestyle skiing. The obstacles available on the market are commonly made of non-wooden materials (zinc-dipped steel, polycarbonate, etc.). However, wooden obstacles are also used: series of logs, sawn timber structures, plywood ramps, timber rails, etc., that are appreciated because of their syntony with the natural outdoor environment.

Figure 26.5 Drawing of an imaginary snowboard recalling modern models that mix the aspect of wood with graphic elements (image F. Negro).

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Wood rocks!

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INTRODUCTION

The use of wood equipment in rock climbing has ancient roots: at the beginning, wooden wedges were used as protections for wide cracks where conventional pitons could not be placed (Figure 27.1). Since the 1980s they have been replaced by spring-loaded camming devices (the so-called "cams" or "friends"). These are mobile protections that are much handier than wooden wedges, made of aluminum cams mounted on an axle and connected to the climber's rope via a stem-sling-carabiner safety chain. Nevertheless, the use of wood is still very popular in sport climbing, although in a completely different fashion.

Figure 27.1 An old wooden wedge used to protect cracks before "friends" invention (image Flavio Ruffinatto).

Sport climbing is a relatively young sport. Born as a training activity for demanding alpine ascents, it gradually became an autonomous sport during the second half of the 20th century. Until then, alpinists were focused on the conquest of the summit by any means, which often involved the use of artificial aids. Sport climbers shifted the focus to the technical and physical challenges of a climb: the goal became overcoming such difficulties without the aid of any artificial equipment, except the one intended as a safety device. As a consequence, any rock formation, even a small boulder or a river cliff, could represent an interesting challenge, regardless of the presence of a summit. A milestone in the evolution of the sport was "Sportroccia" (which later become "Rock Master"), an international meeting that marked the birth of sport climbing competitions. The first edition was held in 1985 in Bardonecchia (Italy), where a natural crag was artificially modified (some holds were chipped while others were filled with concrete) to meet the difficulty requirements of the competition. It did not take long to realize the ethical and sustainability issues of such behavior: artificial alteration of the rock was quite in conflict with the "by fair means" principle at the base of the free climbing ethic. A viable alternative was to use artificial climbing walls, which in fact started to rapidly spread both for competitions and as private or public training facilities. Wood was given its second, bigger, chance in sport climbing.

ARTIFICIAL WALLS AND INDOOR FACILITIES

Although there are remarkable examples of climbing structures made of different materials (e.g., the concrete Flakturm Climbing Wall in Wien, Austria), artificial climbing walls are usually made of several plywood panels mounted on a supporting frame. This solution allows great design freedom because wooden panels can be easily cut into different shapes, resulting in complex and challenging layouts. Once the panels are cut, they are drilled following a regular pattern and threaded inserts (t-nuts) are placed in each hole (about 30-36 nuts/m^2). Artificial holds are either fastened to the holes or directly on the panel with screws, depending on the hold type. Beyond competitions, indoor climbing walls are very popular in urban areas, where climbing is now performed by many people exclusively on artificial walls (FIGURE 27.2 left).

Since a unified ISO standard is lacking, the International Federation of Sport Climbing (IFSC, founded in 2007) adopted many relevant EN standards for competition equipment, including climbing walls (IFSC, 2021). EN 12572-1:2017 specifies the safety requirements and test methods for Artificial Climbing Structures (ACS) with protection points, while EN 12572-2:2017 deals with bouldering walls. The cited standards ensure structural integrity thanks to the verification of limit states, with special attention to the loss of balance and breakage due to over-deformation. Other tests involve impact resistance of surface elements using a specifically designed indenter and panel insert resistance. The standards and their annexes specify the characteristics of all the equipment used and the test rig setting.

The ACS produced in Europe are usually made of 18 mm thick birch (*Betula* spp.) plywood; for outdoor walls, marine-grade plywood is necessary: in this case, plies are glued with specific adhesives (e.g., melamine and phenolic resins) to meet the requirements of the service Class 3 according to EN 335:2013.

Plywood performance in a structural perspective can be described by many different properties; for use in a climbing structure, bending strength and bending modulus of elasticity are particularly important. EN 310:1994 is used to assess plywood panel quality from a general perspective, whereas EN 789:2005 regards the structural use. Some indicative values for 18-mm thick plywood are reported in TABLE 27.1.

TABLE 27.1 Mechanical properties of plywood (18 mm thickness) determined according to EN 789:2005 (indicative data taken from data sheets available online).

Species	**Mean density** (kg/m^3)	**Characteristic bending strength** (N/mm^2)		**Mean modulus of elasticity** (N/mm^2)	
		Longitudinal	Perpendicular	Longitudinal	Perpendicular
Birch	680	40.0 - 40.5	34.0 - 34.5	10,000 - 10,100	7,400 - 7,500
Okoumé	510	23.2 - 23.8	33.8 - 34.3	4,150 - 4,250	5,000 - 5,100
Poplar	420	18.7 - 19.2	14.4 - 14.9	4,350 - 4,450	2,750 - 2,850

As shown in the table above, birch plywood offers excellent mechanical properties, but for outdoor structures okoumé (*Aucoumea klaineana*) is sometimes preferred. In any case, protective paints and finishes are necessary for long-lasting service. Bending strength and modulus of elasticity values depends on wooden species and panel composition (i.e., number and thickness of plies and their orientation). Poplar (*Populus x euroamericana*) plywood properties have been reported for comparison purposes only. More data are available in technical datasheets and declarations of performance (DoP) realized by plywood manufacturers.

Wood is also frequently employed in supporting climbing wall frames, as an alternative to steel. According to European regulation No. 305/2011 (Construction Products Regulation, or CPR), structural timber in Europe must be CE marked. This requirement is intended both for solid wood and engineered products, such as Glued Laminated Timber. If timber can be found supporting small structures, Glued Laminated Timber is the material of choice for wooden frames of big climbing walls (FIGURE 27.2 right). Minimum production requirements, provisions for evaluation and attestation of conformity, and marking of glulam products are laid down by the EN 14080:2013 standard.

FIGURE 27.2 Left: An artificial climbing structure (ACS), equipped with resin holds and fixed quickdraws [photo courtesy of Sint Roc S.r.l., Arco, Italy]. Right: An ACS supporting frame made of glue laminated timber (glulam) [photo courtesy of Explore Climbing s.n.c., Tonco, Italy].

Because of the glues employed, plywood and glulam can release formaldehyde. Being a highly toxic and volatile substance, in the recent past strict regulations have been developed to drastically lower acceptable emissions. To mention some, wood-based products must comply with normative dispositions and technical standards such as Toxic

Substances Control Act (TSCA) Title VI (USA), EN 13986:2004 (EU), and GB/T 39600-2021 (China). Nowadays, minimal emissions and correct ventilation prevent formaldehyde from reaching dangerous concentrations in indoor gyms.

WOODEN TRAINING EQUIPMENT

Sport climbing also features WSE for specific training purposes (FIGURE 27.3), the most important ones being the hanging board and the campus board.

FIGURE 27.3 A set of different WSE used in sport climbing training (hoto courtesy of Explore Climbing s.n.c., Tonco, Italy).

The hanging board was the first training tool to be developed specifically for climbing, with the main purpose of training finger strength. It consists of a series of rungs of different dimensions bolted to a wooden board to perform dead hangs or pull-ups. Nowadays there are countless variations of such a tool, but wood still remains the main material of choice.

The campus board[49] can be considered an evolution of the hanging board. It was developed by Wolfgang Güllich, a German climber considered amongst the most important ones in history, to train the explosive power required to climb "Action Directe"[50]. This instrument eventually became so popular that nowadays it is present in any climbing gym. The campus board, also called Pan-Güllich (especially in France and Italy) from the name of its inventor, is a plywood board with wooden rungs of different thicknesses fixed with screws.

Since it was conceived as a DIY training tool, and because of its simple design, a standard model does not exist. Rungs can be from 1 to 3 cm thick, approximately from 15 to 30 cm spaced, and their edges may be variously chamfered; moreover, the upper faces may accommodate a slight recess. In this case, unlike climbing walls, the plywood used as a support

[49] It is named after the Campus Center, the gym in Nuremberg (Germany) where Güllich set up the first board.

[50] Action Directe is considered a milestone in climbing, being the first 9a route ever. 9a is a level of the French difficult grading system.

is less stressed, but an adequate number of supports must be considered to prevent particularly large boards from flexing excessively in the middle during training exercises. Poplar plywood can be an excellent choice and is widely used. Rungs of both tools are usually made of hardwoods, which are unfinished to maintain natural grip.

Finally, wood can be found in several other training tools too, such as pegboards, rings, the Bachar ladder (named after its inventor John Bachar, a former American climbing legend well known for his free solo ascents), and even climbing holds. For instance, the Moonboard, a standardized interactive training wall developed by the English climbing legend Ben Moon, has several wooden holds sets. Other companies produce resin-textured wooden climbing holds, promoting their reduced carbon footprint and environmental sustainability compared to standard resin holds.

CONCLUDING REMARKS

For the time being, wood in sport climbing seems to be in good shape. Under the sustainability profile, the majority of the species employed originates from temperate or boreal forests, located in countries with high standards of forest management and proper control of the legality of the timber origin. The most critical species related to this sport is probably okoumé: although it is not listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) appendices, nor subject to international or national trade bans or restrictions, it has been reported in the International Union for Conservation of Nature (IUCN) Red List as "Vulnerable" since 1998 (CITES, 2021; White, 1998). If replacing okoumé with more sustainable woods is not possible, requesting a sustainable forest management (SFM) certification is an effective way to at least ensure that it is legally sourced. Obviously, the use of SFM-certified timber is also desirable for any other species used. Given the abundant use of wood in this sport, the explicit request of SFM-certified timber in the IFSC rules would be a great signal towards a more sustainable future.

From a more technical perspective, some DIY guides suggest using Oriented Stranded Boards (OSB) as a cheaper alternative to plywood panels, but it appears to be a practice restricted to domestic use

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Surf with wood for good

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SPORT DISCIPLINE OF SWIMMING ON A BOARD

Anyone who wants to swim on a board will have such an opportunity both on the sea, on a lake, on a river, and on various types of artificial reservoirs. The term surfing usually refers to the act of riding a wave using a board, regardless of the stance. There are several types of boards. The number of them results from kinds of surfing disciplines. Surfing can be done on various kinds of equipment, including surfboards, longboards, stand up paddle boards (SUPs), bodyboards, wave skis, skimboards, kneeboards and surf mats.

Therefore, the basic disciplines of surfing on a board can be distinguished as:

Surfing: a surface water sport in which an individual, a surfer (or two in tandem surfing), uses a board to ride on the forward section, or face, of a moving wave of water, which usually carries the surfer towards the shore. During classic surfing only the natural movement and dynamics of waves are used to move across the rough surface of the water while standing on a special board. It requires good wave analysis to climb it and use it at the right moment.

Windsurfing: a board similar to the one above is needed, but with a special sail attached to it that allows navigating in calm water. The said sail is fixed in such a way that it can be set in almost any position, thanks to which, every gust of wind can be used precisely to perform truly spectacular acrobatics.

Kitesurfing: on the board with a kite. As in the case of windsurfing, the force of the wind is used to move on the surface of the water, with the difference, however, that the board is attached to the surfer's feet. This allows an extremely long detachment from the surface making it feel like you are flying.

Skimboarding: a sport involving skating (sliding) on a board on a wave or shallow layer of water. Unlike surfing, skimboarding starts at the beach by standing by the shore with a board in your hands while waiting for a wave. As soon as the right wave is approaching, the skimboarder runs towards the water throwing the board over the shallow layer of water left over from a receding wave, or into deeper water in front of a wave.

HISTORICAL BACKGROUND OF SURFING

The oldest records about surfing date back to 1778, when Captain James Cook made the first documented visit of a European to Hawaii during his third expedition across the Pacific. In the account of Charles Clerke (commander of the ship "Discovery", participating in the expedition), there was a description of the inhabitants of the islands who rode waves in Kealakekua Bay on surfboards at that time (Horwitz 2005). The roots of wave riding go even further. Examples of similar activities have been found around New Zealand and Tahiti, indicating that it most likely originated in Polynesia. The Polynesians are believed to have arrived in Hawaii around the 4th century AD. The newcomers must have had extraordinary knowledge of water and they brought all the traditions and customs with them, including boarding.

