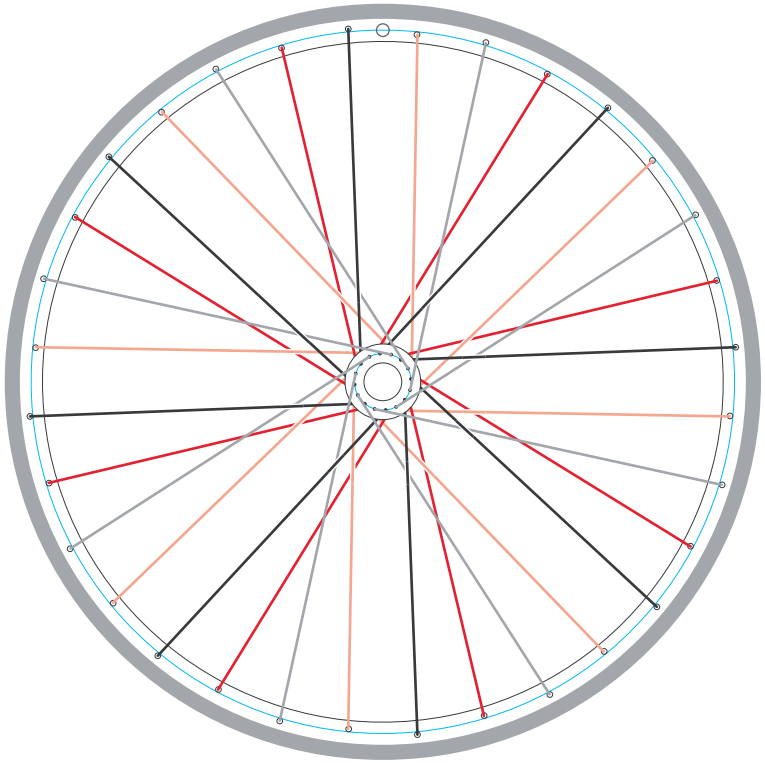
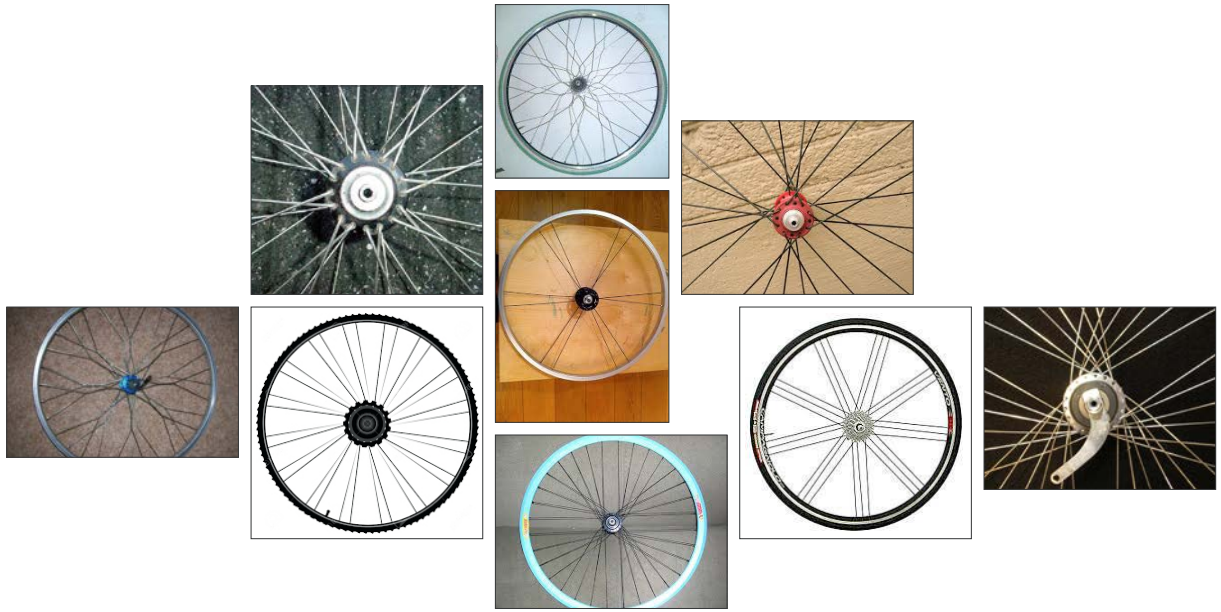


