An Outdoor Game

STRI

Tim Lodge, of the STRI, looks at the science and variables involved in playing the game of golf.

The more I learn about golf the more amazed I am at the enormous number of variables that golfers appear to consider when making even the most straightforward of shots. I think they must assess some of these variables in their subconscious and use an intuitive approach to their game. But there are measurable scientific principles behind almost every link in the chain of events that leads from the 1st tee to the pin at the 18th.

The science of golf is a massive subject area. Research workers in the field include physicists, material scientists, biomechanics specialists, physiologists, psychologists and more, not to mention turf scientists. Volumes have been written, particularly on the more lucrative aspects such as equipment design. Rather less work has been published on the ways in which the turf interacts with play. This is surprising given the controversy that circumstances can often create. In this article, from tee to green, I consider how some turf-related factors can affect the game.

TEE SHOTS

Though not usually a problem at major tournaments, replaced divots can create an unstable and unpredictable surface on which a following golfer's footing could be loosened at a critical point in the swing. It is now accepted that the replacement of divots should not be carried out on tees but that the scars should be immediately filled with a blend of fertile but free-draining soil and seed.

LIE OF THE BALL

When the ball lands short of the green its immediate surroundings determine what shot the golfer will then play. In order to understand the mechanisms involved we need to look closely at what happens at the moment of impact between the club face and the ball.

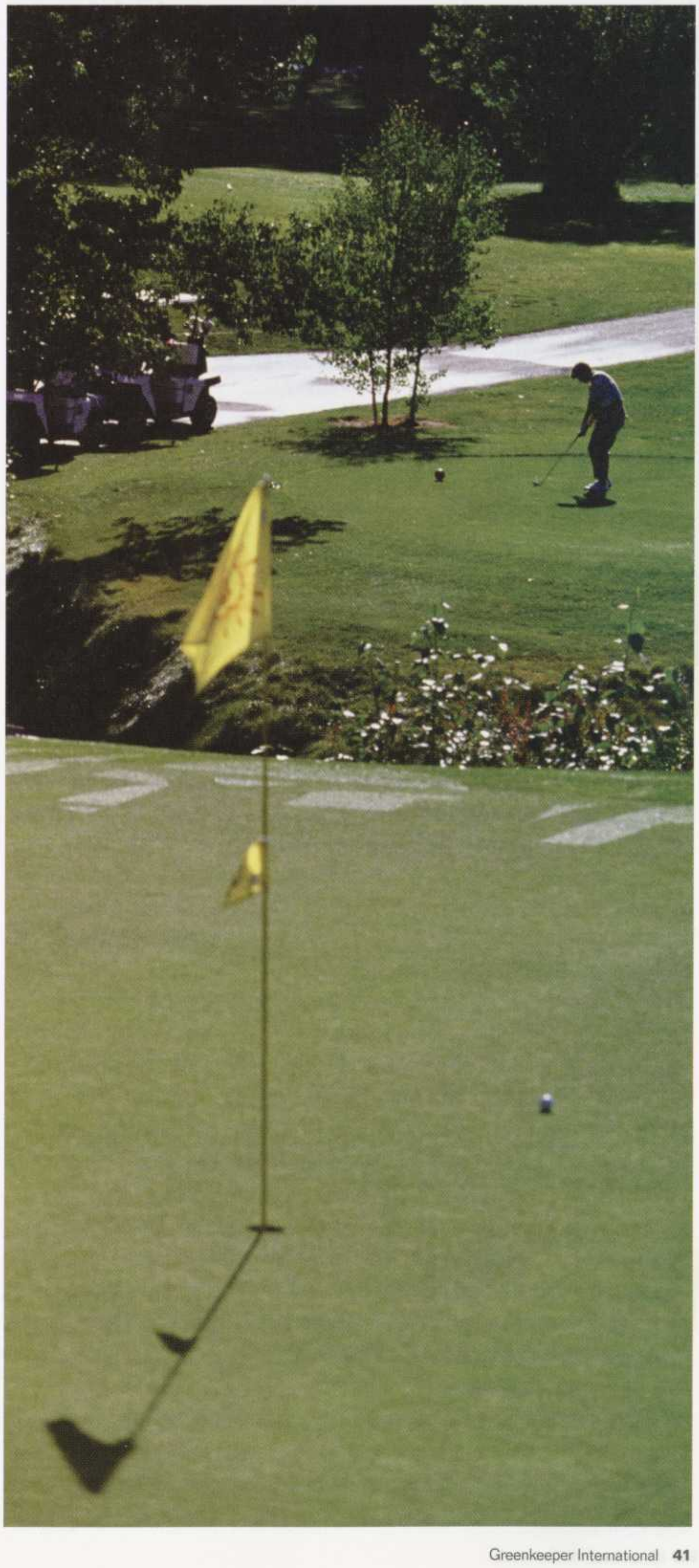
The club passes energy to the ball in two forms: linear (for distance) and rotational (for spin). There is only so much energy available, so the more that goes into rotation, the less there is for distance, and vice-versa.