An important figure in the history of surfing was George Freeth (1883-1919), a descendant of the Hawaiian royal family and an Irishman. As a teenager, he learned the art of traditional Polynesian surfing and carving boards on Waikīkī Beach (Horwitz 2005). One of the fathers of surfing is Thomas Edward Blake (1902-1994). He is considered as the person who turned the original style of surfing on a board into a modern sport. To make the board more stable, Blake created, and patented fins attached to the bottom of the board.

Adding fins to the underside of the board changed the dynamics of surfing, giving surfers greater control and maneuverability whilst wave riding (Warshaw 2010). A board created by Tomas Blake, which was light and technologically very advanced for the 1920s, was a breakthrough in the technology of creating surfboards (Esparza 2016).

SURFBOARD CONSTRUCTION AND DESIGN

Surfboard design has been changing steadily, incorporating each era with materials, ideas and technology to constantly improve the pastime. The sport has not changed much, but the surfboard has. Originally, wooden surfboards were made of hard and heavy solid woods such as redwood, cedar or wiliwili (Abbott 1992). Early surfboards were recorded up to five or more meters in length (Finney and Houston 1996), a stark contrast to boards commonly seen today, with surfers riding boards as short as one to two meters (Oggiano 2017, Oggiano and Panhuis 2020). At first surfboards weighed up to 70 kg and were difficult to travel with or transport. Lighter balsa wood surfboards were a significant improvement, not only in portability, but also in increasing maneuverability. Changes in construction of wooden surfboards made them much lighter, easier to handle and consequently, surfing became more popular. The combination of light balsa wood with the hollow surfboard production technique of surfer legend Tom Blake, made the surfboards much lighter, more maneuverable, and easier to surf.

With the invention of fiberglass during World War II, balsa surfboards were revolutionized. In the 1960s, worldwide foam surfboard manufacturing was revolutionized once again. Over time, surfboards have become shorter, lighter and more durable (Kampion 2007). Advances in materials have seen boards transition from solid wood to fiberglass and to carbon fiber-reinforced polymer (Finney and Houston 1996, Moran and Webber 2013). Board shape has evolved to introduce angular noses and board rocker (upward nose curvature) (Finney and Houston 1996, Gibson and Warren A 2014).

However, due to the environmental burden on the production of plastics, synthetic resins and fiberglass (being also petroleum derivatives), wooden boards are extremely popular. Especially nowadays, wooden surfboards have been experiencing a revival, as they are made of long-lasting, renewable and biodegradable blank material, which helps to reduce pollution in seas, oceans and on beaches - the places surfers love the most. Expanded synthetic resins and foams such as those made of polystyrene, although they can be 100% recyclable, they are a derivative of petroleum and are not biodegradable.

As the first surfboards made of solid wood were heavy, the contemporary construction of the boards has changed. Nowadays, the middle part of the board is full of empty spaces (hollows), creating a lower mass (up to 6 kg). This was invented by Tomas Blake.

The current construction types of wooden surfboards are:

- hollowed out wooden strips, glued longitudinally,
- wood panels compressed and bended against an internal frame,
- thin strips of wood over an internal frame, tied together in torsion,
- inner core and parabolic stringers, covered with a wooden skin.

At the same time, the reduction of surfboard mass allows the use of a wide range of wood species. Thanks to this, wooden boards can be visually more attractive. An example of a wooden surfboard is one made by a Polish manufacturer, presented in FIGURE 28.1. The main wood species used for surfboard manufacturing are presented in TABLE 28.1.

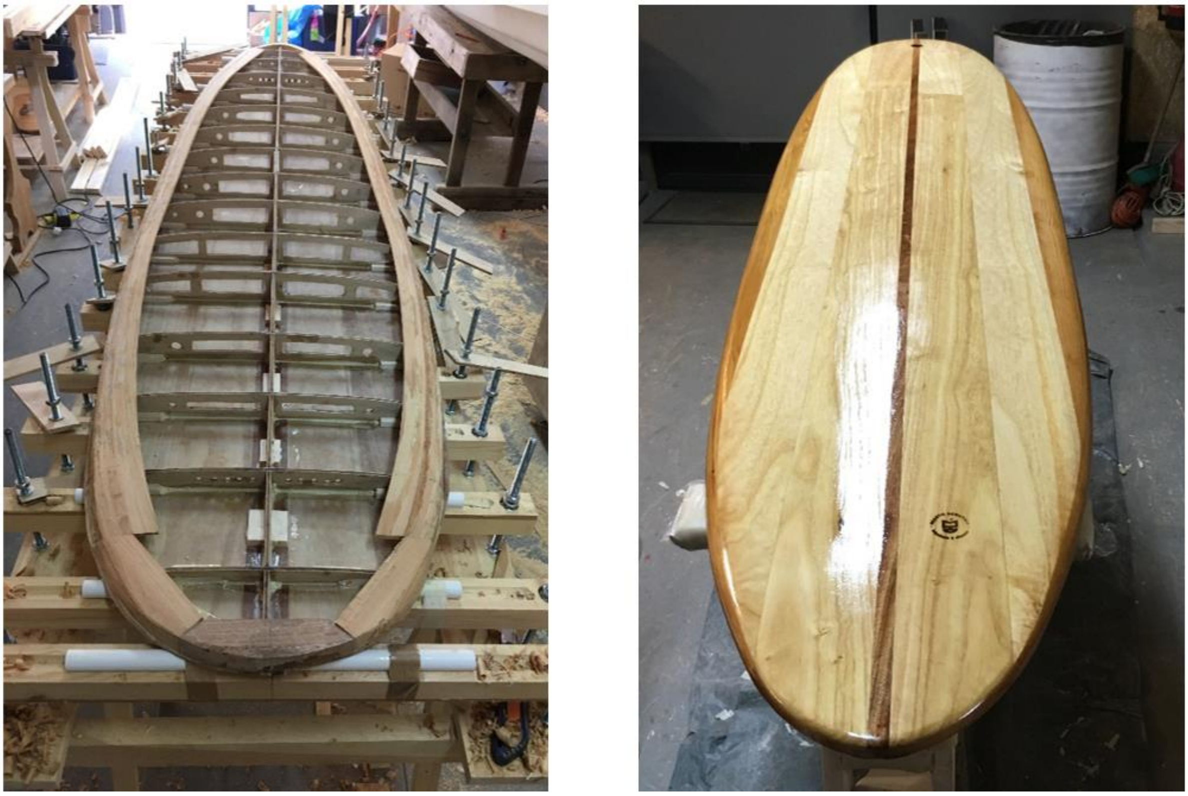

FIGURE 28.1 Wooden surfboard with a core made of thin wooden strips: on the left, during production; on the right, finished (image P. Sobotowski, surfboard produced by MIASTO SZKUTNIA, Poland).

TABLE 28.1 Wood species commonly used in surfboard production (Wagenführ 2007, Bouslimi et al. 2017, Koman and Feher 2017).

Wood species				
Trade name	**Latin name**	**Density*** (kg/m³)	**Origin**	**Kind**
Balsa	*Ochroma pyramidale* (Cav. ex Lam.) Urb.	70 - 260	Americas	hardwood
Douglas fir	*Pseudotsuga menziesii* (Mirbel) Franco	350 - 750	North America	softwood
Mahogany	such as *Entandrophragma cylindricum* Harms or *Khaya ivorensis* A. Chev.	510 - 750	Africa	hardwood
Paulownia	*Paulownia* sp.	262 - 360	Asia	hardwood
Red cedar	*Thuja plicata* Donn ex D. Don	330 - 460	North America	softwood
White cedar	*Thuja occidentalis* L.	260 - 532	North America	softwood
Wiliwili	*Erythrina sandwicensis* O.Deg.	No data	Hawaiian Islands	hardwood

* at 12-15 % of moisture content

Even due to the clear separation between plastic and wooden boards, numerous foam core boards (made of materials such as expanded polystyrene) have a high-grade wooden stringer. Another example of using wooden materials is bamboo (such as *Phyllostachys edulis* (Carrière) J. Houz.). It acts as a great alternative to carbon fiber. This replacement creates a more sustainable surfboard. Usually found on epoxy boards, bamboo is generally a thin skin over the blank which can then be glassed over. This also helps to reduce the amount of fiberglass and resin needed, again adding to the sustainability of the board while maintaining high performance levels.

PERSPECTIVES

Surfing is a sport with rapidly growing participation rates that encourages innovation within the surf equipment industry, leading to the growth of surfing as a sport and a multinational industry. Surfing has struggled to become an Olympic sport for over a hundred years. The inclusion of surfing as an Olympic sport will likely further enhance this growth. The debut took place in 2020 at the Tokyo Summer Olympics.

Surfing equipment innovation aims to increase accessibility to the sport and enhance performance. Surfboards and apparel are the two primary pieces of equipment most often associated with surfing. Over the past century these pieces of equipment have undergone significant changes in design and function (Romanin et al. 2021). This goes hand in hand with following and respecting nature.

Recently, manufactures who produce surfboards using computer aided design and robotic (CNC) shaping tools have gained a larger share of the surfing market, allowing board producers and shapers to produce lighter and more durable boards. Most of them are made of a shaped polyurethane foam core that is wrapped in fiberglass cloth and sealed with multiple applications of a curing resin product. There are projects conducted to find a suitable method to replace fiberglass with a wood-based material (Bessel 2013). Wood usage is also trendy for surfboard manufacturers as well as for responsible surfers.

Nowadays, boards made of wood are still delightful equipment to use in water sports. These are not boards from mass production but are custom made, tailored on demand to exact specifications. Wooden surfboards that are currently produced can match, or even top, the quality of modern mass-manufactured boards.

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A THOUSAND BOUNCES ON WOOD

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INTRODUCTION

In table tennis, two (singles) or four (doubles) opponents hit a ball back and forth across a table divided by a net, using a small racket. Commonly, it is also known as ping pong and it is played for recreational purposes at any age and level, both indoor and outdoor. At a professional level and in competitive practice indoor places are required due to the lightness of the ball, whose trajectory can be affected by the slightest breeze.

The origins of table tennis (ITTF n.d.a) were set in Victorian England during the last decades of the nineteenth century, to replace lawn tennis when it could not be played outdoor due to unfavorable weather conditions. One of the first mentions of "table tennis" was in 1885, when James Devonshire applied for a Patent of the game in London. The application was recognized as abandoned two years later.

The first indoor set for tennis on a table was marketed by David Foster with the name of "Parlour Table Games", patented in England in 1890 and including table versions of Cricket, Football and Lawn tennis. As for the game of tennis, the rackets were small strung and the ball was a 30 mm rubber ball covered with cloth, the net was 10 cm high. Later, in 1891, the game makers Jaques of London released the game "Gossima", with drum like rackets, a 50 mm cork ball and a 30 cm high net.

However, neither of the games were successful due to the unsuitable ball: the rubber ball had an unpredictable bounce, and the bounce of the cork ball was too poor. Only at the beginning of the 1900s did the game become successful thanks to the introduction of celluloid balls. Because of them, the name of "Ping Pong" was launched for the sound of the ball bouncing on the table and patented first in England and later in the United States of America after the acquisition of the American rights to the name. Today, Ping Pong is still a registered trademark.

Over time, the two most popular names of Table Tennis and Ping Pong gave rise to two associations with different rules, leading to confusion. Only with the birth of the International Table Tennis Federation in 1926 were standardized laws established and adopted. In the same year, the first World Championship was held in London.

The popularity of table tennis grew rapidly all over the world and particularly in China, where Mao Zedong made it the new national sport in the early 1950s.

Table tennis also played an important political role in easing relations between China and the United States of America: the so called "Ping Pong diplomacy". During the World Championship held in Japan in 1971 the American team was invited by the Chinese team to visit their country. They were the first Americans to enter China since Mao's takeover. The event paved the way for US President Richard Nixon to visit China in 1972. Nowadays the worldwide table tennis community see the Ping Pong diplomacy as the first step of a long-lasting spirit of creating dialogues and building friendships through this sport (ITTF n.d.b).

In 1988 table tennis was featured for the first time in the Olympic Games of Seoul, South Korea.

WSE IN TABLE TENNIS

The simplicity and low costs of the equipment used in this sport is the key to its diffusion at a recreational and amateur level. But on a professional level there is a very high specialization in the choice and manufacture of the equipment, together with continuous research in materials and products.

In table tennis equipment wood is present in tables and rackets.