WHEEL BUILDING

Introduction to wheel spoking

ROSS SPEIRS

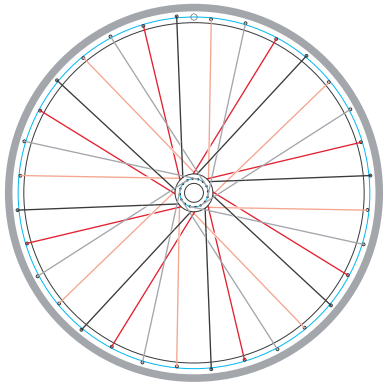
Cycle wheel builder



There are many ways to spoke a wheel, from the conventional and practical to the exotic and outrageous.

These notes introduce some of the terminology and characteristics of conventional tangentially spoked wheels.

Contents



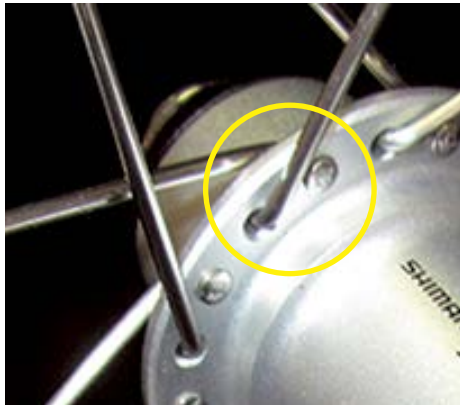
The basics

A bicycle wheel consists of a circular rim attached to a central hub by a number of tensioned wire spokes.

The spokes on a conventional wheel will be J-bend spokes, with a hooked section at one end (the 'J' bend, with a flanged head), and a threaded section at the opposite (straight) end. Each spoke is attached to the hub by hooking the J-bend through a hole in the hub flange, and attached to the rim by threading the straight end on to a nipple passed through a corresponding hole in the rim.

The strength and effectiveness of the wheel depends upon many factors: the quality of the components used, the number of spokes employed, the lacing pattern used, and the tension of the spokes.

36-hole Mavic A719 wheel built onto a Shimano XT hub

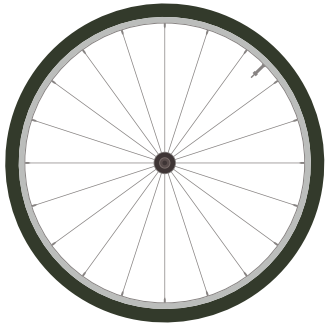


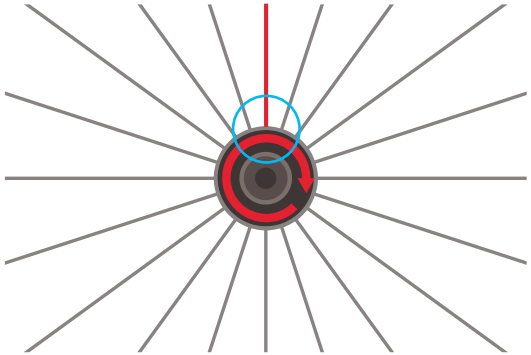
Spokes hooked through holes in the wheel hub

Spokes threaded onto nipples passed through holes in the rim

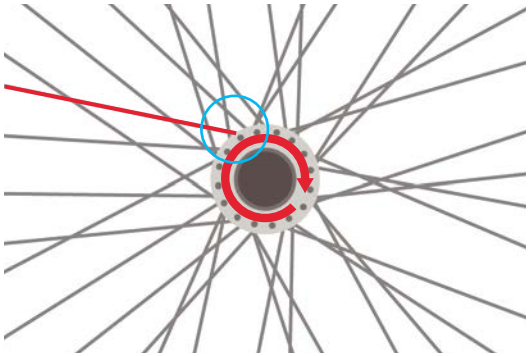
Spoke nipple

Plain gauge J-bend spoke





1



2

Radial vs tangential spoking

Spokes connecting a wheel hub to a rim can either leave the hub at right angles to the circumference, known as radial spoking (1); or at an angle, or tangent, to the hub circumference (2), known as tangential spoking.

