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How to Score

Science and the Beautiful Game

Ken Bray

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Extract

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INTRODUCTION

Football in today's recognisable form has been played for nearly 150 years. From obscure beginnings it has grown into the world's most popular game, played by 240 million people in 200 countries around the globe. Major tournaments such as the World Cup attract television audiences reckoned in billions, more than for any other sport. The pace of change has been rapid over this period, although many of the innovations that make today's spectacle have occurred in only the last 50 years or so. Some changes have been for the worse. Compared with the Corinthian ideals – that is, the gentleman amateur values – of the clubs who formed the early Football Association in England in the 1860s, football has a harder professional edge wherever it is now played. There was originally no need for referees; captains resolved disputes in amicable discussion despite the fact that the early game was much more robustly physical than today's, and would agree punishments for playing infringements such as deliberate fouls. There were no formal sanctions for foul play originally because no player would set out with such a nefarious purpose in mind. When the penalty kick was introduced in 1891 some goalkeepers would refuse to attempt a save, in protest at their team mate's unsporting behaviour in fouling an opponent to prevent a goal. Compare this with the antics that surround penalty shoot-outs in today's game, or the intimidation of referees who make controversial decisions.

Commercialism more than any other factor has driven the

changes in football at the top level. Anyone who doubts this should look at the financial returns (Deloitte and Touche Sport, 2005) for the 'top five' in European football (the English Premiership and equivalent senior leagues in Italy, Germany, Spain and France). In the 2003–04 season, revenues grossed £3.9 billion. The average figure for Italy, Germany, Spain and France was £638 million each and in England alone it was £1.3 billion, double that of the other four countries. Of the £1.3 billion for the English game, something like 45 per cent was accounted for by receipts from television deals, in what has accurately been called a '100 per cent profit-margin business'. Paying spectators – the fans – contributed £395 million in England through ticket sales. They also bought £100 million worth of replica shirts, a highly profitable merchandising activity given the frequency with which a team's playing strip is changed nowadays.

And yet, despite the cynical commercial aspects of the game, its appeal remains its fundamental simplicity. For most of football's early development in the nineteenth century the innovations were made by relatively few individuals, players and coaches who thought deeply about the game's basic nature. Modern playing formations evolved largely in response to modifications to the early offside rule, still a topic of controversy today. These changes were responsible for transforming the Victorian game from an individualistic, dribbling frenzy into the passing team game familiar to modern spectators. But locked into the very nature of stringing a series of passes together is an iron rule, one of the hidden rules of football that would not be appreciated until quantitative science began to be applied to the game in the 1960s. It is a very simply stated statistical fact: your chances of pulling off a sequence of continuous passes falls away rapidly the longer the movement goes on, and more than six is very rare even at the top level. This statement is often met with incredulity; everyone can cite that marvellous sequence of eight passes, possibly more, that ended with a spectacular goal. The problem is that memory is very selective, and instantly forgotten

is the mountain of dross in the average game involving tedious exchanges where the ball is given away, or won after a single pass or two. It is the quality, not quantity, of the passing and its execution that matters in the final stages. When the pitch is divided into thirds along its length – the so-called defending, middle and attacking thirds – research shows that 80 per cent of all goals result from three or fewer consecutive passes in the attacking third and over 60 per cent are scored from possessions won in this part of the pitch. Most curious of all in the professional game is the ratio of goals scored to shooting attempts. Whenever the ratio is measured the conversion rate comes out at between one in nine and one in ten, but no one knows why this should be so.

Findings like these led to much controversy when many observers refused to accept that statistical chance played any part in such an apparently purposeful game. In 1969, an article by the sports editor of *The Times* summed up the views of the dissenters. Its headline read: 'Pins are better than form on the football pools.' This ridiculed the formal research by drawing a comparison between the scientific findings and the many millions who hoped to win a fortune on 'the pools', a form of gambling where participants had to select eight teams in the English and Scottish leagues that would draw their games. Serious entrants studied past form, but many fortune-winners confessed to picking out the teams blindfold by sticking a pin into the fixture list. The *Times* article rather snidely compared statistical match analysis with pin-sticking but such views were brushed aside by a handful of coaches who were sold on the ideas, and who responded to statistical data on passing by producing the effective, if unappealing, 'direct' or 'long ball' game. This was based firmly on the idea that delivering the ball into the attacking third with as little ceremony as possible was the route to scoring goals, and some teams became expert at this in the English domestic game.