THE TABLE

When it appeared as a recreational game, the table tennis set included a large green cloth with white strips drawn to represent a tennis court. The cloth must be placed on a flat table.

Later, having risen to the status of a sport, the table's characteristics were standardized by international rules (ITTF 2016). It consists of the tabletop and the undercarriage, the latter required for the rigidity and stability of the entire structure during play. The tabletop affects the trajectory and the bounce of the ball; its upper surface is the playing surface: rectangular, 2.74 m long and 1.525 m wide, laying horizontally 76 cm above the floor (FIGURE 29.1).

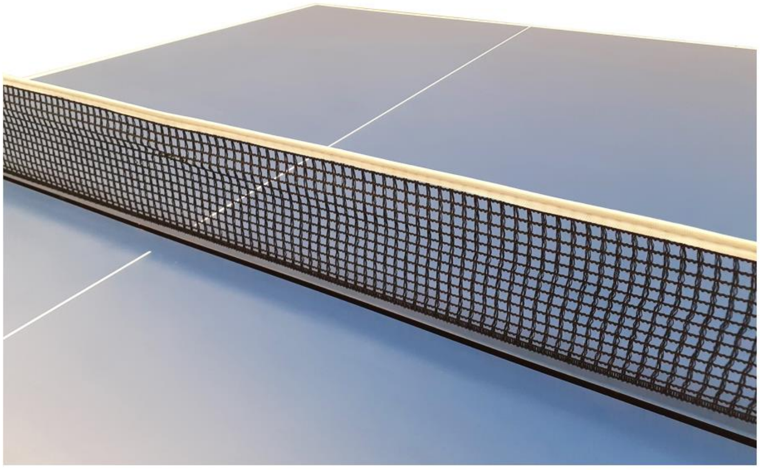

FIGURE 29.1 Table tennis table (image F. Negro).

According to the ITTF rules, the tabletop must be flat and not deformed. Two requirements must be fulfilled for the table to be approved by the Federation: (1) the vertical bounce of an approved ball dropped from a height of 30 cm must reach a height between 23 and 26 cm, and (2) the dynamic coefficient of friction between the ball and the playing surface must be lower than 0.6.

Friction affects both the spin and the trajectory of the bounce of the ball, and it is an attribute of the surface finish. On the contrary, the tabletop substrate must ensure dimensional stability and the requirement for the vertical bounce. The ITTF specifies that it may generally be of any material providing the bounce is suitable; however, for major tournaments only wood or wood derivate may be used for the table to be approved by the federation.

It is also recognized that wood changes its moisture content according to environmental humidity and, consequently, its dimension and shape. Small dimensional variations are somehow unavoidable but should be minimized by the choice of suitable wooden products and proper manufacturing.

To this end, plywood, particle boards, high or medium density fiberboard (HDF or MDF) are mostly used. Manufacturers may also prefer to use several planks instead of a single panel for the tabletop structure and then to apply a thinner sheet of plywood on the top. Most commonly, the tabletop consists of two halves that enable the table to be folded vertically in its storage position.

The thickness of the playing board is also very important to increase dimensional stability and give a suitable bounce: thicknesses between 12 and 30 mm are common, but for wooden tops, at least 25 mm for plywood and

18 mm for particle boards (ITTF 2016) will be appropriate.

Softwoods (fir, spruce, pine) are the most common species processed for plywood manufacturing, but hardwoods can also be used. As an example, the tables for the Tokyo 2020 Olympic Games were made with birch plywood. In this special case, the manufacturer decided to supply Monarch birch (*Betula maximowicziana*) coming from the North-East of Japan, not only for the good quality of the raw material, but also to support the local economy of the region, which was struck by the tsunami in 2011. Thus, technical, socio-economic and environmental benefits were achieved together.

Indeed, the ITTF technical leaflet (ITTF 2016) for table manufacture also takes environmental and health aspects into high consideration, providing the limitation for formaldehyde content for wood and wood material as specified in European standard E1, and for no release of Volatile Organic Compounds (VOC) in the final table. Environmental considerations include paying attention to the production phases in terms of workers' health, reducing the emissions of harmful substances, promoting the use of materials that can be easily disposed of or better reused or recycled, both during manufacturing and in the final product.

While the ITTF deals mostly with tables for competitions, the European standard EN 14468-1 (2015) specifies functional and safety requirements for tables intended for both high-level competitions and recreational purposes. Many of the requirements are similar to the ITTF specification, but it allows the tabletop to be produced in any material that fulfills the ball bounce requirements (the same provided by the ITTF described above), climatic stress (specifically for outdoor tables) and environmental aspects (promote the reduction of potential adverse environmental impacts).

Finally, there is a wide range of prices for table tennis tables. Besides the standard-size table, non-standard tables can be found on the market exclusively for recreational use. They are the cheapest (a few hundred euros). On the other hand, standard size recreational tables of acceptable quality may cost around 500 €. Between 500 and 1,000 € is the cost of mid-range tables, suitable also for training for competitions; above that is the price for top competition tables. Outdoor tables are usually more expensive if compared with indoor tables of the same category because they have characteristics that withstand exposure to natural elements.

THE RACKET

The racket is essential for playing table tennis. Its technical characteristics have been in constant evolution, influencing with them the evolution of the game. Changes in the characteristics of the racket over the years have resulted in just as many changes in the game style.

Initially, the recreational game involved a miniature copy of tennis rackets (strung rackets), but after a few years, drum-like rackets similar to those of current badminton, were introduced. Afterwards, the handles were shortened, and wooden rackets arrived, which were eventually covered with cork, sandpaper or animal hides and subsequently with rubber (pimpled rubber).

In the 1950s, sponge was introduced as a cover over the wood (the blade) and became increasingly popular until it was inserted between the wood and an outer layer of rubber - the "sandwich" racket. Sponge increases speed and helps the rubber to produce spin. This sandwich structure is the one used today, and improvements are aimed at various components.

The blade, the covering, and the handle are the three main parts of the racket (FIGURE 29.2). Here, handles and blades are covered, since they are the wooden components of the equipment.

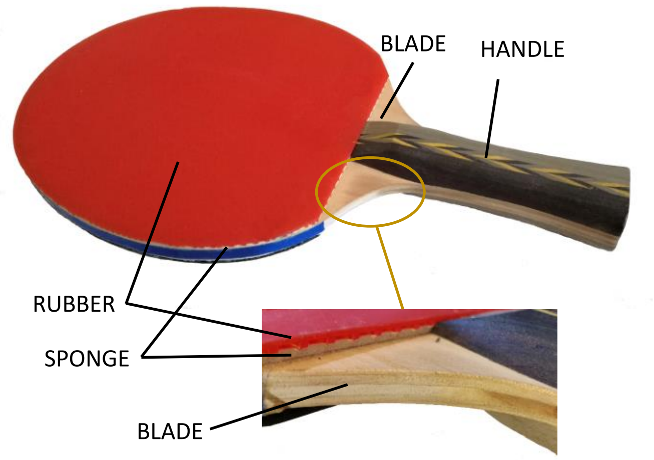

FIGURE 29.2 Table tennis racket (image M. Nocetti).

According to the ITTF (2021) the racket may be of any size, shape or weight but the blade must be flat and rigid. At least 85% of the blade thickness shall be of natural wood; thin layers of reinforcing materials (carbon, arylate, basalt, glass fibers) may be included, but must not be thicker than 7.5% of the total thickness or 0.35 mm, whichever is the smaller.

The blade, along with the handle, make up the wooden structure of the racket and are extremely important, considering the player will use them the longest. At a recreational / amateur level, it is easier to buy a full rubber racket and use it without ever changing the rubber or changing it only after a very long time. At a professional level, it is more common to buy the components separately: the rubber can be changed and applied to the wooden blade very frequently (once a week depending on the duration of the rubber and its maintenance). Instead, the blade must be chosen by the player based on his playing style, and the handle must be comfortable and suitable, since they will both be with him for a long time. A player becomes accustomed to his racket and often tends to keep it for as long as possible.

Initially, blades were made from a single layer of solid wood. However, wood properties can be very variable even within the same species, which depends on many factors, including the growth conditions of the tree. A top-level player would be able to feel the difference during play when he changed the blade of his solid wood racket, even if it was made with the same wood species, but that exact piece of wood had different properties from the previous one.

Moreover, the blade should be very stable, and no deformations should occur. So, blades are currently made of plywood to give both more stability of shape and constancy of performance. The number of layers (or plies) ranges from 3 to 9 (most commonly 5 or 7). The plies are made with different wood species, having two successive plies, their fibers oriented perpendicularly, and the central ply having the greatest thickness (Manin et al. 2012).

The perpendicular orientation ensures greater dimensional stability, and the composition of different species increases the performance the rackets have to offer. Recently, reinforcement (thin layers of light but very stiff material such as carbon fibers, basalt or arylate) has been introduced in the plywood to increase blade rigidity and therefore the racket speed.

Generally speaking, table tennis rackets must be light (normally the weight is lower than 200 g, rubber included). Therefore, wood species with low or very low density are used for the inner layer (the core layer) and possibly heavier and more rigid wood in the outer layers, should the player wish to increase the speed.

Since blades are what mostly decide the playing style, they are classified based on the style for which their composition is most suitable. Basically, three types of playing can be distinguished: OFF (offensive), rather aggressive play, typical of players who mostly attack; ALL (allround) mixed game, for precise players, who wait for the right moment to close the game by launching an attack; and DEF (defensive), for players who make very few mistakes and who base their game on their ability to resist the opponent's attacks.

OFF blades are light but rigid, thus resulting in high-speed playing. The reinforced blades are generally recommended for offensive players. On the contrary, DEF blades are heavier, composed of wood with higher damping capacity or energy absorption.

The variability of the racket performance is very high, and each blade is characterized by several parameters: i.e., overall thickness, dimension, wood species, composition and thickness of the layers. All these factors influence the final characteristic of the racket. Manin et al. (2012) defined the composition of the blades "like a cooking recipe", mostly based on the manufacturer and user experience. So, they tried "to measure" the racket performance by determining the vibration of the blade in a laboratory and relating it to the blade composition. Later, the same authors measured the vibro-acoustic properties of several blades made with different wood species and thickness in their layer composition and compared them with the classification made by top level players based on the sound produced by the same blades hitting the ball. The results were quite consistent (Manin et al. 2014).

TABLE 29.1 shows, without being exhaustive, some of the most commonly used wood species for blade manufacturing. The ITTF is currently talking about lowering the mandatory percentage of wood in the blade composition or even liberalizing the materials that can be used in blade manufacturing, but further research and studies are needed. An example may be that of Arafin et al. (2017), who tested the use of natural fibers such as kenaf, jute, hemp, sisal and ramie to replace wood as a structure of table tennis blades.

Finally, the handle. Table tennis players are divided into two main "grip-styles": the shakehand grip (known as European style) and the penhold grip or Asian-style (the racket is held the way a person holds a pen). They originate four main handle types: straight, flared or anatomical for the shakehand grip (FIGURE 29.3), and the penhold type.

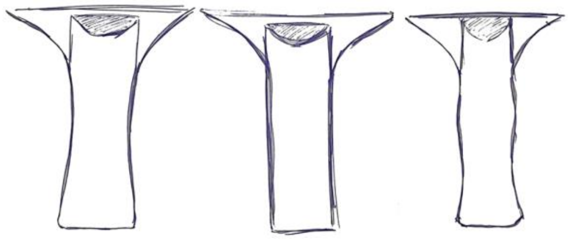

FIGURE 29.3 Racket handle types: flared (left), straight (in the center), anatomical (right) [image M. Nocetti].

The flared handle could be preferable for dominant forehand players and the straight handle could better suite backhand players and defenders; hitting players could prefer anatomical handles, which, may however be weak for spin. Lastly, penhold is weaker on the backhand side.

There can also be variations, for example the straight handle can be more or less rounded (round straight or squared straight) or it can also have a conical shape Whatever the handle type, it is usually made of wood. The species used are the most varied and, in this case, great attention is paid to aesthetics (tropical hardwoods are appreciated). They can be colored and finely decorated.

TABLE 29.1 Wood species commonly used in table tennis blades.