Radial spoking is more aerodynamic than tangential spoking, as there is less air turbulence when the wheel is turning. Some people also find radial spoking more aesthetically pleasing.

However, on a radially spoked wheel the transfer of power from hub to rim is inefficient, as there is very little torque at the point where the spokes leave the hub (circled); this also puts considerable strain on the hub flanges when the wheel is under stress from driving forward or from braking.

On a tangentially spoked wheel, because the pulling spokes leave the hub at an angle (circled), the transfer of drive power from hub to rim is far more efficient.

In addition, because spokes on each side of a tangentially spoked wheel are laced (crossed) with each other, the wheel has higher lateral strength than a radially spoked wheel.

Both styles of spoking can be used on the same wheel (one on each side), but it's hard to think of a reason for doing this.

Note: many suppliers of hubs, such as Shimano, advise against the use of radial spoking, and include disclaimers on their product documentation.

The notes following all refer to tangentially spoked wheels.

1

A 32-hole Shimano LX front hub, with 16 holes on each flange

2

Spokes emerging alternately from the inside and outside of each hub flange

3

Part of a Mavic A719 rim, showing the rim holes staggered alternately towards the left and right sides of the rim

Hub and rim drilling

The wheel hub

A bicycle wheel hub is a cylinder with an axle passing through it, and bearings at each end to ensure the cylinder can turn freely on the axle. At each end of the hub is a circular flange, drilled with holes around the circumference to accommodate the spokes that will connect the hub to the rim. On conventional hubs there is the same number of holes in each flange, and together they should equal the number of holes in the rim to be used. So a 32-hole rim should be matched with a 32-hole hub (i.e. a hub with 16 holes on each flange); a 36-hole rim should be matched with a 36-hole hub (18 holes on each flange); and so on.

The more spokes, the stronger the wheel, but there is a weight penalty. Most touring, commuting or leisure bikes will use 32- or 36-hole rims. Heavier bikes like electric bikes, tandems, and cargo bikes, might use 42- or even 48-hole wheels. Lightweight road bikes can employ wheels with as few as 16 spokes.

The rim

A bicycle wheel rim has holes drilled at regular intervals around its circumference. Spokes are attached to threaded nipples passed through these holes from inside the rim.

On symmetric rims, the holes are usually staggered alternately, with half the holes nearer the left side of the hub, and the other half nearer the right side (see 3 opposite). Spokes from the left hub flange will connect to holes nearer the left side of the rim, and spokes from the right hub flange will connect to the holes nearer the right side of the rim. This reduces the angle of entry of spokes to rim, and so lessens the stress on the spokes when the wheel is under load.

The rule of four

The number of holes in a hub or rim is always a multiple of four. This is because the arrangement of spokes coming out of the hub holes is usually made up of groups of four. Half the spokes will come from the left side of the hub, and half from the right, connected alternately to the rim. To further spread the load that the wheel has to bear, the spokes on each hub flange will emerge alternately from inside and outside the flange (see 2 opposite). This produces a fixed sequence of four; for example, spokes connecting at the rim will be coming from the right inside, left inside, right outside, and left outside of the hub; then back to the right inside, and so on.