The angled face of the club can generate spin of up to 8000 rpm. It does this by pressing against the ball slightly below its central point making it rotate backwards towards the club. For a tiny fraction of a second the ball actually climbs up the clubface. The extent to which it does this affects what proportion of the total energy is transferred as spin and what goes into distance. The process is governed by the amount of friction occurring between the two surfaces.

In wet conditions, friction is reduced so balls leave the clubface faster, but with less spin. Especially in the rough, grass leaves may come between the ball and the clubface. This also reduces spin, making such shots especially difficult and less predictable.

The grooves on the clubface help generate spin by increasing friction. Some players maintain that the more modern U-shaped grooves lessen the effects of wet grass on spin, but there has been some controversy over the move away from the more traditional V-shaped grooves. The R & A stipulates the permissible forms of grooves in the 'Rules of Golf' (Appendix II, 5, c (i)– 'Grooves').

The factors described also affect the amount of spin, if any, that is imparted as 'side'. This causes the ball to 'hook' or 'slice' if in error, or to 'fade' or 'draw' if the golfer has deliberately set out to curve the ball towards its destination. The mind that is able to compute these variables and fade an accurate shot out of a wet grassy rough is remarkable indeed.



THE GOLF BALL IN FLIGHT

After leaving the clubface, the spin, velocity and angle of the golf ball trajectory are the main controllable factors that affect the outcome of the shot. Other factors, such as the construction of the ball, the number of its dimples and the materials and design of the clubs, also affect the outcome but these will have been decided upon before the golfer sets out onto the course.

The table below shows the range of most typical angles (to the horizontal) at which the golf ball will leave the face of each club and also indicates the average distance subsequently travelled by the ball (on a still day). Clearly, distance is significantly compromised when golfers have to play out of a tall dense rough, or over obstacles in front of landing areas.

Typical angle of lift (degrees)		Average distance travelled (yards)	
		Men	Women
WOODS			
No 1	11	220-300	160-180
No 2	13	210-250	155-170
No 3	16	200-230	150-170
No 4	19	190-220	145-165
IRONS			
1	17	190-220	145-165
2	20	180-210	140-155
3	23	170-190	135-150
4	27	155-175	125-140
5	31	140-155	115-130
6	35	125-145	110-120
7	39	120-140	100-110
8	43	110-125	90-100
9	47	90-120	70-80
WEDGES			
Pitching	51-54	70-100	50-85
Sand	58	-	-
Putter	0-4	-	-

LIFT ANGLE AND RANGE PER CLUB
(Reproduced by kind permission of John J. Monteleone)

Wind speed and direction cannot be controlled but they need to be taken into account when playing the shot. The same would apply to the intensity of any rain that might be falling.