Wood species	Botanical name	Density (kg/m^3)	Description
Ayous (Obeche)	*Triplochiton scleroxylon*	380	African fast-growing tree. It is a lightweight wood very common in blade manufacturing; mostly used in the core or very close to the core plies to maintain lightness, rather than top veneers.
Balsa	*Ochroma pyramidale*	140 - 160	The species grows in the tropical belt of the American continent. It is extremely light, soft, porous wood, a very popular material for blade cores and soft inner layers.
Cypress	*Chamaecyparis lawsoniana* *Taxodium distichum*	470	The name cypress includes several wood species used for manufacturing blades. Good, cheap and available, it can serve as cores, medial plies, and outer plies.
Hinoki	*Chamaecyparis obtusa*	430	Japanese wood, soft but relative heavy. Used for precious blades, mostly in the outer layer. More often substituted by cypress due to its scarcity and cost. "Kiso Hinoki" is a particular wood; used for blade manufacturing only when it is 300 years old or more.
Kiri (Paulownia)	*Paulownia tomentosa*	260 - 350	Originating in eastern Asia, its cultivation has spread to other countries and continents. Lightweight wood most commonly used as a core layer; its tight structure helps to control vibration in the racket. It is the most popular core layer for table tennis blades.
Koto	*Pterygota macrocarpa*	590	Naturally distributed in tropical west Africa. It has a fine texture and nice decorative strips; it is often used as a surface veneer, helping to add rigidity to the blade.
Limba	*Terminalia superba*	450 - 650	Native to tropical west Africa. Very common in blade manufacturing as an outer veneer.
Spruce	*Picea* spp.	450	Generally used as a medial ply to create better speed. It has good acoustic properties.
Walnut	*Juglans* spp.	550- 650	Dark colored, hard, mostly used as a top ply.
Willow	*Salix* spp.	390 - 420	Heavy wood used mostly as an outer layer, due to its damping property makes control easier.

But the heaviness, which must not increase the final weight of the racket too much, and the balance of the entire assembly, are still important. If heavy woods are required, it is possible to hollow their undersides to reduce their weight before gluing them to the blade. In any case, solid or hollow handles change the balance of the racket: a hollow handle shifts the weight towards the head and the racket speeds up, a solid handle moves the balance towards the handle and the racket increases control.

Just a few remarks about the prices to conclude. Complete rackets for a couple of tens of euros can be found on the market, but they are mostly intended for recreational and amateur purposes. Higher performance blades can be purchased from 50 up to around 350 €.

CONCLUSIONS

We have seen how wood and the knowledge of its characteristics and properties take the lead in table tennis. The equipment has evolved over time, and the game along with it, but the key material remains wood. Thanks to the great diversity that is typical of wood, it is possible to create equipment with very specific characteristics, adaptable to the player and his playing style. It is appropriate to say that in this sport the materials (and manufacturing techniques) come into connection with the athlete, working as team.

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Breaking wood, on the way to the black belt

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INTRODUCTION

Taekwondo is a martial art that originated in Korea around 50 BC. Its name means "the way of kicking and punching" and comes from the Korean words "tae" (feet or kick), "kwon" (fist or punch), and "do" (path or realization) [1].

Taekwondo is a highly spectacular sport that involves several physical skills such as agility, flexibility, and endurance. This is just a part of it, the other being the development of mental aspects and ethics. The concept of "do" is indeed key in this discipline: both the body and the mind are trained and applying the acquired principles in one's live is encouraged. The elements encompassed are courtesy, integrity, perseverance, self-control, and indomitable spirit (Kim et al. 2021). Thanks to its wide range of educative values, taekwondo is taught worldwide as a way to maintain physical and mental well-being (Petrovic 2017).

Taekwondo entered the Olympics as a demonstration sport at the 1988 Olympic Games in Seoul, and then became an official sport at the 2000 Games in Sydney [1]. Nowadays it is practiced in more than 200 Countries, many of them having large federations and boasting world class athletes.

The wooden breaking boards used in taekwondo are the subject of this chapter. Similar boards are used in other martial arts as well, for instance in karate. In line with the general approach of this book, only taekwondo is considered here to avoid additional information that would be largely repetitive.

WOODEN BREAKING BOARDS

Wooden breaking boards are used for various purposes in taekwondo: for professional and amateur training, in formal tests to attain belt ranks, in freestyle competitions, and in exhibitions (boards made of synthetic materials and bricks are also used). In taekwondo, wooden boards are broken mostly with a kick, but also with the fist. The break provides a double, immediate feedback of the blow: that it is executed accurately, and the force applied is adequate.

Wooden breaking boards are typically made of solid wood or of solid wood panels (that is, of wooden laths glued side by side). Their width and length are typically 30 x 30 cm or 25 x 30 cm, whereas the thickness varies depending on the intended use. Generally, 0.4-0.7-1.0 cm thick boards are suitable for kids training, 1.5 cm thick boards are used in competitions and for average level training, and 2.0-2.5 cm thick boards are used at advanced level and in exhibitions. In some cases, boards are stacked to further challenge the skills of the athletes. Boards can be broken individually or in sequence: in this case, combinations of acrobatic movements unfold in a few seconds, resulting in highly spectacular releases of energy and broken wood. In some exhibitions, broken boards are signed by performers and given to the audience, which somehow confirms the iconic role of these items.

Clearly, wooden breaking boards are intended to represent a feasible challenge: after all, and as stated above, the difficulty of the exercise can be easily increased by stacking multiple boards. Mid-low density wood species are used, especially pine (450-520 kg/m^3 at 12% moisture content), spruce (460 kg/m^3), and paulownia (280 kg/m^3) (EN 350; [2]).

Wooden breaking boards used in taekwondo typically derive from the radial cut of round timber. Noteworthy, the strike shall be done parallel to the wood grain (FIGURE 30.1). This can be explained by recalling the classic lecture demonstration in which a bunch of sticks, like *spaghetti*, is used to represent the structure of wood as a bundle of linear cellulosic fibrils. These consist of the union of polysaccharides (especially glucose) connected longitudinally and laterally to each other by chemical bonds of different binding energy and resistance to hydrolysis, which are much higher along the longitudinal union. Consequently, it is easier to separate the sticks laterally than to break them by tensioning the bunch in a direction parallel to its length. Similarly, wooden breaking boards are essentially broken by separating the wood fibers from each other, along roughly straight breaking lines.

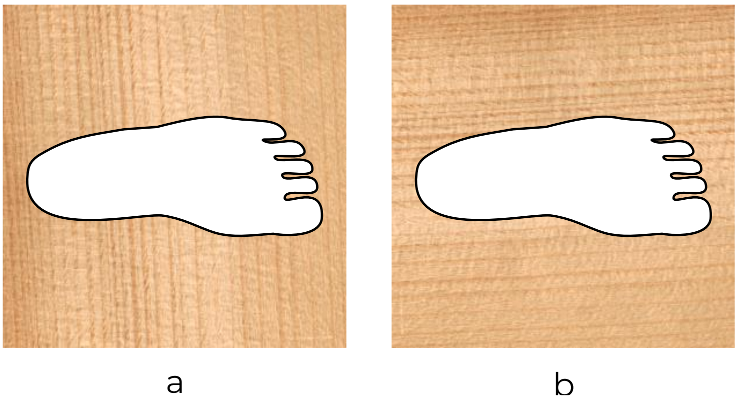

FIGURE 30.1 Relative orientation of foot and wood grain, as seen from the kicker's point of view: perpendicular in (a), correctly parallel in (b) [image F. Negro].

THE PHYSICS OF BREAKING WOODEN BOARDS

Breaking a wooden board is a practical and spectacular application of the impulse-momentum theorem.

The momentum is defined as the product of an object's mass and its velocity[51]:

$\mathbf{p} = m\mathbf{v}$

Any massive object that is moving has a momentum: the greater the mass or velocity of the object, the greater the momentum.

Impulse is a physical quantity that can be determined as the product of the average force F acting on an object and the time interval Δt in which the object experiences the force:

$\mathbf{I} = \mathbf{F}\Delta t$

The impulse-momentum theorem states that the change in momentum of an object equals the impulse applied to it:

$\mathbf{F}\Delta t = \Delta\mathbf{p}$

This law can be used to understand how a quick blow can break hard objects like wooden boards. Let's consider the arm moving towards a board. When the hand hits the board, its impulse rapidly drops to zero: this change of momentum over a short period of time is the result of a strong force. The impulse-momentum theorem allows to estimate the average force applied by the wooden board to the hand, provided the duration of the collision Δt is known. For the third Newton's law, such a force is equal in magnitude to the force applied to the board by the hand. The time interval Δt depends on the wood elasticity and the hand velocity. To estimate its order of magnitude let's take the example of a hand hitting a 2 cm thick, 30 cm long dry white pine board with a velocity of ~10 m/s: according to [3] the collision lasts about 4 ms. Assuming an effective mass of 4 kg for the hand (the whole arm is swinging, not only the hand), an average force of ~10,000 N can be derived. Such a force, equivalent to the weight of a ~1,000 kg object, is applied to a small area, for instance

[51] Vectors are in bold in all equations.

corresponding to the first two knuckles. The resulting stress is larger than the typical stress a wooden board can sustain and the board breaks.

ADDITIONAL NOTES

In conclusion, some additional remarks on wood in martial arts are mentioned here.

Taekwondo matches are played on mats that can be laid on supporting wooden platforms, i.e., made of a plywood plane fixed on to solid timber frames.

In some martial arts, such as in karate, wooden dummies are used for training. They are generally constituted by a cylindrical, vertical element from which various rods emerge, in a schematic representation of the opponent's body.

Finally, various martial arts envisage the use of wooden combat items: this is the case, to name but one, of the wooden sticks used in aikido.

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TRACK IN TIMBER, LAP AFTER LAP

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INTRODUCTION

Track cycling is a generic term for all events that take place indoors and outdoors on a banked, hard-surfaced oval track in structures called velodromes, which normally have a circumference of 500 m or less (Craig and Norton 2001). UCI regulations (International Cycling Union, the world governing body for cycling sports and international competitive cycling events) do not prescribe the substrate of the track nor do they specify the material of the surface (UCI, 2021), however, wood has demonstrated to be the favored material for track structures and surfaces for many of its advantages over other materials, particularly for indoor velodromes (only 250 m) and highly ranked international competitions.

The first track-cycling competitions date back to the late 19th century. In 1876, the first international bicycle track race was held on an outdoor crushed-brick surface in Wolverhampton, England. Two years later in London, a flat wooden velodrome was built in the Royal Horticultural Hall (Van Rheene undated).

Track cycling has been an Olympic sport since the first edition of the modern Olympic Games in 1896, with the exception of the 1912 edition. Track cycling is currently very popular in many European countries, in Russia, in Japan (particularly the “keirin” motor-pacing category), in Australia and in New Zealand. Formerly, the “Six days” races were very popular in the USA and in central Europe.

VELODROME STRUCTURE

A velodrome is a structure for bicycle racing (from French “vélo” = bicycle, velócipéde (Lat. *velox* - swift, rapid and *pes* - foot) and - “dróme” (Gr. - *dromos* - road, course). The racing track of a velodrome consists of two parallel, straight units of a track, inclined at 12° to the inner edge, joined by two semi-circular segments at 180°. The curved sections (clothoid) are gradually and increasingly steeply inclined toward the center of the track - up to at 42° or even 47.5 ° - to compensate for the centrifugal force generated at the athlete passing the curvatures at high velocities (records exceed 95 km/h). The complex geometry required to join the straights with the banked curves was made more challenging by the need for the track to cope with the cyclists’ changing center of gravity, balance and friction (Solarczyk 2020). Internet offers the sites of several architect’s offices that specialize in the design of the tracks or complete domes and the presentations of famous velodromes (e.g., London, Rio or Tokyo Olympics), with references to the achievements (e.g., World or Olympic records) realized on their tracks.

The UCI regulations (UCI 2021) indicate that the total length of the track be measured precisely on the upper edge of the “blue line” drawn at 20 cm from the inside edge of the track. That length may amount to between 166.66 and 500 m so that the total distance of covered laps or half laps can be rounded to 1 km. The tracks practically measure 250, 333.33, 400 or 500 m. However, the UCI prescribes that the tracks for the World Championships and Olympic Games have a 250 m standard length.