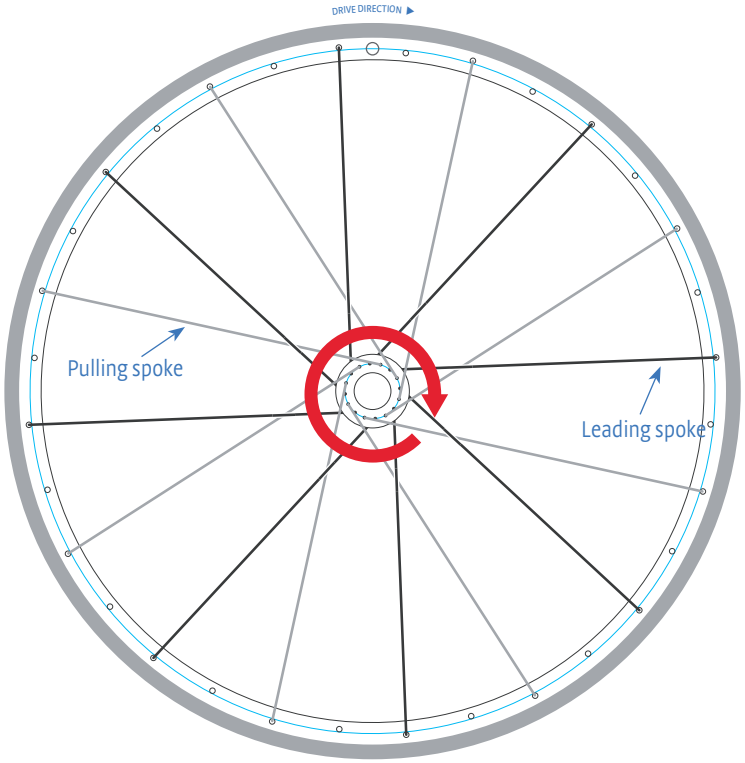
Left, right, left

The unqualified terms ‘left’ and ‘right’ are inexact. Assume you are sitting on a bike. The drive mechanism (cassette, chain rings, and chain) are on your right. For the purposes of these notes, this will define the right, or drive side, of wheels and hubs. So ‘right’ will always mean ‘drive side’, and ‘left’ will always mean ‘non-drive side’.

Pulling and leading spokes

On a tangentially spoked wheel, half the spokes will *pull* the wheel round as power is transmitted from the pedals, and the other spokes will *push* or *lead* in the direction of the drive. For the purposes of these notes, these two sets of spokes will be termed **pulling** and **leading** spokes respectively.

On a tangentially spoked wheel, pulling and leading spokes are connected to alternate holes on each hub flange.



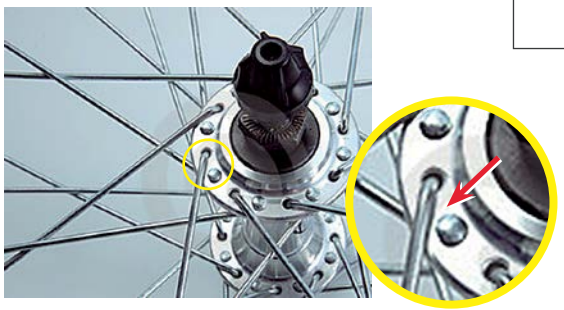
Spoke crossings

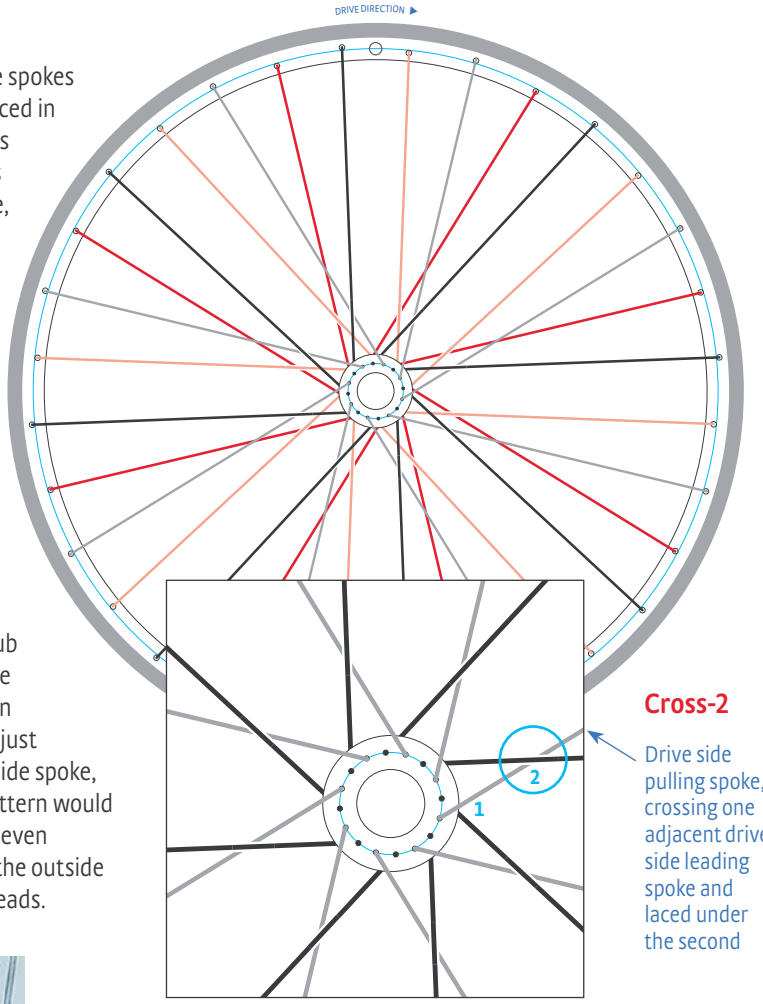
On a tangentially spoked wheel, the spokes coming from each hub flange are laced in such a way that each spoke will pass across a number of adjacent spokes on the other side of the same flange, before being laced over or under the final crossed spoke.

