Professional Wheelbuilding: The Manual

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Preface

When I first started building wheels commercially I found myself answering the same questions regularly. This led me to write a number of articles on the subject of wheel building, these can reassure people or educated people about my methods for building certain wheels. The list of articles grew to a reasonable number and after a point I realised were approaching the length of a book.

The original version of this book was as such called 'Bicycle Wheel Building: An Anthology of Articles'. After working on this version for some time I realised the book would be improved if the articles complemented each other and flowed together as a progressive volume. Most literature on wheel building focuses purely on building the wheels. Little attention is given to the finer details of the component parts. A wheel can only be good if it is built well. However, poor product selection could land you with an inappropriate set of wheels which may be incompatible with your bicycle, it could cause the wheels failure. Or it could simply cost more than necessary or the performance could be lower than necessary. This book attempts to guide product selection as much as possible and understand what goes into making a great wheel.

Wheels are absolutely fundamental to a bicycle, they have one of the greatest impacts on the way that a bicycle feels when you ride it, or what that bicycle is capable of doing. A trials or downhill rider would fail immediately if their wheels were weak. A trekking cyclist has to have reliability. A time trialist has to have aero-dynamics and a hill climber has to save weight. Understanding function is essential.

The majority of riders demand much less performance from their wheels than professionals, yet their wheel choice is still important. They need to work out what they are using the wheels for, how much they are looking to spend and where that money will be best spent.

Most importantly when it comes to product selection – be critical. Much of what you are told will be an attempt to sell products and most opinions are poorly researched. If you want quality, performance and value for money, you need to be critical. That includes criticism of what you are about to read. If you go away after having read this book with criticisms of my opinions I would consider my work to be a success. This is not a book of answers but a way of encouraging you to be more rigorous with your decisions and an attempt to objectify product selection. This combined with good building practice should help you repair wheels well, build them well and select the right set for you even if someone else builds them for you.
1. Introduction

Hubs

Hub selection principally involves three key factors: function, price and aesthetic. Is weight a factor? What about strength? Gear suitability? Brake suitability? Selection of colour and profiles of parts can also be aesthetic considerations. Normally when it comes to balancing weight, strength and price you can roughly pick two, so you can have a strong light part, but it will be expensive or it can be strong and cheap but it will be heavy or light and cheap but it will be weak. Making strong wheels is addressed in chapter 16. Making light wheels is addressed in chapter 17.

Rear hubs come with four types of gearing options. Single speed (fixed or freewheel), screw on freewheel with gears, freehub and cassette or internal gears. The most common is freehub and cassette, most common of that is an 8 speed freehub which can also take 9 and normally 10 speed cassettes as well. However, there is a growing popularity for internal gears. Traditionally these would have been Sturmey Archer and these are still available today in a range of models. However manufacturers like Sram and Shimano now make their own versions. Many of these still come with traditional drum or back pedal brakes although modern versions are available with up to 14 gears and disc brake compatibility. Gears are addressed in chapter 9. High end internally geared hubs are addressed in chapter 11.

Hub compatibility

The most important aspect of hub selection whether the hub is compatibility with the sort of bicycle you are working with. There a number of different interfaces so they need to match up. With mountain bike (MTB) hubs you can have quick release or thru axles on the front. Thru axles come in two sizes 15mm and 20mm. There is variation in rear end spacing and interface as well. Generally wider rear spacing and bigger front axles are used to make the wheel stronger and as such are used on more aggressive off road applications. These methods are discussed in chapter 16.

Road spacing is typically 130mm, older versions were 126mm and touring is generally 135mm along with standard MTB hubs. Fixed gear and single speed road wheels are normally 120mm spacing and require horizontal or forward facing frame ends to adjust chain tension. Fixed gear and single speed road hubs normally come with nutted axles rather than quick release skewers to prevent the wheel from slipping. Bicycles with vertical dropouts are better for quick release versions as horizontal frame ends are more prone to wheel slip. Forward facing frames ends can be comfortably run with either. Steel frames can be pulled or pushed by about 5mm without any problems. So you can put a 135mm hub in a 130mm spaced steel frame without concern. However you should avoid running 135mm hubs in 126mm frames. Equally, avoid running 120mm hubs in 130mm frames. If you go beyond the 5mm recommendation steel frames need to be professionally re-spaced. Aluminium and carbon fibre frames cannot be respaced.

There are different interfaces for fitting different gear types. See chapter 9 for details on this. There are two types of disc brake mounting used on hubs. 6 bolt international standard and
center lock. It is possible to get center lock adapters to run 6 bolt disc rotors. Drum and back pedal brakes normally require fittings on the frame for their installation.

**Hub failure**

Most people when choosing a hub want to avoid failure as a high priority. When it comes to saving weight in a wheel the hub is the least important element because of its low rotational weight which is worth considering when shaving off a few grams. Normally when hubs fail it is because of bearing wear or an axle snapping. Bearing wear is likely to be particularly pronounced if these are improperly serviced and is accelerated by impacts and heavy weight. Bearings will probably be the first component to fail if disc brakes are used or if rim brakes are used on high mileage riding with minimal braking – for example in flat, rural terrain.

There is more information on high end hubs and their features in chapter 8. Dynamo hubs which generate electricity are discussed in chapter 10 and bearings in chapter 12.

**Interesting manufacturers of hubs**

Shimano offer good value road and MTB hubs and are an excellent starting point. They offer fairly generic products at benchmark prices. Novatec make some versatile economical road hubs in a wide variety of hole counts and are lighter than shimano. Hope offer some more exotic hubs, boasting improved alloys, freehub body engagement, versatility, colour availability, hole counts and so forth. Their hubs are focused more around the MTB market than road where their versatility is a great advantage. They are able to run with quick release, 15mm and 20mm thru axles without changing the hub.