The guidelines and regulations of the UCI (2021) concerning the geometry of the cycling track are quite scarce and leave considerable freedom in the choice of solutions for the designer of the object. According to Solarczyk (2020), the construction of the cycling track itself is entirely the responsibility of the designer. The stability and resistance of the materials and fixings which make up the structure of the velodrome shall meet the legislation regarding the construction and safety of the country in which it is built. If the track length exceeds 250 m by more than 0.0012 m, the track will be rejected by the controlling UCI representative. In any case, the issue of designing the geometry of the cycling track is complex, mainly for the choice of transition curve and superelevation section, and complex mathematics (clothoid) is applied nowadays to calculate the fastest trajectories of the athletes. The UCI recognizes the reliability of the wooden material, the designers and the builders around the world.

WOOD AS A MATERIAL OF CHOICE FOR VELODROME TRACKS

There are both historical and functional reasons why wood makes for the best choice of material for cycling tracks. Formerly, tracks were also made of concrete, asphalt concrete or tarmac, whose resistance to weathering and durability by far overreached the properties of wood in exterior, uncovered velodromes. There are also examples of historic open-air tracks made of wood, but their maintenance and repair render them economically unfeasible. On the other hand, wood remains the dominant material for the recent indoor velodromes that exclusively host top-class competitive cycling events, because indoor velodromes enable controlled conditions for both athletes and spectators and can efficiently provide the entire necessary infrastructure.

From the functional standpoint, wood offers the best solution for essential requirements of the track surface, which are antagonistic by nature. On one side, the surface should render sufficient friction, thus ensuring the adequate tire grip and restricting the risk of athletes slipping. On the other side, however, the friction should be minimized to provide the lowest possible rolling resistance, thus enabling the greatest possible speed. Wood is much more forgiving than concrete and asphalt for falls, and its surface is less sensitive to traces of oil and sweat and rubber marks than other materials. The wooden surface may be easily maintained in optimum functional condition by re-sanding and re-finishing. Finally, compared to concrete or asphalt, wood can be easily repaired by replacing individual battens or by gluing-in the repair blocks on the damaged spots.

Last but not least, wood is attractive from an aesthetic point of view. Tradition now becomes another argument for the use of wood for cycling tracks, enabling the comparable conditions for cycling events in the modern era, and fulfilling the requirements for the permanency of UCI regulations.

WOODEN TRACK CONSTRUCTION

The sub-structure of the cycling track must be rigid to ensure the stable and constant geometry of the surface. Track pliability or structure ductility should be kept to a minimum so that preferably no energy, transmitted by the athlete through the bicycle onto the track, would be absorbed by the structure. However, wood structures should also offer some subjective sense of comfort to the riders, which cannot be achieved on completely rigid concrete structures.

Timber framing principles are adopted for the construction. The structure is made of an array of radially oriented wood trusses at spans as low as 70 cm in certain places, which differ in geometry and size to shape the riding track plane. Nailed, gang-nailed or nail-plate assembled boards were used in the past, instead modern structures use prefabricated board trusses or softwood laminated wood (GLULAM) members whose lamellae are kiln dried to a specific moisture content. Lamination gluing offers exquisite form and dimension stability and an improved rigidity of the wooden structure. Modern CAD-CAM technology enables the precise fabrication of individual trusses regarding the dimensions and top-edge inclinations to accommodate the complex curviplanar geometry of the track plane. The trusses are anchored to the concrete base by steel fasteners and their nodes are fixed with standard glulam connectors. The trusses are joined at the perimeter by purlins or other systems for lateral stability.

The flooring is simultaneously acting as a structural membrane and as a riding surface. It consists of a series of rings of wood battens that are bent to the perimeter and fixed to the trusses. The battens are all of the same cross-sections and their dimensions vary from 40x40 mm to 50x50-60 mm, depending on the flexibility of the wood species and radii of the track. Batten lengths vary but must be sufficient to span at least three trusses; sometimes the lengths reach 4-6 m to ensure a smooth curve around the bends. End-joints are butted, and battens commonly do not have a tongue-and-groove joint on their sides like parquet flooring. This would improve the planar stability of the track and prevent lipping between the elements but would also eliminate the possibility of simple replacement and repair. Battens may be fixed askew by the side or from above. Commonly, battens are nailed through the side at an angle to the sub-structure and horizontally to each other. The other fixing method implies screwing. This is easily and effectively done laterally and diagonally from the top, but the screws directly on the top should be head-sunk and the holes plugged with wood pegs and levelled or filled with hard sealant to the surface plane.

Surface finishing is not prescribed by the UCI regulations, it is only stated that “the surface shall be completely flat, homogenous, and non-abrasive“. If a coating is applied, it shall be uniform in rolling qualities and all other aspects over the entire track surface. The demarcation lines and advertisement paintings must be of the same non-slip properties as the rest of the surface. Obviously, the choice of the surface finish is left to the designer, and common anti-slip coatings for sports floors may be applied. The wood on the exterior must be protected to enhance its hygrophobicity and weathering resistance but must not impede the frictional properties of the wooden surface.

CHOICE AND PROPERTIES OF WOOD MATERIAL FOR CYCLING TRACKS

Several properties of chosen wood species are important for selecting the track material. Wood must be as clear as possible, straight-grained, with a low tendency to split and check, with good nail-holding properties. Defects are excluded save for the small, sound knots often present in softwoods. It should have a certain mechanical stiffness but still enable easy bending without splintering or compression failures. It should sand well and contain not much extractive such as resin. Above all, the hygroscopic properties of the species (moisture uptake rate and dimensional stability in climatic changes) are the crucial technological demand: the tracks are wide (often over 7 m) and the swelling of wood - even within normal indoor climatic fluctuations throughout the year - could cause warping, distortions or even loosening of the nail fixings. On the other hand, excessive shrinkage could cause fissures and lipping between the adjacent edges of the battens which may jeopardize the safety of the track. The price is also an issue, and this is the one of the ecological reasons that tropical hardwoods, although exceptionally durable, are rarely used, and if so, only for outdoor tracks.

The generic term and trade name *Siberian wood*, referring generally to *spruce*, *larch* or *pine* (TABLE 31.1), is commercially proposed to indicate the wood material used for tracks in many top velodromes around the world, including the London, Rio and Tokyo Olympic tracks.

Here we report generic characteristics of some wooden species but, as generally known, the geographic and/or genetic variations in the physical and mechanical properties of wood should also be considered for effective wood utilization.

Siberian larch, which comes from northern provenances, and could be *Larix decidua* (common larch that grows in vast areas of Russia) or *Larix sibirica* is used the most. Larch has superior mechanical properties to spruce or fir but swells and shrinks to a somewhat greater extent and contains larger amounts of extractives. Resin pockets or veins must be either repaired or excluded from the material. Another timber used is Baltic pine (*Pinus sylvestris*), or spruce (*Picea abies*), that grows high in the Arctic Circle.

Siberian spruce (generally Norway spruce, *Picea abies*) has the strength and flexibility required to shape curved indoor cycling tracks. These technological characteristics are due to the climate and very short growing season of trees in Siberia, Scandinavia, but also in Alpine regions of central Europe, which create dense, straight wood with tight growth rings and consequent high stability, low shrinkage and restrained swelling deformations. Slow growth and high-density spruce may come knot-free in the first 4-8 meters of a trunk and adequately compete with larch or pine for the purpose. Siberian pine (*Pinus sibirica*) is famous for its ability to bend into new shapes without splintering or breaking while still maintaining the strength needed to build an Olympic level cycle racing track.

Reputed to be the fastest surface for racing on in the world, Siberian pine can be affected by changes in temperature and humidity which cause the wood to warp. Velodrome tracks need to be flawless to achieve the best results in competition. Even small bumps or irregularities can make a track impossible to race on, which means that conditions must be perfect for wood before track construction can begin.

Siberian pine (*Pinus sibirica*), Siberian larch (*Larix sibirica*) and Baltic pine (*Pinus sylvestris*) have recently been assessed for The IUCN Red List of Threatened Species (Farjon 2013, Gardner and Chadburn 2016).

The natural durability of pine and larch, which is significantly better than that of spruce or fir, makes them also applicable in outdoor applications, although surface photodegradation and erosion cannot be avoided even with those species unless covered by spectator stand roofs.

Hardwoods are rarely used for several reasons, not the least of which is the sustainability of the source, but they do not tend to function well in an indoor environment due to low dimensional stability and the tendency to dry and splinter if attention is not paid to humidity and temperature. Hardwoods can also be very difficult to bend into shape on a velodrome, and they produce massive forces that distort the track as they expand and contract (Douglas 2012).

In the case of the velodrome built at the Omnisport Apeldoorn for the 2018 UCI Track Cycling World Championships, the architects chose to work with a chemically modified wood material, also known as acetylated wood (Mantanis 2017), instead of Siberian wood. Modified wood exhibits significantly better dimensional stability than native wood. Architects believe that this kind of material highlights a smooth texture that makes the surface a very fast track. In addition, they think that the finished track has fewer seams than a standard velodrome, meaning cyclists will benefit from less resistance and fewer frictional losses in speed. Modified wood material was also used for Athens, Mexico City, Tbilisi and Majorca velodromes.

TABLE 31.1 Important technical properties of wood species commonly used for cycling track construction.

Common name	Scientific name	Density ρ_{12} (kg/m^3)	Durability class (EN 350:2016)(4)	Bending strength(4) N/mm^2	MOE Bending(4) N/mm^2	Total shrinkage(5) % rad (5)	tang (5)
Siberian larch	*Larix sibirica*	641-779(1)	2-3 Moderately durable to durable	-	-	-	-
	Larix decidua	540-620(4)	3-4 Slightly to moderately durable	88-100	10,600-14,500	3.3-4.3	7.8-10.4
Siberian pine	*Pinus sibirica*	386(2)	3-4 Slightly to moderately durable				
Baltic pine	*Pinus sylvestris*	510(3)	3-4 Slightly to moderately durable	79-100	10,800-13,000	3.3-4.5	7.5-8.7
Spruce	*Picea abies*	300-450-600(4)	4 Slightly durable	65-77	10,000-12,000	3.5-3.7	7.8-8.0
Afzelia (Doussie)	*Afzelia pachyloba, A. bipindensis*	740-930(4)	1-2 Durable to very durable	110-150	12,200-17,700	2.2-3.0	3.6-4.4

(1) Koizumi et al. (2003); (2) Jankowska et al. (2017); (3) www.trada.co.uk; (4) Sell (1997); (5) Wagenführ and Scheiber (1974)

REPAIR OF HISTORIC TRACKS - THE EXAMPLE OF MASPES VIGORELLI

The Maspes-Vigorelli velodrome has been one of the most significant sports structures in Milan for nearly a century. Due to its role in the history of cycling, partly earned by its central European location, it presents an iconic sports object and emotional symbol for all Italians, but also for cycling fans around the globe.

The idea to build a semi-covered *pista* in Milan was born by Giuseppe Vigorelli, an ex-cyclist, in view of the upcoming 1936 Olympic games. The new premises were inaugurated on October 28, 1934 with a wood track designed by German architect Clemens Schuermann. Today, Vigorelli is a unicum in the world panorama of velodromes, for the period of its realization (1932-1935), as well as for its dimensions (the track is 397.76 m long). The first in a long series of records was set by Giuseppe Olmo on October 31, 1935, who covered 45.090 m in an hour. During the War, the object suffered significant damage throughout bombardments in 1943 and 1944 but was restored and re-opened for competitions in the spring of 1946. After the achievement of Olmo, Vigorelli became an ideal place for a total of 9 hour-records: Maurice Richard (1936), Frans Slaats, Maurice Archambaud (1937), Fausto Coppi, Jacques Anquetil, Ercole Baldini (1956), Roger Rivière (1957 and 1958), to be followed with an unapproved record by Anquetil (1967) and two trials by Francesco Moser (1986). In all, Vigorelli hosted more than 150 world records in various disciplines (Di Franco 2014). After years of abandonment, the track of the velodrome became the object of extensive restauration that was completed in 2016. In 2013, the velodrome came under the auspices of the Ministry of cultural goods and activities of Italy (currently the Ministry of culture) which prevented the demolition of the building (FIGURE 31.1).