The number of spoke crossings on a wheel is most typically two or three, but can also be one or even four.

The diagrams opposite show a **cross-2** pattern and a **cross-3** lacing pattern respectively.

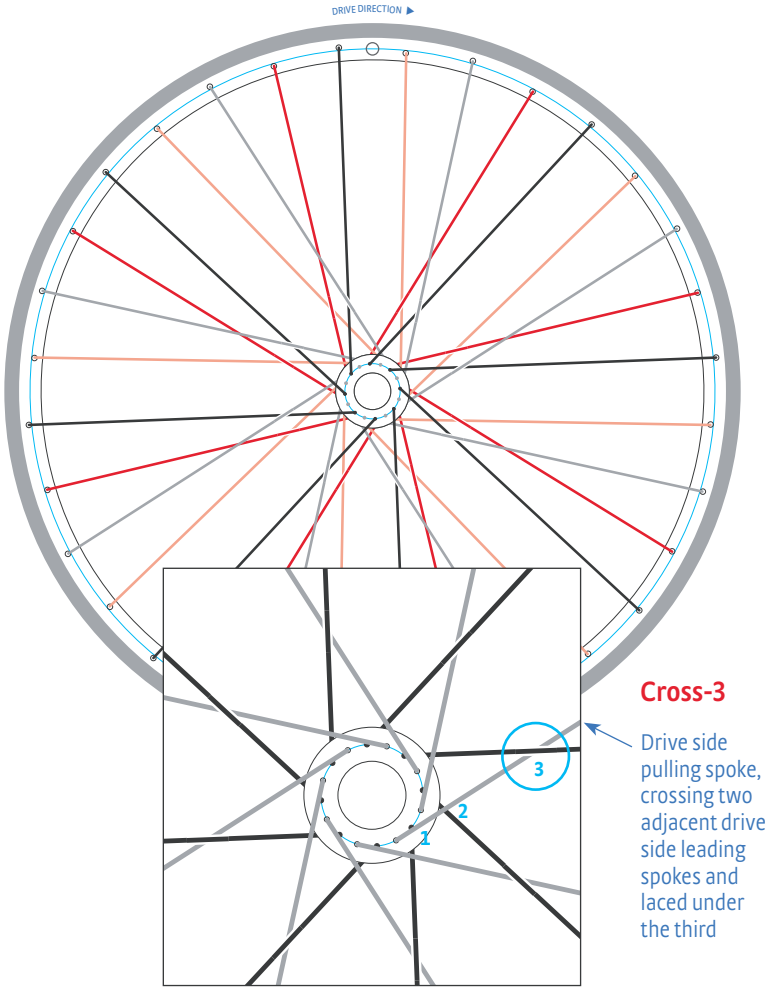
The more crossings there are, the stronger the wheel will be. However, the number of crossings is limited by the diameters of the hub and rim, and by the number of spoke holes in both. On the cross-3 pattern below, the outside spoke is passing just clear of the head of the adjacent inside spoke, which is fine; however, a cross-4 pattern would mean the spokes exiting the hub at even shallower angles, possibly causing the outside spokes to foul the adjacent spoke heads.