Statistical research was quickly enhanced when techniques drawn from many other branches of science were applied to football in the 1960s, and football science has since become an

essential tool in understanding and developing the game. My own interest in the science that lies behind football began at that time. It seemed to me that the swerving free kick was as legitimate a topic for theoretical physics as problems in quantum mechanics. This spectacular way of beating the defensive wall was just becoming established in the European game following its earlier introduction in South America. What could possibly be going on in the fleeting eight-tenths of a second between the shot and the goal that could modify the ball's trajectory so spectacularly? I consulted one of the England players who had competed in the epic World Cup final at Wembley in 1966. My question was simple: why does the ball so often end up ballooning over the bar when an inexperienced player takes the shot? I was inching towards the idea that spin was the determining factor, implying that top players were using this mechanism, consciously or not, in bringing off spectacular free kicks. He thought for a moment and said, 'It's because the ball is light and full of air, so it loves to rise.'

I was so taken aback by this bizarre answer that I did a simple experiment to discover if there was anything behind his interpretation. All I needed was a pump, a pressure gauge and a sensitive weighing balance. Theoreticians are not supposed to go into the lab as they have a tendency to break things, so I ran the gauntlet of my experimental colleagues and endured much leg-pulling, but the answer was easily obtained. To inflate a match ball to regulation pressure takes only 7 gm of air, less than 2 per cent of the ball's weight. Nor, given its regulation weight of between 397 and 454 gm (14–16 oz), is a ball especially light. Correct inflation is essential for the ball's resilience in a bounce and also in ensuring a regular aerodynamic shape as it speeds through the air, but as far as making it rise is concerned, the air it contains is absolutely irrelevant. The unwanted effect that makes it rise uncontrollably is the aerodynamic force caused by backspin, always to be avoided in a free kick. In the event I ended up little wiser about the science of a swerving shot than my

adviser at that time. The mathematical equations describing the flight of a spinning football were easy to formulate but solving them with 1960s-vintage computers was another matter. And to have accurately measured the ball's position in three dimensions in an experimental free kick in order to test correctly the theory of ball spin would have been a practical impossibility at that time.

The field has grown considerably since the 1960s and while there are still some sceptics who feel that the phrase 'sports science' is a contradiction in terms, others take an enlightened view. In at least one discipline, human physiology – the science of the mechanical, physical and biochemical functions of life – the contribution of sports scientists is vital. Sports commentators often say that the game has become much less physical, meaning that less and less contact is allowed between players competing for possession of the ball. In fact, the opposite is the case: physical contact may be limited but the demands of the game in terms of the stress placed on body metabolism have magnified as the intensity of play has increased. In a match that goes into extra time a midfielder who stays on for the full 120 minutes can expect to run approaching 13 kilometres (8 miles). This is not a jog in the park; throughout that period the player will be operating at an average level of 75 per cent of the body's maximum aerobic capacity, the mechanism responsible for transporting oxygen to the active muscle cells to fuel the physical exertion. This should be compared with a figure of only 6 per cent, which is a fit athlete's resting aerobic energy requirement. For short intensive bursts the metabolism will be stressed beyond the maximum aerobic limit and finite energy reservoirs must be plundered in the muscle groups themselves, so-called anaerobic sources. Professional clubs retain physiologists to quantify these requirements on a player-by-player basis and, more importantly, to determine the nutritional requirements for restoring energy levels, often almost completely drained after hard matches.

Similar examples could be drawn from many related areas in the field. Look at any of the scientific journals dedicated to sport

and you will find contributions from such diverse disciplines as physics, mathematics, biology, physiology, biomechanics, computing science and psychology. Football in all its codes (Rugby football, Gaelic football, Australian Rules football, etc.) is reviewed in the literature, although Association football dominates and the game and players have greatly benefited from this applied research. There is even a World Congress on Science and Football, held every four years since 1987, bringing together all parties with an interest in quantitative research in this field. It was first held in Liverpool, and the venues have been as diverse as Eindhoven, Cardiff, Sydney and Lisbon.