Since the turf itself is not directly involved in the flight of the ball, we will not go into any of these aspects here. This is, however, a fascinating subject about which a great deal has been written.

SHOTS FROM THE ROUGH

For a golfer unfortunate enough to find him or herself there, the nature of the rough may affect club selection. A dense rough, perhaps containing a large proportion of coarser grass species, such as perennial ryegrass or Yorkshire fog, will be more likely to affect a ball passing through it than a rough containing more wispy species such as fescues. The height of the rough will affect the ball in a similar way and by emerging at a steeper angle the influence of the rough on the flight of the ball may be reduced.

IMPACTS ON THE GREEN

Spin, velocity and angle are also the main factors that govern the behaviour of the ball when it hits the green. Two phases can be identified. Typically, the ball bounces (usually twice or more) before entering a 'roll' phase. Different qualities of the green affect both these processes.

BOUNCE

Well-struck shots by the top professionals usually result in short bounces. This is because the ball tends to come down relatively steeply. Balls do not therefore bounce far even on very hard greens.

Short bounces also follow when a golf ball 'plugs' into a soft green. This can occur even with shots coming in at shallower angles. Such shots are usually struck by less able golfers and this is unfortunate because they then acquire the impression that they are better at 'holding' the ball on the green than they actually are. Subsequently they demand soft greens all the time, which brings a range of problems for the greenkeeper and does nothing to improve the standard of golf of both low and high handicappers playing the course.

Attempts have been made to model the behaviour of greens during golf ball impacts. Models have employed the physics of springs and dampers (shock absorbers) to do this. At the highest levels of the game, however, these processes may be of less significance than the manner of golf ball flight mentioned above, and how the ball behaves on the surface of the green.

ROLL

After bouncing, the backspin retained at the roll phase reduces the forward motion of the ball. Friction between the ball and the green can slow a forward roll, check the roll entirely or cause the ball to 'screw back' from its position at the end of the bounce phase. Sometimes the ball will screw back beyond the point of initial impact. Watch out for this when the top golfers are playing with lofted irons or wedges from very close to the green.

The surface of the green affects the consequences of this spin retention. It does this by the nature of the 'grip' or friction that develops between the ball and the turf. In my own research, back in 1994, I found that a full and dense grass cover was able to grip the ball more effectively and allow the spin to pull the ball back on itself to a greater extent than a thinner, more open sward.

PUTTING

About 43 % of the shots played in The Open will be made with putters on the greens. It is in putting that the greatest interaction between the ball and the turf takes place.

On impact with the putter the ball first slides over the surface and then, as friction between the ball and the grass takes effect, the ball rolls towards the hole. Various turf-related factors affect the distance the ball travels over the surface, usually referred to as the green speed. Features of the green that affect speed include:

HEIGHT OF THE SWARD

A lower sward height will give a faster green speed. This can be achieved by cutting more closely but this puts the turf under a great deal of stress. An alternative approach would be to build up the ground level at the base of the grass, effectively reducing the sward height from the bottom up. This can be achieved by top dressing.

LEAF WIDTH AND GRASS TURGIDITY

The more contact that takes place between the ball and the turf the greater will be the resistance to the forward roll. Wide, stiff, upright leaves will touch more of the golf ball than narrow and flaccid leaves and a green made up of such coarser plants will therefore be slower.

Excessive use of fertiliser and water has long been known to reduce green speed. The resulting rapid growth will place more leaf in the path of the ball and slow down its forward motion. Where the grass is growing vigorously, as a result of excessively moist and fertile conditions, green speed tends to fall during the course of the day as the leaves extend.

Factors related to leaf width may also explain why greens get faster on hot, dry days. As dry conditions develop, the leaves of grasses, bents in particular, curl up to conserve moisture and effectively become narrower, presenting less resistance to the ball's roll.