Cross-2

Drive side pulling spoke, crossing one adjacent drive side leading spoke and laced under the second



Cross-3

Drive side pulling spoke, crossing two adjacent drive side leading spokes and laced under the third

WHEEL VIEWED FROM DRIVE SIDE

- Drive, leading, inside
- Drive, pulling, outside
- Non-drive, leading, inside
- Non-drive, pulling, outside

1

Symmetric lacing, cross-3 pattern

2

Asymmetric lacing, cross-3 pattern

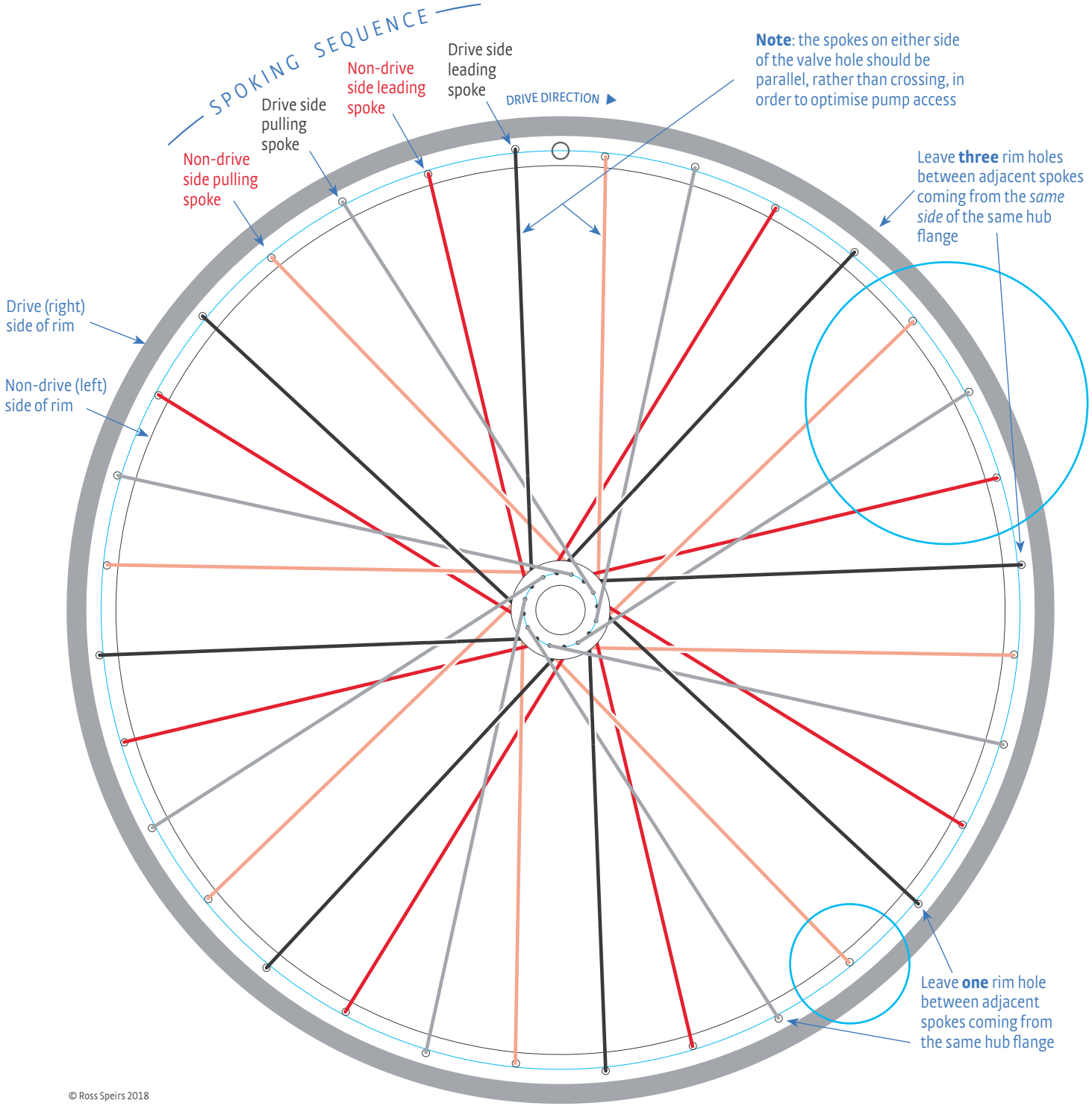
Symmetric and asymmetric lacing

On a tangentially spoked, **symmetrically** laced wheel, the *pulling* spokes exit from the outside of both hub flanges, and the *leading* spokes exit from the inside, as in example (1). (The symmetry can be reversed, with the pulling spokes coming from inside the hub flanges, and the leading spokes from the outside.) The pattern of spokes leaving the non-drive side flange will be a *mirror image* of the pattern on the drive side flange.

On a tangentially spoked, **asymmetrically** laced wheel, the *pulling* spokes will exit from the *same side* of each hub flange, and the *leading* spokes will exit from the opposite side. In the example shown (2), the pulling spokes exit from the outside (left) of the non-drive side flange and from the inside (left) of the drive side flange. The leading spokes exit from the inside (right) of the non-drive side flange and from the outside (right) of the drive side flange. The pattern of spokes leaving the non-drive side flange will be *identical* to the pattern on the drive side flange.

The theoretical advantage of asymmetric lacing (2) is that when the bike is under forward power the increased tension on the drive-side pulling spokes will pull the inside spokes *away* from the cassette and chain at the crossing point, because the pulling spokes cross in *front* of the leading spokes (circled); while in symmetric lacing (1) the same tension will tend to push the leading spokes *towards* the cassette and chain, because the pulling spokes cross *behind* the leading spokes (circled).

In practice this effect is too small to measure – the lacing pattern is more a matter of personal preference than mechanical advantage.



Anatomy of a symmetrically spoked wheel

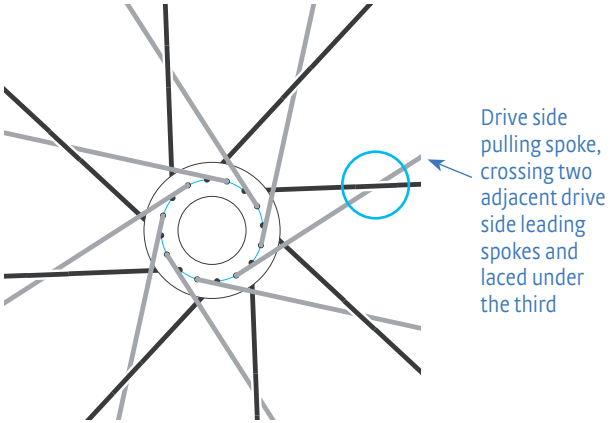
This 32-hole wheel is spoked symmetrically, with the pulling spokes coming from outside the hub flanges.

The lacing is a cross-3 pattern: on each hub flange, spokes cross two adjacent spokes on the other side of the flange and are then laced over or under the third (circled below).

On the hub, holes on each flange take pulling and leading spokes alternately (see drive side flange shown below).