In the chapters that follow I address the broad theme of science and football, starting with football's history, not simply to recount an often fascinating story but to show how the game was shaped by the constraints under which it was originally played. Science is then used to illuminate the evolution of playing tactics and reveal how elite footballers have exploited aerodynamics in producing spectacular free kicks. Football's moves then go under the microscope, starting with the studies that first revealed the energy players expend in various positions, leading to the impact that these findings have had on fitness and nutrition. Another growing scientific field is the psychology of sport. The game is often won or lost in the mind, underlining the importance of correct psychological preparation. Football's basic skills, kicking, heading and throwing, are then reviewed, leading to an analysis of set pieces such as penalties and free kicks, the 'games within the game'. Finally, I take a look at the future; not the distant future but developments on the horizon, such as technology to resolve goal-line incidents and artificial playing surfaces, now making a serious comeback at the top level of football.

Some readers may feel surprised that there is so much to say about science in the development of football. Others might argue that its presence in what Pelé called 'the beautiful game' is an intrusion; football according to this view is an art, and close scientific scrutiny diminishes it as a spectacle. It is an old argument.

The poet John Keats bemoaned Newton's explanation that a rainbow was a mere spectrum of colours, and in his poem 'Lamia' asked, 'Do not all charms fly at the mere touch of cold philosophy?' Philosophy in Keats' era meant science, perhaps not quite the science of laboratories and computer analysis that we recognise today, but his criticism is echoed by modern dissenters and I think it overlooks the great advantages that science can confer. None of the game's grace and purpose is undermined by scientific insights; instead, as football's hidden rules are revealed, our enjoyment can only increase. Let us apply a little cold philosophy to football; the game can take it.

CHAPTER 1

EARLY DAYS – FROM MOB FOOTBALL TO THE GROWN-UP GAME

Football's roots can be traced directly to a raucous, violent game played originally in the towns and villages of medieval England. Four surviving descendants of these early contests give us an idea of what went on. They are the Shrove Tuesday games still played at Alnwick in Northumberland, Ashbourne in Derbyshire, Atherstone in Warwickshire and Sedgefield in Durham. One hundred and fifty years ago the list was much longer and there are records of Shrovetide football at such places as Derby, Scarborough, Whitby, Twickenham and London, to name a few. The ancient game was also played in Wales and the border region of eastern Scotland, and there are accounts of a related game called *la Soule*, played in Brittany and Normandy since the Middle Ages. *La Soule* died out in France towards the end of the eighteenth century, although it has enjoyed a limited modern revival. Football in Italy, *calcio*, has a similar, though younger, pedigree than the English and French medieval games and a traditional form was played in Florence during the Renaissance.

The rules of the Shrovetide matches, played once a year before Easter, were simple. Anyone from the local district could play, with team numbers often counted in the hundreds. In these traditional games goals were easily identifiable landmarks: a door or tree, or the porch of some prominent building. Sometimes

neighbouring parishes competed, as St Paul's and St Michael's still do at Alnwick. In the Ashbourne game, where Up'ards play Down'ards, the distinction has always been one of birthplace. Up'ards are born north of the River Henmore, which forms part of the 'pitch'; Down'ards are born south of it. The goals in this game are stone plinths set three miles apart in the banks of the river, replacements for the original goal markers located at the mills of Sturston and Clifton.

The Ashbourne game has been played since at least the Middle Ages and good records have survived from 1891 to the present day. Browsing the statistics over the years makes interesting reading. Only the countryside restrictions caused by foot-and-mouth disease in 1968 and 2001 have prevented play. Each Shrove Tuesday and Ash Wednesday the ball is 'turned up' (thrown to the crowd) in the Shaw Croft car park and the free-for-all ensues. The game is played between 2 and 10 p.m. each day, the record for the fastest strike (traditionally called a 'goaling') standing at 30 minutes, which in a match lasting eight hours counts practically as a goal straight after the kick-off. There have been three disputed goals over the years, although how such incidents could even be recognised in the chaos of Shrovetide football, when the modern game is still struggling with the technology needed to resolve goal line disputes, is a mystery. There is one recorded 'own goal', in 1972, when a Down'ard gained possession and bizarrely scored for the opposition. His family is said to have ostracised him.

The league table for the 112 years' play is also revealing. The Up'ards just shade it with 75 wins to 71 and have the better goal-scoring record with 118 for, 108 against. Whether some form of transfer system operates is not clear, but perhaps the Down'ards, like Chelsea in the English Premiership, would benefit from a rich patron. Also interesting is the fact that spectators have seen, on average, one goal per game over the years. Not a bad record when one considers some of the sterile, ultra-defensive encounters thrown up by the modern game.