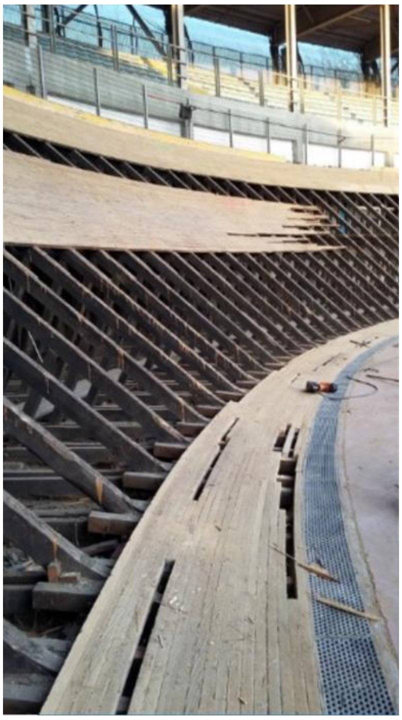

FIGURE 31.1 Track of the Vigorelli velodrome during its restauration phase, completed in 2016 (image A. Galbiati).

Due to severe degradation by exposure to excessive humidity or exsiccation, the current track was refurbished in 2016 by replacing ca 20 % of the pre-existing boards and by restoring the remaining wooden elements (FIGURE 31.2). The principal problems to be solved during the restauration concerned the consolidation of the load-bearing segments and fixing of the track plane.

Every batten is a 5x5 cm section, laid in multiples of 80 cm up to a maximum width of 400 cm. The complete surface was coarse sanded and cleaned with a pressure washer, to be finally disk-sanded with a 40-grit size paper. The current wooden track consists of 4.5 x 5 cm thick spruce (*Picea abies*) battens from Val di Fiemme (Trentino Region, Italy), while the original track was completely built of Siberian pine. The track is supported by a framework of 496 triangular trusses of the same wood species (never in contact with the ground) with varying inclinations from 12.5° to 42.5°, based on concrete blocks. Two longitudinal slots situated at the sides of roof trusses that bear the track, enable the natural circulation of air, so excessive drying or the presence of humidity may be eliminated. The surface has been sealed with highly elastic, silane-based putty, with excellent fissure-filling properties and mechanical resistance.

Finally, the surface has been treated with non-film-forming, water-based impregnation to render the wood material hydrophobic and more resistant to weathering (FIGURE 31.3).

FIGURE 31.2 During the restauration of the Vigorelli velodrome track, around 20% of the boards were replaced and the remaining wooden elements were restored (image A. Galbiati).

FIGURE 31.3 Final aspect of the refurbished track of the Vigorelli velodrome (image A. Galbiati).

CONCLUSION AND PERSPECTIVES

Wood remains the dominant material of choice for indoor cycling tracks for its advantages over other materials. It enables the best combination of functional properties such as good friction and low rolling resistance, is easy to maintain, repair or replace, is favorable regarding the ecological and economical values and is highly esteemed from the aesthetic and traditional point of view. The variety of wood species offers a wide selection of options and the optimum choice of the species for the purpose regarding wood provenance and specific species' qualities, even in outdoor applications. The use of chemically modified wood and modern surface treatments may reduce the significance of some technical disadvantages of wood, such as hygroscopic sensitivity and low surface durability, which will contribute to the future development of cycling track technology and the popularity of this sport.

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SECTION III

WOOD IN NON-OLYMPIC SPORTS AND GAMES

Wood and slate under cloth

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INTRODUCTION

Billiards is a generic set of games to be played with a cue stick where the purpose is to hit balls that move around a table (bed) covered with a cloth to travel smoothly where they are forced to be contained by means of elastic bumpers positioned on the outer profile of the table, which are called cushions.

The most played billiard specialties today are snooker, pool, carom, 5-pin billiards and Russian pyramid. All of these specialties are played with a cue stick. From these basic disciplines, lots of different local or regional variants are available. Both the table and cue sticks are different in terms of size, mass and wood species used. Billiards can be considered both a game and a status symbol. In the former case, billiards were manufactured in industrial facilities while in the latter, highly skilled craftsmen manufactured unique pieces of art (Figure 32.1).

Figure 32.1 Mauro Rogai, the second generation of Rogai Billiards, in his workshop in Florence in the early 1970s (image G. Rogai).

THE TABLE

The table is composed of several parts, the main ones being the legs, bed, cushions and cloth. A billiard table is made from a minimum of 15 parts, in the simpler case, and up to more than 40 parts, for more complex structures. An example of a modern billiard table made of tulipwood that is under construction and is to be finished with a varnish is shown in Figure 32.2. The parts are assembled together with high strength bolts in order to guarantee a strong and stable connection. The bed is made of slate and self-tapping wooden screws are used to fix it to the wooden frame. The wooden frame must be made with a strong, rigid and high-density hardwood for the screws to hold and guarantee the necessary performance. The individual parts composing a billiard table are discussed hereafter.

FIGURE 32.2 The EMI 54 billiard table under construction in the Rogai workshop (image G. Rogai).

The legs can have different shapes (pyramidal, turned, parallelepiped) but the main driver is the design. It means there is no usual shape for the legs, but the table designer defines the shape thinking about aesthetics and to avoid disturbing the players during the game. The height of the legs is calculated according to the whole design of the billiard table in order to bring the bed to a height of 80 cm.

There is no special wood used for the legs, and they can be made of different materials to wood. Wooden legs reinforced with other materials such as steel are also available. The wood used for the legs, together with the designed structure, must just guarantee the mechanical performance needed to sustain the upper part of the billiard table. Depending on the type of legs, different types of wood may be more suitable for the construction: for legs with a transparent finish, walnut, oak, ash and mahogany are the species used most frequently; for varnished legs, usually beech, lime and tulipwood are the most frequently used species. Precious wood or special figures can be used to improve aesthetics depending on the buyer's preferences, either as solid wood or as veneer or inlaid panels. A rigid and sturdy billiard table structure is required, and the legs play an important role in this part, to ensure precise and permanent positioning of the bed, which must be perfectly level and stable over time.

The frame is one of the most important parts of the billiard table that must ensure the perfect alignment of the playing surface that in modern billiards is made of several assembled parts of thick slate. The various game specialties have different bed sizes, which can be made from a minimum of three slate plates up to five slate plates for Snooker and Russian Pyramid specialties.

The mass suspended over the legs varies according to the different specialties and to the rules defined by the different federations: 300 kg for Pool, 700 kg for Carom and 5-pin Billiards, 900 kg for Snooker and Russian Pyramid.

Different species of wood, of temperate or tropical origin, are used for the construction of the frame. Among others, the main species used are Scots pine, Mahogany, Ramin, Ash, Tulipwood and Beech. Several engineered wood products are also used, such as glue laminated panels (especially Beech wood) or laminate veneer lumber (LVL). The chosen material must guarantee the required strength, rigidity and hygroscopic stability to keep the bed perfectly aligned and allow long-term levelling of the bed itself. The main species of wood and engineered wood products with their corresponding physical and mechanical properties are shown in TABLE 32.1.

TABLE 32.1 Main physical and mechanical properties of wood species and engineered wood products commonly used for billiard table frames. The properties are extracted from Ruffinatto et al. 2017 when the species is marked with [1], from the Wood Database website (https://www.wood-database.com) when marked with [2], from the datasheet of the BauBuche S/Q panel from the Pollmeier website when marked with [3] (Pollmeier 2021). MOE refers to bending.

Wood species	**Density** (kg/m^3)	**MOR** (MPa)	**MOE** (GPa)
Scots pine (*Pinus sylvestris* L.)[1]	520	97	12.9
European walnut (*Juglans regia* L.)[1]	670	117	11.8
American walnut (*Juglans nigra* L.)[1]	620	102	12.0
Cuban Mahogany (*Swietenia mahogany* (L.) Jacq.)[2]	600	74.4	9.31
Honduran mahogany (*Swietenia macrophylla* King)[2]	590	80.8	10.1
Ramin (*Gonystylus* spp.)[2]	660	120.1	15.6
Beech LVL[3] - BauBuche Pollmeier	800	80	16.8

Modern Billiards is a sport with ancient origins and the first playing tables were made of wood and not slate. They were also covered by a cloth. To ensure the necessary stiffness, strength and hardness, high quality beds were made of high-density hardwood such as walnut or ash. Lower density species of wood such as poplar were also used to allow easier machining and polishing. During the 19th century, beds were also manufactured with marble, which was replaced by slate at the end of the century. In modern times heat resistors have been introduced under the slate surface to allow a fast reduction of the moisture content of the cloth just before playing and smoother ball travel.

The cushions are made of vulcanised rubber whose physical and mechanical properties are strictly defined by the various federations. Cushions are supported by solid wood elements whose height varies between 4.5 and 5 cm according to the height of the cushion to be used. This part is typically made of beech or tulipwood and is fixed to the upper rails. The upper rails are made of the same species used to manufacture the billiard table.

Billiard tables can be finished in very different ways according to the manufacturing process. When high-quality solid wood is used, it is finished with transparent varnishes to highlight the beauty of wood. A transparent finish is also applied when the surface is veneered with precious wood species such as cherry, mahogany, walnut or ebony, or when special veneers such as Burl or Curly or Birdseye or quilted figures from different species are used. Billiard tables can also be finished with multilaminar dyed wood veneers such as those manufactured by Tabu or Alpi. Sometimes, billiard tables are finished with a pigmented varnish that prevents the wood from being seen, and in this case cheaper types of wood or engineered wood products can be used. For solid wood billiard tables, the most used species are walnut and oak, but tulipwood and ash can also be found. In high-quality billiard tables, walnut is often used, even if covered by other species. Prior to being used, the wood must be dried to below 10% moisture content as for conventional indoor applications. A finished billiard table can be seen in FIGURE 32.3.

FIGURE 32.3 The EMI 54 billiard table installed in a games room (image G. Rogai).

CUE STICKS

In modern times, most cue sticks are made from two parts (butt and shaft) of similar length that are connected together. The one-piece cue stick can still be found in the Snooker specialty and three-part cue sticks are also available on the market. The length of the cue stick varies between the different specialties from a minimum of 140 cm to a maximum of 165 cm. Longer cue sticks are often used for the Russian pyramid specialty. Today, most cue sticks are still made of wood or by engineered wood products, but the evolution of the market has led to the diffusion of glass and carbon fibres as well as aluminium. Different model of cue sticks can be seen in FIGURE 32.4.

The butt of the cue stick has no special mechanical function but must allow the cue to be handled and the mass of the materials used must allow the cue to be balanced. The main factor in choosing the material for the butt, once the balancing criteria has been met, is aesthetics. For high value cue sticks, precious or figured species of wood such as burl, olive, ebony and rosewood are used. For more standard, high-quality production, the most used species are maple (especially for pool) and ash (especially for snooker). The butt can also be made of different parts assembled together by epoxy resins. The butt is produced by turning and usually finished with a transparent varnish. Special varnishing effects, colour fading, decals or screen printing can also be applied.

The shaft needs good mechanical performance and a straight grain. It requires careful selection of the material and usually the first cut is made by splitting the material along the grain in order to perfectly align the grain to the longitudinal axis of the cue stick itself. When made of wood, the shaft is usually made of maple or ash. Engineered wood products such as LVL can also be used.

The cue stick is optimised for the specialty both by the selection of the right wood and by giving the appropriate taper that results in sections that allowing for appropriate stiffness.

High stiffness is required in pool, and the tip section is usually 13 mm in diameter, while for snooker it is only 9 or 10 mm. For carom and 5-pin billiards, the tip diameter usually varies between 12 and 12.5 mm. These diameters are also a consequence of the diameter of the balls in the different specialties, which allow the player to give the desired effect, when interacting with the ball.

FIGURE 32.4 Exposition of cue sticks in the Rogai workshop (image G. Rogai).

Special shafts can also be requested by players and among those manufactured by Rogai the following species have been used: Pear, Ebony, Ramin and Rosewood. Engineered wood products such as LVL can also be used for this part. As these materials need to be very strong, today they are replaced in most cases by aluminium, carbon or fibreglass. Melamine or phenolic resin can also be used. For the ferrule, which is currently made of PTFE®, an interesting alternative could be resin impregnated and densified beech plywood or LVL. The main wooden materials and engineered wood products discussed above with the corresponding physical and mechanical properties are shown in TABLE 32.2.

Despite the material used, a fundamental point for the cue stick itself is the size, mass and balance. Each player handles a cue stick in a different way, and it can be highly customised in size, balance, taper and the materials used.

A cue stick for Pool has an average mass of 560 g with a balance of 44 cm. For 5-pin billiards, the average mass is 640 gr with a balance of 39 cm. These differences stem from the needs of each specialty to transfer a higher or lower momentum, to direct the ball more or less precisely and to apply effects to the ball during a game. A specially patented biconical cue stick has been developed by Rogai Biliardi to provide a very strong grip.