DENSITY OF THE SWARD

Short turf with a very high shoot density can give a faster surface. This is because the size of the individual grass plants is necessarily smaller (so they all fit into the space available), resulting in less contact with the front face of the ball. Also, the ball will sink less into a dense sward which will therefore present less resistance to its forward roll.

A high shoot density can develop, in certain circumstances, if the grass is persistently mown very close. This occurs for example on some links greens. However, this carries a plethora of risks and implications for the welfare of the green.

Conversely, where shoot density is very low, faster surfaces can also result. This is because the ball is then rolling over a surface provided chiefly by bare ground (sand or top dressing) rather than grass.

It is probably by reducing the size of individual plants that procedures such as verti-cutting and grooming are able to increase green speed. The reduction in shoot density and/or plant size will lessen the general resistance to the roll of the ball. Vert-cutting also allows the integration of top dressing into the sward which can improve pace through its effect on the height of the sward as mentioned above.

SPECIES

It is widely acknowledged that different grass species produce different green speeds. Thus, for species normally found in the UK, fescues give faster surfaces than bents, which in turn give faster surfaces than annual meadow-grass (assuming all are at the same height). This corresponds, in most circumstances, with the leaf width and general size of the plants. For example, the needle-like leaves of fescue will support a golf ball but will not touch so much of its surface as will a lush, annual meadow-grass leaf.

GRAIN

This only tends to be an issue on creeping bent greens, most common in the northern United States and southern Europe. Speed is lower against the grain, into the tips of the leaves, than with it, along the lie of the leaves. Intensive verti-cutting is usually required to reduce the nap and create a more uniform, upright sward.

SURFACE MOISTURE

The presence of surface moisture usually increases the drag at the contact points between the ball and the turf. It is likely that these effects will be greater on lush greens where such contact points are already more abundant.

There are also those factors that affect the course taken by the ball on its journey. These include:

UNIFORMITY OF SURFACE

Bumpiness can result from the varying growth rates of different grass species. This often occurs where a mosaic of grasses in a green are all growing at different rates. The phenomenon is most common in early spring as the grasses respond differently to rising temperatures.

Another source of unevenness may occur where aeration procedures have been carried out resulting in the stimulation of growth in one place, for example over a hollow core hole, but not to the same extent in the area immediately around this. The use of a top dressing with a grit content can also create a bumpy surface. The results are that putts follow an unpredictable, and hence unfair, path.

SLOPE AND BORROW

These are the elements of the green's topography that are fair and must be read by the golfer when visualising the course of his putt. Some work has been done on how a ball behaves going straight up and straight down a uniform slope, but I have been unable to find any research work on the rationale behind putting across varying slopes and the prediction of the route taken by a ball over an undulating surface. This is clearly an area where the intuition of the golfer takes over, but the subject seems to me to be ripe for a more objective study.

IN THE HOLE

Some good science has been done on the process of 'holing'. Though not really related to the qualities of the turf, this is interesting nonetheless. Some facts (from 'The Science of Sports' by Sharon L Blanding and John J Monteleone):

- If a ball is rolling without sliding it must be moving at 1.63 metres per second or less to be holed. Otherwise it has enough velocity to sustain the straight-line path across the top of the hole. A ball leaves the end of a Stimpmeter at 1.9 metres per second.
- Between 1.31 and 1.63 metres per second the ball will hit the opposite rim. What happens then is determined by how much the ball bounces against the walls of the cup and on how much friction is generated from the ball's rotation against the rim.
- If the ball is bouncing or skidding it can be holed at greater speeds. This is because such a ball has less angular momentum that can provide 'kick' to bounce the ball out of the hole.
- It has been found that it is easier to sink a wound ball than a two-piece ball.

CHAMPION!

I don't think that Ernie Els and Tiger Woods concern themselves too much with the biophysics of golf ball impacts on greens or the leaf extension rates of bents and annual meadow-grass. But it is surely the case that, by breaking down and focussing on these issues, the greenkeeper can empathise with the processes I have described and deliver even better playing surfaces.