Royce is a nice boutique choice for a quality road or touring hub. They do make a disc hub as well, but it is only available in quick release. Their hubs are available in different axle lengths, hole counts and freehub versions. There are also different shell sizes to match different functions. The titanium axles come with a lifetime warranty making them a popular choice for high mileage riders.

Chris King offers some of the strongest and lightest hubs on the market, all coming with a 5 year warranty. There are variations in hole count, colour, freehub body and axle length. Road specific hubs are available.

DT offer a range of high end hubs at high end prices. The 190s hub is exceptionally light, comes with ceramic bearings and the front hub can be laced radially (rim brake only). The 240s is the more economically priced version but is based on the design of the 190s hub. There are a huge range of other hubs with many other features at various price points and specialities. High end hubs are discussed in chapter 9.
**Spokes**

Careful spoke selection can be an easy way to boost strength and/or save weight in a wheelset. Good spokes are unlikely to fail unless the build quality is low. There are comparatively few spoke manufacturers out there making selection easier. Spoke selection based on spoke type is addressed in chapter 5. Spoke manufacturers are addressed in chapter 7. Sils alloy and other nipples are discussed in chapter 6.

**Rims**

Rims come in different diameters depths and widths. Other variables are:
- hole number/count (this needs to match your hub)
- profile of the rim
- material it is made from
- type of tyre: clincher or tubular

My most commonly used rim manufacturers are Alex, Ambrosio, DT, Exal, Kinlin, Mavic, Rigida and Sun Ringle. Rigida rims are an economical solution; they are strong but normally quite heavy. Mavic offer some well priced, good quality rims although they are a lower tension rim than most other manufacturers which can make them inappropriate. DT rims are good quality options for road and MTB applications.

Ambrosio offer an excellent selection of elegant and good quality tubular and clincher rims for the performance road market. The Ambrosio Excellight is a light weight, double walled, double eyeleted rim, ideally suited to fast road use. The Excellence is a heavier version of the same rim with a slightly different profile, ideally suited to applications where endurance is more important. The FCS28 is an aero rim. This rim tapers to a fine point because the nipple is supported internally within the rim. The Ambrosio Chrono is an exceptionally light and classic looking tubular rim and the Nemesis is a heavier and tougher tubular rim. Tubular and clincher rims are discussed in chapter 16.

When it comes to 700c touring rims, the market is a little limited. Rims normally jump from between 13-15mm internal for road racing applications, to 19mm internals for 29er, trekking or cyclocross applications. Touring rims are ideally 17mm internal. This means you can run down to a 25c tyre comfortably or up to 37c. It is possible to push these boundaries further, but it makes sense to select a rim that holds the range you require comfortably. If you are looking for a 17mm internal rim, there are three obvious options to choose from. The Alesa Endeavour was a favourite among touring cyclists but Alesa has now gone bankrupt. Part of their equipment was purchased by Rigida (where the Exal brand was also established). Rigida and Exal hold a lot of the touring market now. The Exal LX17 is an attractive box section, double walled, double eyeleted rim weighing 565g. Rigida offer the Sniper which is a double walled, single eyeleted version weighing 500g. Ambrosio also offer a double walled single eyeleted version called ‘The Frog’. Eyelets are discussed in chapter 14.

For vintage applications, wooden rims can still be sourced from Ghisallo. These are an interesting selection; they can compete well on weight and look brilliant; they are rarely used now. Wooden rims are discussed in chapter 21.
Performance road and now performance MTB wheels are increasingly using Carbon Fibre rims. DT Swiss manufactures some excellent carbon fibre MTB rims and Zipp are particularly popular in the road market. Aluminium and Carbon fibre rims are discussed in chapter 20.

Similarly to hubs there are a wide variety of rims out there. To an extent your choice will be limited by the application of your wheelset as well as the availability of the rim in your country.

2. Why are some products more popular than others?

In an ideal world, the best products would be the most popular. However, when it comes to making wheel decisions there are a number of factors worth considering. Firstly you want to choose the right product for the job. Beyond that there may be a number of products available at a range of prices and you have to decide which one is right for you. Opting for a popular product can land you with a bad product. What then governs the popularity of products?

Marketing is essential for brand popularity. This means a large number of things. Some key ones are: a regular presence at trade/public shows, advertising campaigns designed to reach relevant audiences, positive reviews in publications and effective distribution. Effective distribution has a number of factors to it, some are not marketing related. Easy and fast provision of a product is good distribution but not directly good marketing. However if a representative of a trade company visits a retailer they may be better or worse informed about a particularly product that they sell. Well informed, persuasive representatives are a great way to market a product.

Reviews

It may seem like reviews are an impartial way of understanding quality. However consider a number of potential problems when using reviews as a source of information.

1) Considering the enormous variety of products out there, the reviewer may have limited experience of relevant alternative products. Experience they do have may be outdated or unrepresentative. A product may now have been modified to overcome a former criticism of it without the reviewer’s knowledge.

2) While reviewers attempt to be thorough in their investigations, they will only have the product for a short period of time before the review needs publishing. Product failure is unlikely to occur during this time frame.

3) Some reviewing bodies will have a good relationship with some brands/distributors. If a reviewer is given an item (rather than merely lent it for testing), they may be more likely to provide a positive review of the product. Moreover if they regularly review for a company/brand, they may have a personal relationship with individuals within that company. This is also likely to have a positive influence of the review’s slant. This could even be a factor on a subconscious level. They may have had
positive experiences or negative experiences of this brand in the past and this review will be influenced by that experience.