In memory of Mauro Rogai (1950-2022), master in billiard table manufacturing.

TABLE 32.2 Main physical and mechanical properties of wood species and engineered wood products commonly used for cue stick parts. The properties are extracted from Ruffinatto et al. 2017 when the species is marked with [1], from the Wood Database website (https://www.wood-database.com) when marked with [2], from the datasheet of the Ranprex® products from Rancan website when marked with [3] (Rancan 2020).

Wood species or EWP	Density (kg/m^3)	MOR (MPa)	MOE $_{bending}$ (GPa)
Cue stick part: Shaft			
Maple (*Acer pseudoplatanus* L.)[1]	640	100	13.0
Ash (*Fraxinus excelsior* L.)[1]	700	113	12.9
Gaboon ebony (*Diospyros crassiflora* Hiern.)[2]	960	158.1	16.9
Ramin (*Gonystylus* spp.)[2]	660	120.1	15.6
Pear (*Pyrus communis* L.)[1]	680	83	7.8
Possible replacement of cue stick parts: Ferrulae			
Resin impregnated and densified beech LVL[3] - Ranprex®	900-1100	150.0	14.0
Resin impregnated and densified beech plywood[3] - Ranprex®	900-1100	130	9.5

ACKNOWLEDGEMENTS

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Rolling on wood… to strike wood!

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INTRODUCTION

The game of bowling can be traced back to approximately 5200 B.C., when ancient Egyptians used stones as balls. According to the International Bowling Museum and Hall of Fame, a British anthropologist discovered evidence of bowling items in an Egyptian grave in the 1930s.

Primarily an outdoor sport until around 1840, bowling was called the game of ninepins and popular with gamblers. To put a stop to gambling, the state of Connecticut banned the game in 1841, which led the newly indoor lane owners to add one pin to their alleys to circumvent the law.

New York had the first indoor bowling lanes built and one of the most famous Americans that enjoyed bowling was Abraham Lincoln. Although he was considered an awkward bowler, he liked the game (Busey 1895).

Clubs tried organizing and creating set rules, but it wasn't until 1895 when the American Bowling Congress came together at Beethoven Hall in New York City and established a maximum score of 300 which still stands today. Other rules, such as lane length, widths, and distances between pins were also determined.

The use of wood in bowling is dated to 1862 when the use of wooden bowling balls started instead of balls made from rock. According to multiple sources, the modern bowling ball was invented on December 29th, 1862.

The equipment used in modern bowling includes: bowling ball, tote bag and shoes. The most important equipment for this sport is the ball. The weights of bowling balls can vary from 4 kg to 7.2 kg and the players should choose the heaviest ball they can handle. However, young players should not use a ball heavier than 5.5 kg (University of Missouri 1914).

WOODEN BOWLING BALL

A bowling ball is a hard spherical ball used to knock down bowling pins in the sport of bowling. Balls used in ten-pin bowling typically have holes for two fingers and the thumb. Balls used in five-pin bowling, candlepin bowling, duckpin bowling, and kegel have no holes, and are small enough to be held in the palm of the hand.

Wooden bowling balls were used for almost five decades. Bowling balls were made of lignum vitae (*Guaiacum officinale* and *G. sanctum*) until the introduction of rubber balls. Lignum vitae, also called palo santo, guayacan, and holywood, is a hardwood from Central America and northern South America.

Lignum vitae is hard, durable, and is also the densest wood traded (basic density: 1060 kg/m^3). On the Janka scale of wood hardness, lignum vitae ranks highest in traded wood. Unfortunately, lignum vitae has been exploited to the brink of extinction and is now an endangered species. Lignum vitae was among the very first species to be listed as endangered by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) back in 1975.

LAMINATED BOWLING PINS

Bowling pins can take a severe beating during service and may fracture before their desired service life. Pins are given a life expectancy in "lines". A line is a complete ten-frame game by a bowler. Two thousand lines is desired for a pin (Kyanka 1994).

Another interesting fact is that a pin is shaped so that the mass of the head and the base resonate through the neck to give the familiar and pleasant sound produced when the pins are struck by a ball. The frequency is in the mid-2,000 Hz range. The propagating crack in the neck region can alter the resonance and cause the pin to sound "dead" or make a clanking noise when struck, requiring it to be replaced.

Pins are made from laminated boards to expose the impact surfaces to forces that are distributed to a combination of radial and tangential faces, thereby lowering the possibility of a deep split from developing. The lamination process uses over 20 pieces for a pin. The boards are glued with urea-formaldehyde resin (Kyanka 1994).

Bowling pins have also contributed to preserving forests. In 1912, the Forest Products Laboratory (FPL) conducted a series of experiments on laminated pins (FIGURE 33.1).

FIGURE 33.1 Strength tests conducted by Forest Products Laboratory researchers on bowling pins (image courtesy of US Forest Service - Forest Products Laboratory).

The data collected from the strength tests performed by FPL resulted in standards that are still in use. The "United States Bowling Congress (UBSBC)" and its "USBC Equipment Specifications and Certifications Manual" cites: "Gluing procedures should conform to those described in the Forest Products Laboratory (U.S. Department of Agriculture) manual entitled 'Fabrication and Design of Glued Laminated Wood Structural Members.'" (Wise 2015). FIGURE 33.2 shows a glued bowling pin fabricated by FPL that was used in 1700 games on a prominent Chicago alley.

FIGURE 33.2 Original glued bowling pin (image courtesy of US Forest Service - Forest Products Laboratory).

Brashaw et al. (2012) studying possible applications for urban trees attacked by invasive species such as emerald ash borer (*Agrilus planipennis*), Asian longhorned beetle (*Anoplophora glabripennis*), gypsy moth (*Lymantria dispar dispar*) cited that the tree species inside the hard maple group (sugar maple - *Acer saccharum* and black maple - *A. nigrum*) are viable species to manufacture bowling pins and bowling alleys.

WOODEN BOWLING LANES

Bowling alley wood is laminated side-by-side like a butcher-block countertop. Often 2 1/2-inches[52] or more in thickness, the side-by-side lamination gives the wood incredible strength and resiliency. A bowling alley lane is about 63-feet long, and measures 42-inches wide. A single bowling lane includes approximately 22 feet of maple wood and 41 feet of old growth pine (*Pinus* spp.).

Prior to 1980, bowling alley lanes were made entirely of solid wood. Contemporary builders now use a combination of fiberglass, synthetics, laminates and/or other engineered wood products. The products in lanes built after 1980 will not yield the same results for repurposing a lane into a table or countertop.

Bowling alley lanes are often divided into thirds; the first section usually contains sugar or hard maple, pine typically outfits the middle section, while the end section can contain maple or a combination of about 40 linear feet of maple, and 20 linear feet of pine. The breakdown may be different on some alleys with shorter maple sections of about 16 feet on both ends (Wade 2017).

Getting the most use and abuse, maple can take a beating and be sanded and finished multiple times. Because pine is more affordable and less dense, it is often chosen for the middle of a lane where it receives less use and abuse than maple. Pine does not tolerate repetitive refinishing processes. Older bowling alley floors were different, using pine harvested decades ago. Old growth pine, taken from the center of the tree is harder and denser than ordinary pine with a straighter grain.

52 This book uses metric units, yet bowling measures are commonly referenced in English units. It has therefore been chosen to also use English units in this chapter (1 inch = 2.54 cm; 1 foot = 30.48 cm; 1 yard = 91.44 cm; 1 ounce = 28.35 g; 1 pound = 0.45 kg).

Contemporary pine is milled from smaller trees and is not as strong in comparison. The age of the pine or its quality may be hard to determine without extensive research. Walnut (*Juglans nigra*) is another wood component of bowling alley lanes. Often inlaid as markers, the dark chocolate color provides a direct contrast to the amber color of pine and maple. Reusing these smaller pieces is difficult at best, but they add an interesting element to your project. Properties of the common wood species used in bowling are listed in TABLE 33.1.

TABLE 33.1 Physical and mechanical properties of wood species used in bowling.

Species	**Density** (kg/m^3)	**Compression perpendicular** (MPa)	**Janka hardness** (N)
Lignum vitae	1060	85.4	19,510
Maple	705	54.0	6,450
Pine	672	50.1	3,070
Walnut	610	52.3	4,490

CONCLUDING REMARKS

For the time being, there are no wooden bowling balls being used nowadays. Even so, wood is still important for modern bowling. From pin core to bowling lanes, wood is still the most used material in this modernized sport. Lignum vitae was selected to be used due to its unique physical and mechanical properties. When looking back over these 100+ years of using wood in bowling, the need of investments and improvements in the "bowling grade" wood supply is shown. Positive that the new synthetic material has gained the market over time, engineered wooden products are available to continue the historical use of wood in bowling.

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In the service of queens and kings

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ORIGIN AND PRESENT OF CHESS

Chess is among the oldest and more widespread mind sports in the world. The origin of chess dates to the 6th century AD when, in India, its predecessor was named *chaturanga*. This can be translated into "four divisions of the military", from which the chess pieces pawn, knight, bishop, and rook derive (FIDE 2009). Over time the name evolved, until the Persian denomination *shah* (king) became the modern term *chess*. The rules of chess also evolved over time, and by the 15th century AD chess had acquired the form that has substantially arrived in the present day. During the last decades computer science has greatly impacted on the world of chess. Playing software has grown ever stronger, online games have become widespread at a global level, and games played in person on electronic chessboards can be followed in real time worldwide (Figure 34.1).

The International Chess Federation (FIDE), the governing body of chess, was founded in 1924 and recognized by the International Olympic Committee as a Global Sporting Organization in 1999. Nowadays chess continues to be played worldwide: 195 countries are affiliated to the FIDE, and more than 60 million games are estimated to be played every day [1].

Figure 34.1 Chessboard made of walnut and maple wood, with pieces made of varnished boxwood. Electronic components in the chessboard and in the pieces enable to recognize the moves: the chessboard is connected to a computer so that moves can be displayed on a screen in real time (image courtesy of DGT).

In addition to the recreational and competitive aspects, chess has a relevant educational value. Chess is taught in school programs all around the world, courses are offered to professionals to empower their reasoning skills, and so on. Overall, being skilled in chess is perceived as a value.

Chess pieces and chessboards can be made of varied materials: plastic, bone, clay, marble, glass, wood, etc. Among these, wood can arguably be defined as the most important, considering its tradition, diffusion, and aesthetic value. Many examples could be chosen to confirm this, one being the expression "woodpusher". This is used among chess players to ironically depict someone who, without any strategy, plays by just pushing the pieces. The fact that the term *wood* is used in such an expression is emblematic of the strict connection between wood and chess. In this sense, one can also note that in chess software, the moves and captures of pieces are often accompanied by the wooden sounds that are so familiar to chess players.

WOOD IN THE FIDE RULES

Wood and wood species are repeatedly mentioned by the FIDE handbook (FIDE 2018), which prescribes that "Chess pieces should be made of wood, plastic or an imitation of these materials". According to the handbook, the natural color of wood can be exploited to make white and black pieces: "The 'black' pieces should be brown or black, or of other dark shades of these colors. The 'white' pieces may be white or cream, or of other light colors. The natural color of wood (walnut, maple, etc.) may also be used for this purpose" (FIGURE 34.2). Similarly, the natural color of wood can be exploited in chessboards: "Natural wood with a sufficient contrast, such as birch, maple or European ash against walnut, teak, [...] may also be used for boards, which must have an opaque or neutral finish, never shiny". It is worth of note that wood is indicated as the material of choice for the most relevant competitions: "For the World or Continental top level competitions wooden boards should be used. For other FIDE registered tournaments, boards made of wood, plastic or card are recommended".

WOOD IN CHESS PIECES

Wooden chess pieces are typically handmade on a lathe. Additional details, such as the knight's mane, are sculpted afterwards. Metal weights can be included into the bases of pieces to lower their center of gravity and improve their stability, and the bases can be overlaid with wool felt.

A wide variety of wood species is used to make chess pieces. Typically, noble hardwoods are used, such as maple, walnut, boxwood, rosewood, sheesham, ebony, etc.

FIGURE 34.2 Staunton style set in which the natural color of wood is exploited to distinguish between "black" and "white" pieces (image courtesy of DGT).