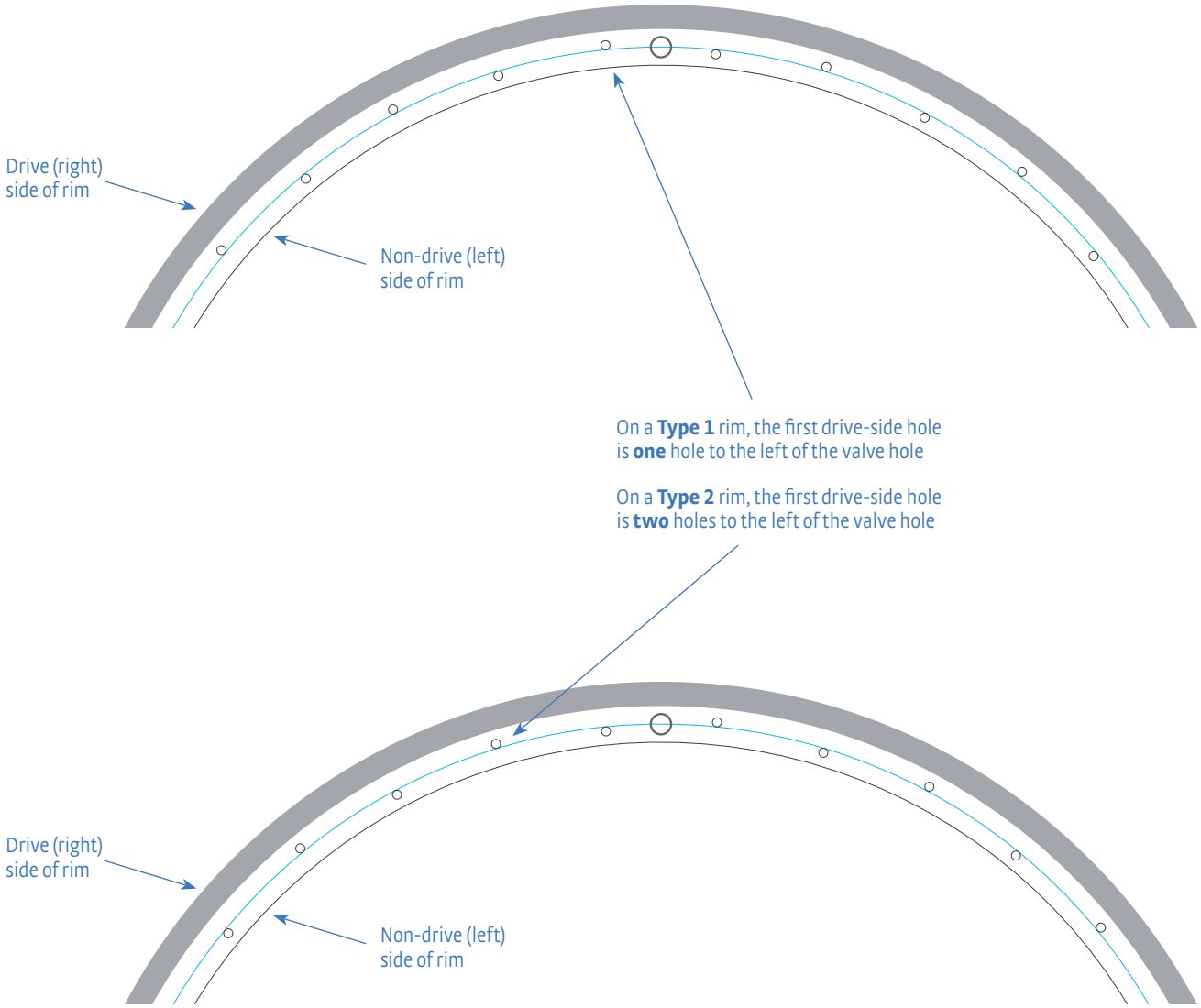
On the rim, holes take spokes in a repeated sequence of four. On the wheel opposite, starting from the first hole to the left of the valve hole and moving anti-clockwise, the sequence is: drive leading, non-drive leading, drive pulling, non-drive pulling. This is repeated around the rim.

So, for spokes coming from the *same side* of the same hub flange, there will always be **three** rim holes between each pair of spokes; and **one** rim hole between adjacent spokes (circled, opposite). *Note: this is a useful check during lacing.*



WHEEL VIEWED FROM DRIVE SIDE

- Drive, leading, inside
- Drive, pulling, outside
- Non-drive, leading, inside
- Non-drive, pulling, outside



Type 1 and Type 2 rims

On conventional rims, holes are usually offset alternately towards the drive and non-drive side of the rim. Spokes running from each side of the the hub will be fastened to the rim hole corresponding to that side (drive or non-drive), enabling each spoke to enter the rim at less of an angle than would otherwise be the case.

Depending on the rim model, the hole offsets can appear on different sides of the valve hole.

On a **Type 1** rim, the first drive-side hole is **one** hole to the *left* of the valve hole.

On a **Type 2** rim, the first drive-side hole is **two** holes to the *left* of the valve hole.

To determine whether a rim is Type 1 or 2, view the rim from directly above the valve hole.

Building tip

Start each wheelbuild by putting the first spoke into the first *drive-side* hole to the left of the valve hole. This will always be a *leading* spoke.

WHEEL VIEWED FROM DRIVE SIDE