4) Discrete events: the circumstances under which the product is tested may not reflect a typical set of circumstances for testing that product. It may rain excessively; the rider weight may be unusually high or low or it may be a one off faulty product.

Aside from the margin for error, reviews are an excellent way of obtaining information about a product. They are theoretically not based around an attempt to sell a product. Moreover they are far better informed (in all likelihood) than anecdotal evidence. However, when reading a review on a product, the aforementioned should be taken into consideration. A review should be critical and should scrutinise the product, some reviewing bodies are more rigorous than others and some reviewers are better than others. Make sure you apply similar scrutiny to their review and knowledge to make the best decision.

**Popular and established brands**

Anecdotal evidence is another common reason for the popularity of a brand. Imagine that brand X manufactures a lot of bicycles or parts that are of a fairly good quality and fairly well priced. As a result a large number of people purchase them. These products fail irregularly and the customers are generally happy. These customers recommend these products to their friends who go out and buy the products themselves and the circle can continue like this. The brand retains presence because it established. Adding to this, the popularity of the product increases the volume it can be manufactured in. This then lowers the costs of manufacture and distribution. This money can then go towards more marketing, lowering the cost of the product or increasing the profit margins of the retailers who are then more inclined to sell the product.

**Aesthetics/feel**

Some products are popular because of their appearance. It may be that they simply look great which draws people in, or perhaps they are available in varied appearances. The product may be available in different colour options or different designs. It can be hard to select a product which looks particularly unattractive even if you know in all other respects it is great. Similarly the finish on a product has a major impact. Often a product can feel or look cheap which is unappealing. It may be perfectly durable, but it seems like it will break. Ergonomic products can be more popular or ones too. The opposite can even be the case, for example with tools. In this case a well finish, shiny tool may be deemed overly complex and impractical.

**Cutting edge**

Fashion is a more minor player in the cycling industry, despite this sometimes certain types of bicycle or certain components grow in popularity quickly. In this instance a company that can produce a good product in high numbers to meet that demand can become a well
established brand on that basis. Big manufacturers often plan their work years in advance, sudden changes in trend can catch them out allowing faster moving players to prosper.

Price

Price is one of the biggest factors in popularity. Often the recommended retail price of a product bears little relation to the marginal cost of its manufacture. Generally most of the costs involved are marketing, distribution and development. This can appear sinister, however good product development should be a major part of the products’ price. Innovation takes skilled individuals a long time. It can be exceptionally expensive. To recover these costs people will have to know about the product so efficient marketing is essential too.

If an item is sold in volume its development costs can easily be recovered. This in turn reduces manufacturing and distribution costs. However, this may not be a good reason to reduce the products retail price or even the wholesale price. A product which is regularly discounted can erode the value of the product. If a product regularly has significant discounts offered on it, eventually the product will become a permanent discount brand, one that cannot be sold at its recommended retail price. However if it is never discounted, people trust that it is a premier product. Often a product is trusted more for carrying a higher price tag.

Again, avoid cynicism with this phenomenon. Some products have a high marginal cost. They may need regular redevelopment, maybe they are entering into a niche market and fixed advertising/marketing costs required for product awareness keep the price high.

Distribution

Manufacturers choose their distributors carefully, ones that will effectively promote their brand to the retailer. Some distributors have more extensive networks, some are more specialist. If you release a niche product with a big brand distributor it may get lost in its network, unlikely to be pushed by their representatives. The other side to this is that big distributors will allow for easy distribution of products. If a retailer is regularly purchasing from a distributor, they may feel inclined to try out a new product or brand they have released. If they irregularly purchase from a distributor they may be unprepared to try out the product, even if it interests them.

Some distributors are effective at their distribution, keeping healthy stocks of products which can be easily ordered via different methods. They may offer next day delivery free of charge on even comparatively small orders. By contrast other distributors may be poorer with stock levels and may charge higher prices for delivery. Prices vary at a distribution level as well and some brands are distributed through multiple distributors which makes them easier to source.

A cause for concern?
Ultimately when you are drawn to a product it will probably be because of a number of reasons; an effective advertising campaign, a positive review on the product, advice from a friend/relative or their presence within a retail establishment. This decision is then governed by factors that run behind the scenes, if you cannot source the product, you will need to select an alternative. Careful research of products can be a valuable activity, particularly when making a big purchase. There may well be a poorly marketed product out there which is well priced and better suited to your needs than that which is being more obviously pushed upon you.

Take a more academic approach to the advice you are being given. If you are told A is better than B, ask why is this the case? Also, if A is better than B in one respect, is that relevant for you? Perhaps B is cheaper and you would gain no real benefit in using A. What perspective are you coming from? Is a better for competing, for longevity, for value for money?

Consider a scenario discussing a product with a sales assistant. They are telling you how fantastic a product is. Are they selling a product because it is fantastic, or are they telling you that a product is fantastic, so that they can sell it? In reality it is probably a combination of the two.

An aside on product manufacturing location

I prefer to use European or American components when building wheels. My main reason for doing so is because of labour conditions. Workers in western nations are protected by stricter labour laws so I prefer products to come from there. Equally, I dislike the erosion of western manufacturing industries and would like to support local industry in particular. However, there is a misconception that products from Europe or the USA are made to a higher standard than East Asian manufactured products.