The use of noble hardwoods can be attributed to various reasons. A relevant element lays in the high symbolic value of the "game of kings", which possesses a traditional and intellectual image that encourages the realization of valuable chess sets. It is not by chance that chess sets are often displayed in homes as valuable, elegant furniture pieces. The same is valid for tables with chessboards embedded into the top (FIGURE 34.3 left), whose crafting can also reach cabinetry levels.

The choice of the wood species is also related to technical reasons. As above mentioned, color contrast is required by both pieces and squares. Choosing wood with fine texture also enables the precise sculpting of the details, as in the case of the knight's eyes. Finally, denser wood also enables stabler pieces.

As for the style of the pieces, *Staunton* (FIGURE 34.2) is the most widespread, and noteworthy is that the FIDE handbook recommends the use of such style in competitions. The FIDE also recommends the height of the pieces (from 9.5 cm for the king, to 5 cm for the pawn), and that the diameter of the base is 40-50% of the height of the pieces. However, several styles of pieces are on the market, the limit being the imagination. An example are the chess sets inspired by the 1972 World Chess Championship, played by Fischer vs. Spassky, and known as the "Match of the Century". Another example is that of chess sets inspired by the *Queen's gambit* series. Handcrafted and artistic wooden chess sets with unique design, and often of high value, shall also be mentioned here.

WOOD IN CHESSBOARDS

Wooden chessboards can be made of solid wood or of a supporting wood-based panel overlaid with sliced veneers. The broad range of the above-mentioned noble hardwoods is also used in chessboards (several models of wooden chess clocks also exist). Of note, the wood species of a chessboard are not necessarily the same as the pieces placed on it. The size of the squares shall be proportioned to the base of the pieces; the FIDE handbook recommends 5-6 cm long square sides.

Electronic boards are made of an inner supporting wood-based panel (MDF or plywood) that is milled to reduce the overall weight and to fit the electronic components. An antenna foil is sandwiched between the core and a thin carrier panel, on top of which the checkered, high-quality veneers are applied. These boards detect and recognize the chess pieces and their movements, thanks to the communication between the antenna foil inside the board and resonators embedded in the electronic chess pieces. The moves can be displayed on screen in real time through USB or Bluetooth connection.

Finally, an interesting detail can be found in chessboard squares that purposely show fiddleback grain (FIGURE 34.3 right). This is an aesthetic effect that results from the wavy grain of timber: after sawing or slicing, shiny waves can be seen on the surface of wood due to the different incident angle by which the light hits the wood grain.

FIGURE 34.3 Left: table with an embedded chessboard; the chairs, table, chessboard, and pieces are made of wood (image courtesy of Società Scacchistica Torinese). Right: waves of fiddleback wood displayed in the light-colored squares and oriented perpendicularly to the grain of the dark squares to further enlarge the contrast between squares (image F. Negro).

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ALL THAT WEIGHTS IS NOT (ONLY) WOOD

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INTRODUCTION

The game of wooden bowls with weights can be considered a vernacular variant of the sport of bowls, widespread in a fairly limited geographical area of the Tuscany Region, in Italy (especially between the provinces of Florence and Arezzo). Currently, it seems that this sport is no longer played, but the testimonies and the "cultural background", as well as the interest in this sport are very strong and diffused in the territory. Many "traces" still survive today.

HISTORICAL BACKGROUND

The origins of the game of bowls are very ancient (Di Chiara, 1997): it is probably one of the first playful activities practiced by man and dates back to the Stone Age. Obviously the first "equipment" used were rounded stones, perhaps collected inside a riverbed. The first findings of rounded stones by man date back to 7000 BC, in the city of Catal Hüyük close to Konya, in southern Turkey. There are also several testimonies of the game of bowls in ancient Egypt (at least starting from 3550 BC), as well as in the ancient Greek and Roman civilizations. In particular, during the excavations of the Archaeological Area of Pompeii, eight perfectly smooth stone spheres and a jack were found inside a room, which led to the name of this place being called a "bowl court".

Two innovations in the practice of the game are probably due to the Ancient Romans:

1) the transformation of the game of bowls into a skill game, rather than of a matter of strength;

2) the introduction of the use of wooden bowls, in particular, made by poplar and olive timber (www.boccecaudera.com). Further evidence of the use of wood in this sport is also found in an English miniature from the 13th century, where clay spheres were also used in addition to wooden ones. In the same period in Florence, people gathered to play bowls with wooden balls in Piazza delle Pallottole (this square still exists now, very close to the Cathedral of Santa Maria del Fiore): the city authorities in fact encouraged the practice of this sport, considered "quieter" than other gambling games, which created problems of public order due to related bets (such as the game of dice).

THE GAME OF WOODEN BOWLS WITH WEIGHTS

The game of wooden bowls with weights has some peculiarities, which distinguish it from that of the most common bowls:

- the larger dimensions of the spheres, which could even reach 30 cm in diameter and weigh up to 15-16 kg;
- the presence of a lateral weight, consisting of metal (iron or lead) inserted inside the wood;
- the playing field, made of clay or sand, which has a "trench" at both ends (where the balls must not fall, otherwise they are considered lost); moreover, in some cases the playing field also presented a slight "U" section, with raised lateral sides. These peculiarities, associated to the presence of an asymmetrical weight inside the spheres, make the setting and execution of the trajectories more complicated, ingenious and unpredictable;
- the wood species utilized for the bowls, generally made of solid wood, belonged to the genus Sorbus (*Sorbus* sp, Viccaro 2006) or, more frequently, to holm Oak (*Quercus ilex*). Holm oak was much appreciated due to its high density (960 kg/m^3 at 12% MC)

and hardness, which made it suitable for turning and highly resistant to wear;

- the bowls were conserved by dipping them in water to prevent the appearance of shrinkage cracks and deformations.

To have an idea of the wide diffusion of this sport in Tuscany, consider that there are several pictorial representations dedicated to the practice of this game. In particular, the two most famous paintings have the same title ("The game of bowls") and were made in the same year (1889): the first painting, by Ruggero Focardi, is exhibited in Florence, Modern Art Gallery - Palazzo Pitti), while the second one, by Raffaello Sorbi is part of a private collection (FIGURE 35.1). In both paintings some players engaged in a game of bowls with the background of the typical Tuscan countryside were depicted, with a wealth of details typical of the realism / verism style. These two paintings show that this game was already widely practiced at the end of the 19th century, but the discovery of a bowl with a weight characterized by a clearly "ancient" feature, suggest that this variant of the game had been present in Tuscany for a long time.

FIGURE 35.1 “Il gioco delle bocce”, (The game of bowls), by Raffaello Sorbi, 1889. Private collection, courtesy of M. Salamon (image courtesy of Matteo Salamon).

THE PREPARATION OF BOWLS WITH WEIGHTS

The timber collecting for the preparation of bowls was generally linked to the felling of individual isolated trees, located in gardens, parks, or in any case close to houses (sometimes too close to buildings.... with some risks for the residents!). The basal logs were brought to the sawmill to obtain, by means of a band saw and after seasoning, a prismatic "draft" that was finished by lathe; the turned surfaces were then further refined by sanding with progressively finer grit. To add the weight, a (non-through) hole was drilled along a radius and molten lead was poured into it. Craftsmen took care to add more or less lead to obtain bowls with a very similar final weight.

Prior to competitions, the bowls were kept constantly immersed in water to avoid cracks or deformations occurring, due to the shrinkage of wood. The decision of when to take them out of the water depended on the weather conditions (more or less warm and dry), usually between 24 and 2 hours before the start of the match.

RULES OF THE GAME

The matches were played by two teams generally made up from 2 to 8 players, with 4 bowls per each team marked with signs to recognize who they belonged to (FIGURE 35.2 and 35.3). The aim of the game was to place as many bowls as possible close to the jack (or to the trench on the opposite side from the throwing area). The team received one point for each bowl placed in a better position than the opposing team and the score needed to win was 6.

FIGURE 35.2 The game of bowls with weights, Bar Tangocci, province of Florence, 1950s (image courtesy of Bar Tagnocci).

The presence of the unsymmetrical weight inside the bowls, combined with the non-flat field, allowed the bowl thrown by a player to drive through the court on the sloping side and only descend near the jack, thus bypassing the opposing team's bowls; the best players were able to draw very complex trajectories. Obviously, opponents' bowls were allowed to be hit by a teammate, but due to the big size, it was a complex option.

The throwing order and the number of bowls to be assigned to each player, was defined on the basis of a preliminary throw towards the jack (or trench): the player who came closest could throw first and, in the case of an odd number of players, the team with the fewest players would start.

At the same time, however, the player who made the best preliminary throw earned one point for his team.

The evidence of the practice of this sport dates up to the early 90's of the last Century; unfortunately, no active sports-clubs currently play wooden bowls. In the historical documentation of the Italian bowls federation, no official references to this sport are present, confirming that it was a "variant" present in a limited geographical area and that the practice of it was not subject to an official regulation.

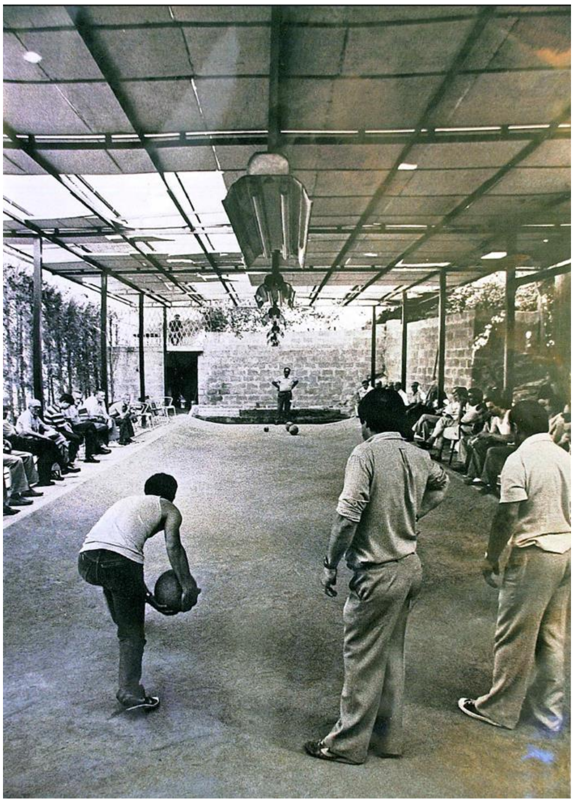

FIGURE 35.3 The game of bowls with weights, "La Torretta" club, province of Florence, 1980s (image courtesy of Circolo La Torretta).

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SECTION IV

CONCLUSION

It is hard to draw a conclusion for a book that deals with such a vast topic as the one considered here. In fact, the size of the theme was clear to me when I prepared the book project and submitted it to the World Wood Day Foundation. Nonetheless, its vastness has become more and more impressive during the drafting of the book. While discussing the content of the chapters with coauthors, who I thank once again for their valuable collaboration, the common challenge of staying concise arose several times. During such talks we repeatedly commented that we were writing a book, but an encyclopedia would have been needed instead.

It therefore seems appropriate to conclude this book by looking at why this topic is so extensive. In short, I believe there are three main reasons, quite evident indeed: wood and sport are vast worlds, they have widely interacted over the ages, and they are of key importance to humankind. It is not surprising that such conditions have given shape to a universe, made of tradition, passion, know-how, innovation, diversity, performance, health, culture, and so on. It is fascinating to see how wood and sport are continuously shaping this universe, and how many paths they are taking year after year.

As a matter of fact, in some cases they have parted ways after a long time. As already mentioned in various chapters, today wood has become residual or outdated in various disciplines, and its future use is in doubt in many others. Synthetic, high-performing materials have in fact gained great space over recent decades. This is surely a relevant challenge to the future interaction between wood and sport. Nonetheless, in many cases, such interaction is well established and not only: often it goes beyond being well established, and wood and sport continue to deliver great results together. Based on the above elements, a complex and mixed perspective can be envisaged for the years to come, with a broad range of possible evolutions that depend on the disciplines considered. In this sense, the development of innovative, high-performing wood-based composites can have interesting perspectives.

Above all, a new element has strongly emerged over recent years and will likely gain even more importance in the future. Wood and sport have in fact found a pivotal territory to collaborate on: sustainability. This can add new meaning and richness to their universe. While providing their well-known benefits to humankind, they can now join forces to markedly contribute to a more sustainable world. This is a great challenge and, as is often the case, also a great opportunity.

I have confidence in them and am eager to see where they go.

Francesco Negro

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