The Ashbourne ball is typical of the historical leather-cased models, but filled with cork to make it buoyant since it, and the players, invariably end up in the river. If you want an image of the traditional game think of a modern rugby scrum hugely expanded, with the ball hidden by hundreds of heaving, shoving bodies. Doubtless the opportunity was taken to settle a few old scores in the general mayhem and it is not surprising that there have been severe injuries, even deaths, over the years.

How football arrived in Britain is not an easy question to answer. The most likely candidate may be the game brought by the roman legions after the conquest in AD 43. Called *harpastum*, this was played with a small ball on a rectangular pitch with a centre line and two baselines. The broad objective was to throw the ball over the opponents' line by passing it from player to player. Tackling was very physical, players wrestling with one another for possession of the ball. There seem to have been recognised positions equating roughly to defenders and attackers and one key player, especially skilled, who was stationed near the middle of the pitch. He was called the '*medicurrens*' ('in-between man') and it is tempting to see his role as that of the modern midfield 'playmaker'. The Shrove Tuesday games may simply represent a primitive attempt to mimic *harpastum* and, if so, would point to a common source for the Shrovetide game in Britain and for the similar game, *la Soule*, in France.

There are claims, though, for more ancient ancestry. W. Branch Johnson, writing in the 1929 *Contemporary Review*, called football 'A Survival of Magic', and argued that the Shrove Tuesday games in England and France were the folk successors of a kind of sun ritual, enacted to ensure success in the harvest. The ball, naturally enough, represented the sun. At Scone in Scotland a goal was scored when one team succeeded in burying the ball in a defined location. The opponents had to 'drown' the ball by dipping it in a river. Both goals are located in the river banks at Ashbourne but at Scarborough the objective was to plunge the

ball into the sea. Branch Johnson associates these actions with the warming of the earth (burying the ball, i.e. the sun) to ensure that seed would germinate and with rainfall to nurture the growing crop (dunking the ball in the river or sea). The struggle for the ball and its return to the home parish is interpreted as a contest to capture the sun, so securing a better harvest.

Today's soccer fans may scoff at these notions and argue that the Shrovetide kick-about was simply an opportunity to let off steam before the fasting and restrictions of Lent set in. We shall never know either way, but what is certain is that the game was firmly established by the twelfth century and played with gusto from the early Middle Ages onwards. The earliest written record dates from 1175 when William Fitzstephen reports a Shrove Tuesday game in London, probably at Smithfields. He calls it 'the famous game of ball' and describes the spectators as 'older men, fathers and men of property'.

There are also glimpses of the game's darker side. In 1280 Henry de Ellington was killed during a game at Ulgham in Northumberland when he and David le Keu collided violently. The inquest heard that le Keu's dagger was sheathed but nevertheless penetrated de Ellington's stomach in the impact. Misadventure was recorded. In 1321 William de Spalding, a cleric, killed his friend in exactly the same way. De Spalding was apparently so contrite that he sought and obtained a dispensation from the Pope. The cynic might question whether sheathed daggers could really have inflicted such terrible wounds and argue that they were in reality drawn, as tempers ran out of control in the violent clashes between the players. The problem was not confined to the English game: there were many similar requests for papal absolution following games of *la Soule* in France, albeit for 'broken heads' rather than stabbings.

This player violence, probable injury to innocent bystanders and certain damage to property prompted many official bans on the sport. These extended from the fourteenth to the seventeenth centuries. Royal proclamations were issued from Edward II's to

Henry VIII's reigns and there were many by what we would now call the local authorities. In a strange twist Edward II was buried in Gloucester Cathedral, close to possibly the world's first image of football, a woodcarving celebrating the game he did his best to suppress.



Fig. 1.1: Traditional footballers, Gloucester Cathedral, c. 1340

The carving (Fig. 1.1) dates from *c.* 1340 and is located underneath one of the seats in the choir, just a few steps from Edward's ornate tomb. It shows two young footballers enjoying the game, an image drawn perhaps from the carver's own experience of football in medieval Gloucester. What is amazing is that nearly seven centuries ago he depicted what the game would become, a skilled and athletic contention for the ball, rather than the mayhem and violence of mob football of the time. This image gives some idea of how much football had become part of everyday life and the popular resentment of all the royal and official edicts that would follow. Richard II's version, issued in 1388, clearly identifies the target groups. It decrees that '. . . servants and labourers shall have bows and arrows and use the same on Sundays and holidays, and leave all playing at ball . . . and other such importune games'.