There is a correlation between high quality and the western nations and lower quality and East Asian manufactured products, however there is a good reason for this. Labour in East Asia is cheaper so lower quality products are manufactured there to keep costs low. More expensive, higher quality products are more profitable and so are more likely to be manufactured locally. Equally East Asian manufacturing lends itself best to higher quantities which are normally required in lower quality products and to keep costs low. Higher quality products are normally more niche and produced in smaller workshops which lend themselves better to a more local manufacturing and distribution network. However, Asian manufacturers are perfectly capable of producing goods to as high a standard as Western manufacturers. Some of the highest quality components I have worked with have been made in China. So if you avoid East Asian manufacturing, ensure you do it for the correct reasons. A western product at a given price point is likely to be produced to a lower standard than an East Asian counterpart.

3. Building Bicycle Wheels

Building wheels is easier than you might imagine. It is made easier by appropriate tooling and experience but it is possible to do so with limited facilities. If you follow the process
carefully and slowly, the wheel should come out well. Bad wheels are normally bad either because the process is misunderstood or they are rushed. Once we can build a good wheel, there are a few finer points that can turn it into a great wheel. Read this article once through before attempting to build your first wheel.

To build a wheel you will need:

- A rim
- A hub
- Some nipples
- Some spokes
- A spoke key

You need to ensure that these parts are compatible. Normally compatibility issues are related to the wheels application. So you may have built a wheel correctly, but it is the wrong sort of wheel for the bicycle or riding style. It could have the wrong O.L.D. (over-locknut dimension – 130mm etc). It could be unsuitable for disc brakes; it could be the wrong diameter and so forth. These issues will be addressed in time an in various chapters in this manual. However, for now, we only need to make sure that the rim, nipples, spokes and hub will fit together.

It is essential that the hole count of the rim and the hub match up. It is possible with certain wheels to have different hole counts on one side of a hub, or to avoid using certain holes in a hub or rim, however these wheels make up <1% of the wheels out there. Forget them for now. If you have a 36 hole rim and a 32 hole hub, they are incompatible. Change the rim, or the hub.

Certain rims require longer than standard nipples. Wooden rims, deeper section rims and sometimes when using a single walled rim with washer this is the case. However normally 12mm nickel coated brass nipples are used. These nipples also normally come in the box with the spokes. Sometimes there are issues mixing and matching nipples from different manufacturers, so using the supplied nipples is normally best.

Spokes come in different lengths. They also come in different styles and profiles. The majority of hand built wheels will use either a standard plain gauge or a simple double butted spoke, either in 2mm diameter throughout or tapering to 1.8mm in the centre portion. Double butted spokes are stronger and lighter than plain gauge versions. More exotic choices are possible and are covered in chapter 5. For now, assume you are using a standard spoke. The length needs to be calculated. These measurements need to be taken from the rim and hub to calculate spoke length:

- The Effective Rim Diameter (ERD)
- The Centre to Flange distance (CTF)
- The Flange Diameter or Pitch Circle Diameter (PCD)

There are other factors governing spoke length but these are more for fine tuning. Spoke hole diameter in the hub affects length as well, but only by fractions of millimetres. Sometimes
people factor in spoke stretch as well which can affect the built length of the spoke. However these are subtle variables which are unlikely to affect the actual choice of spoke length. Spokes are normally available in even numbered 2mm increments so if the spoke hole diameter is 2.35mm rather than 2.4mm, it will only change your calculation from say 296.35mm to 296.4mm. In this case the length of 296mm will remain your spoke length selection.

You will also need to know the hole count and required lacing pattern to calculate spoke length. You should already know hole count because you have counted them to work out compatibility between hub and rim. Lacing patterns do vary but the standard is 3 cross for most wheels.

The Effective Rim Diameter (ERD)

The ERD is the diameter between the beds where the spokes nipples sit in the rim. Most rim manufacturers specify their ERDs or you can normally ask when the rim is supplied. This should give an accurate measure to work with. Measuring ERDs can be less accurate because it relies on the rim being perfectly round. Nevertheless, checking the ERD is good practice because records of ERDs can be inaccurate.

When measuring an ERD I use a specially adapted set of nipples which sit in the relevant spoke holes in the rim and measure the distance between them, I use a DT spoke length calculation chart for this which automatically adds the length of the guide nipples to give me
the ERD. It is best to make your calculation from a nipple rather than adding the wall thickness which is difficult to measure accurately. You can make a set of guide nipples easily by using a spoke and a nipple. Add two nipples to the end of two spokes in the incorrect orientation. Feed the nipples into the rim opposite one another. Measure the distance between the ends of each of the nipples. Then add the distance between the end of the nipple and the ball part where it sits in the rim. Remember it is double this distance because there are two nipples. It is worth taking the ERD measurement from several parts of the rim as the diameters can vary if the rim is oval or misshapen.

Pitch Circle Diameter (PCD)

The PCD is the centre to centre diameter between the spoke holes on the flange of a hub. Sometimes the left and right flanges are different diameters so it is worth measuring both. Similarly to ERDs, PCDs are normally published by the manufacturer. When measuring a PCD it is best to do so with a vernier calliper for precision. A ruler is an inaccurate measuring tool and this measurement is done crudely by eye because the axle prevents the ruler from lying flush against the flange.

The PCD must be measured from the centre point to the centre point of the spoke holes in the hub.

Centre to Flange (CTF)
The centre to flange length on the hub can also be measured by the DT chart. On a non-dished wheel you can measure the distance between the flanges and halve it. On a dished wheel the flanges are not equidistant to the centre so you must know their distance from the centre line. A common reason for a wheel to be dished is to accommodate gears, normally in the form of a freehub body on a rear wheel. The centre line will be half way between the locknuts on the hub, the centre to flange is the distance from the hub centre line to the flange. The result of this normally means a 2mm difference in spoke length on a dished wheel. Wheels with disc brakes will also be dished as well as some single speed versions.

**Calculation**

When you have all of these measurements you can calculate your spoke length. It is possible to do this using the spoke length chart, however modern formula based calculators are more accurate and easier to use. There are various calculators out there, the DT Swiss version is widely endorsed but a more basic calculator may be preferable. You simply input the data into a form or spreadsheet and the spoke length will be specified in millimetres. Wheels with dishing or varying PCDs require more than one calculation, one for each flange.

**Preparation**

The next stage is prep. Many people miss this stage altogether but it is important. Even cheap hubs are generally finished to a fair standard. Surprisingly, by contrast, rims are often finished quite badly. Manufacturers normally leave swarf after drilling the spoke holes. Chamfering tools remove excess material from spoke holes and valve holes. This material can be quite sharp, causing injury or punctures. It also adds stresses in the components which weaken them. By removing it there is also a better aesthetic finish to the rim. Some rims have eyelets and as a result this process can be avoided.

Spoke threads are normally best lubricated. Thick oil can be used for this although boiled linseed oil is normally better. Linseed oil acts as a lubricating fluid for the build as well as a locking agent to prevent loosening during use. You can easily apply linseed oil by dipping the threads of the spokes in a bottle and laying them on a cloth to remove the excess. It is good practice to add oil to the outside of the nipples where they meet the rim as well. This is most easily applied with a syringe immediately after lacing. Linseed oil is unnecessary here as there are no threads, any cheap oil will suffice.

**Lacing**

Lacing is perhaps the hardest part of building. There are a number of patterns out there and different ways of establishing them. The two fundamental types of lacing are radial and tangential. Radial lacing has a limited application, restricted almost exclusively to front wheels with rim brakes. It is reportedly a stiffer technique although it is also weaker. It
has a tendency to damage the hub. Spokes lacing tangentially together pull against one another in the hub. Spokes laced racially pull the hub apart and can damage the shell. Many hub manufacturers refuse to warranty hubs used in radially laced wheels.

Most wheels are tangentially laced, normally in a three cross lacing pattern (3x). Three cross means that each spoke from a given side of the wheel will cross three spokes pointing in the opposite direction before it reaches the rim. Normally warm lacing is employed as well, which means that a spoke leaving the hub will travel under two spokes and over the third. This technique is stiffer.

Two cross lacing (2x) or 1x lacing can also be used. This can be appropriate for a number of reasons. Smaller rim diameters require lower cross counts; in this instance warm lacing is normally avoided. Larger hubs such as the Rohloff hub require a lower cross count. Low spoke counts also reduce the cross count. Similarly higher cross counts are used such as 4x and even 5x when when spoke count is high. So a 16h wheel is probably best laced as 1x, whereas a 48 spoke wheel is best as 5x, 40h 4x. It can be a bit of a judgement to make based on feeling. When you have too high a cross count one spoke can rub on the head of another at the hub. The spoke may also enter the rim at an extreme angle causing it to bend and break. Higher cross counts are normally considered stronger although beyond 3x there is a fairly limited improvement in strength.

Lacing a wheel radially is easy. Simply feed a spoke into the hub and run it out to the rim. Each flange of the hub takes it in turns to feed spokes to the rim. Feed the spokes from the hub from in one flange at a time into alternate holes in the rim. You can have the heads pointed in or heads pointing out when lacing this way. Heads out is less likely to damage the hub. Heads pointing in is reportedly stiffer because it increases the bracing angle.

Lacing a wheel tangentially requires a bit more thought. Think of it as having four sets of spokes. There are two flanges that they come out of and two orientations they come out of on each flange. I start with two spokes, on a rear wheel I will start on the drive side. On a front disc wheel I will start on the disc side. I look directly at the flange with the second flange behind it and feed a spoke into it from the back. I then count round clockwise seven holes and in the seventh hole I feed another spoke. Rotating the hub back round you should have an image like this:

The 'leading' spoke is shown in red and the trailing spoke is shown in black. The leading spoke is now sitting behind the flange with the head facing towards you. The trailing spoke is sitting in front of the flange with the head facing inwards.

You can see there are six holes between the two spokes. It is six holes because this is used for a 3x lacing pattern. Were this a 2x lacing pattern there would be four holes between them. Were it 1x there would be two holes between them. Radial lacing can also be called 0x and it would have 0 holes between them. Similarly 4x would have eight holes between them.
There are two other important aspects to determine at this point. If you have laced as I described on a rear wheel or on a disc wheel, then the leading spoke will be under strain when pedalling on a rear wheel or braking on a disc wheel. The trailing spoke will become slacker under pedalling or braking. It is stronger to have the leading spoke on the inside of the hub flange. So as you look at the drive side or disc side of the wheel, the leading spoke should be on the inside.

The next stage is to feed the spokes to the rim and apply the nipples. It is important that you do this at the valve hole. You take either spoke, push it through on one side of the valve hole and thread the nipple onto it. You then take the other spoke and thread it on the other side of the valve hole missing out one rim drilling between them. On a wheel you have spokes alternating from hub flanges. The spokes feed from the rim to the left flange, then the right, and then back to the left. So when you are lacing one flange, you use alternate holes in the rim.

A rim will often have eccentric drilling, so each hole will have a pre-assigned flange. If you look at the holes dead on from the inside of the rim you can see this by eye. Failure to place the correct spoke in the correct hole on the rim will put undue stress on the rim and spoke which could cause failure of either. Another point; good rims normally have double walls but only some have double eyelets. This can lead to nipples being lost in the rim in the gap between the two walls. I have a special tool to hold the nipple to prevent such an irritating set-back; it is also possible to hold the nipple on a syringe and then fed into the rim. Alternatively a nipple grip can be used for this function. Tightening the nipple onto the spoke can take some time, to speed up the process you can use a nipple driver. This is a bit like a screwdriver which allows the wheel to be laced much faster.
rim. When this process has been completed you will have filled 50% of the holes on the rim 100% of the holes on one hub flange and 0% on the other hub flange. Remember to check that all of the spokes have been warm laced over one another.

When you start feeding in the spokes from the other flange normally it is a mirror of the first flange but offset at the hub. The holes on the hub are not drilled in the same location on the opposing flange but between each of the holes on the opposing flange.

After having laced the first flange you will have one spoke hole free next to the valve hole. Start with this spoke and ensure that it pulls away from the spoke it sits next to adjacent to the valve hole. Spokes that sit next to one another at the rim on a tangentially laced wheel are not identical as they pull away from the rim, some pairs as the leave the rim parallel as they leave in one direction, some pull away parallel in the opposite direction, some pull together, some pull away from one another. It needs to be this pulling away permutation either side of the valve hole. This will allow a gap above the valve hole which makes access with a pump more straightforward. Now you can apply the final set of spokes through the only remaining hub holes and feed them to the only remaining rim holes remembering to warm lace them.

I lace until the threads have disappeared on the spoke. However, often when you calculate spoke lengths you round up or down by 1mm, so bear this in mind when you are lacing. It is better to round up, rather than down, but if you have rounded down the lacing will be naturally tight, if you have rounded up then the lacing will be loose. You can save time on loose lacing by doing an extra 360 degrees on each nipple. You can make lacing easier on a tight build by leaving a couple of threads exposed during lacing.

Another consideration is nipple size. Different rims have different beds for the nipple to sit in. Some have a shelf on the inside for it to rest on such as the Ambrosio FCS28. This then requires a longer nipple, 16mm in the case of the Ambrosio. Without such a nipple you will be unable to attach your spoke key and build your wheel. It is not a good solution to run longer nipples and shorter spokes, the same length of spoke is required when using longer nipples. When using longer nipples you will need to do additional turns during lacing or building. If you do this during lacing it can save time.

Finally, a good wheel builder will make it so that the brands of the rim manufacturer and hub manufacturer can be seen simultaneously. This is something determined when you start lacing a wheel and it depends on where you place your lead spokes. It has no structural impact but it is a convention followed by good builders. It is only done for aesthetic reasons so you can see what the wheel is without hunting both brands separately, you can often tell an amateur wheel by this measure. They will also ensure that the spokes are laced so there is space above the valve hole to attach a pump. This is determined when you begin lacing and it is easiest to start lacing at the valve hole for this reason. You take your first two spokes and hole them to the rim, where you have inserted the spokes in the hub will determine whether the manufacturer labels line up together.

It is worth making a quick assessment of the wheel after lacing. Squeeze the spokes together and see if they feel very slack or very tight. If they are slack, you may want to start by adding some tension. If they are tight, best to start with a basic true. When using a spoke key on a nipple you turn the spoke anticlockwise as you look at the rim from the perspective of the hub if you want to add tension, clockwise to remove it. Initially you will do complete turns or perhaps even several turns at once. Ensure that you turn each spoke the same amount to preserve the evenness of tension.

When it comes to truing a wheel it is a case of tightening and loosening spokes. If a rim is pulled one way you can correct this by loosening the spokes which pull it in that direction.
and tighten those that pull in the opposite direction. It is best to make small adjustments and a lot of them until you are confident. A quarter of a turn is normally best. Fine tuning at the end may be 1/8 of a turn at a time. It is important to loosen and tighten to preserve the overall evenness of tension in the wheel.

Using a wheel stand with a clock or dial gauge makes truing easier and more precise although it can take a while to get used to. It allows you to specify the trueness of a wheel. I normally build new wheels to within 0.12mm and re-true old wheels to within 0.25mm. It is unnecessary to true beyond this point because the wheel will flex to a far greater extent under load.

Roundness is less important than trueness although a wheel that is near perfect in roundness is preferable. Often you will find discrepancies in the rim which prevent this, particularly around the join. It may be proud or sometimes it can dip. In this instance it is best to ignore the discrepancy rather than use exceptionally high tensions to correct it. I try to round a wheel and build up tension simultaneously. You can round a wheel by tightening high spots, try to tighten spokes in pairs (one from each hub flange sitting together at the rim) to pull the rim in. As the rim gets pulled in you increase tension slightly over the wheel. This can be a nice way to fine tune tension near the end of the build by taking in high spots or loosening low points.

It is always worth getting dishing sorted early on in the build, normally it will remain correct from then on. I use a dishing tool to do this. When the wheel is dished, roughly round and true I apply more tension. Sometimes if spoke heads are sitting proud in the hub it is worth punching each of the spoke heads with a specialist concave spoke head punch. This ensures proper sitting in the hub which will prevent wear on the spoke elbow as well as ensure that all the heads look flush.

It is worth checking tensions with a tension meter at an early stage during building. If two spokes on a given side carry a load unevenly, loosen one and tighten the other. A good wheel will have even tensions throughout the wheel. This gives it strength and stability. Only build up the wheel to full tension when the tensions are held evenly on the spokes. If you pluck them like an instrument, they should play roughly the same note. This is a simply way of measuring evenness of tension if you are without a tension meter. However, a tension meter is important if you want to ensure the wheel is built to the appropriate tension. A wheel should be built to the maximum tension that the weakest component can tolerate which is normally the rim.

When the wheel is at tension you should stress it. There are three stress tests worth undertaking. One involves laying the wheel down flat so that it rests on the rim and axle. Imagine the wheel is resting on the floor at 180 degrees (6 o’clock); place your hands at 90 degrees and 270 degrees and push. Rotate the wheel and repeat this several times, the reverse and repeat again. You should feel the rim start to flex. Do not over flex it at this point. Another stress is to stand the wheel up and push down on it. Rotate and repeat this process a few times, this can be done with considerable force. You can even sit on the wheel if you feel confident. Finally grab sets of parallel spokes on each side of the wheel and squeeze them together hard, do this on every set of spokes on the wheel.

After stressing the wheel will have lost tension. Build this tension back up, retrue and ensure the wheel is round. You can then stress the wheel again and the tension should remain, if not then retension and repeat. When the wheel is dished and round, tensions are remaining high give it a final true and it is ready for riding. After turning a spoke you will probably need to backturn slightly to undo the windup in the spoke, this will prevent stress sitting in
the spoke which can lead to failure.

4. Spoke Failure: Diagnosing the Cause, finding a Replacement
The overwhelming majority of spokes that fail are on low quality, well used wheels. The spokes in the wheel will be unbranded, plain gauge versions. They will probably be on a 26” or 700c wheel and their length will as a result be somewhere between 254 and 266mm or between 286 and 296mm. They will be 2mm in diameter and have a J bend at one end and they will be threaded at the other with a 12mm nipple. The spoke will probably fail on the drive side of the rear wheel at the elbow. This is the weakest part of the spoke which takes the greatest strain. Most shops carry suitable replacements for these spokes in those lengths. In the UK they will probably carry DT Swiss Competition spokes as they are the easiest to source. The failure of a basic spoke is unsurprising and will probably shortly be followed by other spokes snapping in a similar way in a similar area. The wheel is fairly worn out, you will probably find that the bearings are also fairly worn and/or the braking surface is worn. Sometimes spokes are made of lower quality steel, perhaps galvanised steel, which may rust in the middle which causes failure in the middle of the spoke. Sometimes the nipple fatigues and fails completely in which case the spoke has held up but the nipple has collapsed.

If the failure is different to this, the replacement gets more interesting. The next most common failure would be similar but with a better quality spoke. Good quality branded spokes should not break. They should outlast the other components on the wheel. As a result their failure is probably caused by them being damaged or their misuse. The most common way for these spokes to become damaged is on the rear wheel. They have either been damaged by the chain or by the derailleur. The derailleur, if it has become bent or has been improperly set up can knock the spokes as the wheel goes round. This can chip away at the spokes until they fail. A serious knock can bend and weaken the spokes.

If the chain slips down behind the cassette or freewheel it can slice piece of the spoke away. If you remove the cassette/freewheel you can see the damage done by the chain. Normally the spokes will not fail straight away but after time. On a 36h wheel there will probably be 9 damaged spokes from this cause; the ones that sit proud on the drive side. If your chain slips down behind the cassette/freewheel, it is worth checking the integrity of the spokes. If they are damaged it is worth replacing all damaged spokes.

Sometimes spokes fail because another implement has gone into the wheel. This is a common cause for failure on a front wheel. In which case, assess which spokes have been damaged and replace them all.

It is important to have even tensions among spokes if you want a strong and stable wheel. If the rim has been damaged it may be the shape of a pringle. As a result, certain spokes will need to be under much higher tensions to compensate and keep the wheel true. However sometimes two spokes on one given side will be sharing a load unequally. If you even the tensions between them, they will be less prone to breaking. Remember, spokes can break from being too loose as well as too tight.

Certain hubs are drilled for larger spokes. In this instance if a smaller spoke is used there can be movement which causes damage. It can also lead to the elbow sitting inelegantly in the hub flange. In this instance it may be best to replace the spoke with one of a large gauge.
If such a spoke is unavailable a washer can help. A spoke washer is designed to sit between the spoke and the hub flange to reduce the play between them. For more details on the application of washers in wheel building see Chapter 19.

It is also possible to have hubs which are drilled to only accept thinner spokes. Royce hubs are drilled to 2.35mm and as a result will not accept anything other than 2mm spokes at the elbow. As a result, it is best to avoid the application of Sapim Strong or Alpine 3 or any other larger spoke with these hubs. It could lead to damage of the hub shell or the spoke at the elbow. If the spoke bend is too short for the hub flange this can cause the head of the spoke to pop off.

On certain wheels when the spoke length is particularly short a 3x lacing pattern will cause the spoke to enter into the rim at an extreme angle. The nipple will resist this angle and this creates a bend in the spokes near the threads. This will stress the spoke and cause it to fail after time. If you are building small wheels or using large hubs you may need to reduce the lacing pattern to a 2x or even 1x. This is relevant for building with a Rohloff hub, for more detail see the chapter 11.

Sometimes particularly unusual spoke lengths are required and they need to be ordered specifically to undertake the repair. However if only one length is required a box of 100 seems excessive. It is possible in these cases to make a spoke of a custom length. It is best to do this with a plain gauge or single butted spoke because they can be cut to almost any length. When the spoke has been cut it will need to have thread applied. This requires a specialist tool carried by many cycle shops. It will roll the threads onto the spoke rather than cut them which is stronger. This is a good solution when replacing only a few spokes. However the process is lengthy and is not appropriate for making spokes on a larger scale. For that, more advanced spoke cutting and threading tools are needed like the Phil Wood version.

When repairing a wheel it is worth checking the length of spoke used before. Sometimes threads will be showing just below the nipple. In which case the spokes are too short and will be prone to failure. Equally if spokes are proud out of the top of the nipple the spokes are too long and are prone to failure.

Certain light gauge spokes, such as the Sapim Laser, are not suitable for use with disc brakes. This is mainly because they are prone to twist and damage during their installation. When you install a spoke, it is important it is suitable for the function of the wheel. Equally, it is important to stress the spoke before riding. Light gauge spokes are prone to wind up so backturning is a good practice to get into when adjusting tension. For more details on truing and tensioning wheels, see chapter 3.

It is important that the right length nipple is used during building or spoke replacement. Commonly nipples are 12mm long and take spokes that are 2mm in diameter. These diameters can vary and sometimes longer nipples are required. If the nipples used are too short the tops can be taken off when using a spoke key, they will also not support the spoke properly in the rim. Sometimes longer nipples are used if spokes are too short. This is poor practice. It is a solution that will get you home but should be avoiding in wheel building if possible.
Sometimes spokes loosen from vibration and movement when the wheel is in use. It is worth checking tension regularly and particularly when a spoke is replaced. Low tensions place strains on one spoke at a time which causes them to break. High tensions can damage rims and sometimes hubs, particularly with radial lacing. It is possible to buy spoke freezes from major spoke manufacturers. These prevent the nipples from loosening but allow for retrueing. Equally most major manufacturers make specialist nipples which prevent spoke loosening see the chapter 6. When building without locking nipples I use linseed oil which acts like a locking solution. For more details see the chapter 3.

Sometimes spokes have been bent when they were installed in the wheel. Spokes are normally made out of stainless steel which can flex to an extent. If you bend it beyond that point it will damage the spoke which can then break when it is under full tension. High end wheels require spokes to hold considerable tension so their integrity is important.

Sometimes specialist spokes which are straight pull, made out of aluminium, titanium or carbon fibre, or those with unusual rim interfaces are used. In this instance spare spoke kits are normally offered by the manufacturer. Sometimes complete rebuild services are also offered if many spokes have been damaged.

When a spoke snaps it put strain on the spokes around it which then have to bear its load. These spokes are normally the next to fail. You can probably get away with replacing only those spokes which failed. However it is worth checking the integrity of the neighbouring spokes when you do so. If you are buying spokes to repair the wheel yourself, it is normally worth buying more than you need.

Finally aero spokes such as the CX-Ray require a special tool to hold them steady when you tighten or loosen them. Failure to use this on the CX-Ray or any aero spoke can cause them to become damaged, particularly because they are cold drawn specifically to preserve their strong molecular structure.

5. Choosing Spokes

A bicycle wheel can only be as good as its parts. A wheel is made of three main parts; hubs, rims and spokes. If any of these is poor then it will lead to a poor wheel. Even a stout rim will go out of true rapidly the wheel is built badly; a good build requires good spokes. Spokes literally hold the whole item together. Spokes enable wheels to have remarkable strength with surprisingly little weight.

I use (almost exclusively) Sapim spokes. Sapim offer a range of high end products at competitive prices.

Different spoke types

The most basic spoke is known as the plain gauge spoke. Sapim’s Leader spokes is an example of this. There is a big variety in plain gauge spokes, although you may be unable to
tell this by eye. Sapim’s leader spokes receive the same strengthening treatments as their butted spokes, which means they have a lot more strength than most competing versions. Their main disadvantages over other Sapim spokes are weight and strength. However, it is important to note that Leader spokes are the exception, most plain gauge spokes are weak and should be avoided. Even the leader is the weakest of the Sapim range.

A spoke is subject to two key kinds of force. One is constant, because of the tension it is held under. The other is inconstant and more violent which occurs when an impact is made upon the wheel. It is when a wheel receives these sudden forces that butted spokes become important. The dimensions of a butted spoke differ from plain gauge because they are not a continuous thickness throughout. The most common is the double butted spoke which is thicker at the elbow and threaded end. Butted spokes can flex and absorb impacts better than plain gauge because their thinner central section allows them to stretch. The extra material around the elbow and nipple allow strength to be retained in the areas that commonly fail.

Sapim’s most common double butted spoke is called the Race spoke. They are 2.0mm thick both ends and 1.8mm thick in the central section. Sapim also offer a higher quality but lighter duty version known as the Laser which are butted in a 2.0mm-1.5mm-2.0mm design. These are slightly more expensive than Race spokes and are better suited to lightweight road wheels. Sapim have recently released a triple butted spoke known as the Force, although this is not available in the UK. This is butted in a 2.2mm-1.8mm-2.0mm design. Spokes most commonly break at the elbow, furthermore hub manufacturers have increasingly moved towards 2.5mm hub drilling, which means that a 2.0mm elbow can sit quite loosely. The Force takes advantage of the butted spokes flexibility and reinforces the spoke at its weakest point. Being 2.2mm at the elbow the Force will still fit in 2.3mm hub holes. The Force is one of Sapim’s most expensive spokes, although it is also one of their best. One other butted spoke that is relevant is Sapim’s Strong spoke. This is single butted in a 2.3mm-2.0mm design. Single butted spokes possess less flexibility than double butted. However it is more economical and more available than the Force and it is strong option when flexibility is less important.

One final spoke in Sapim’s range is the CX-Ray. This is an aero spoke and is their most expensive. It is 2.0mm at the elbow. The centre section is oval and is 2.3mm deep but only 0.9mm wide. This not only improves aero-dynamics but also makes for an exceptionally strong spoke – Sapim’s strongest.
It is also their lightest. It also has the longest fatigue life. However it is nearly eight times the price of Sapim’s Race spoke. One disadvantage of previous ‘bladed’ spokes is that they often required hub filing. This was not only tedious but also weakened the hub. Some hubs came pre-filed but these limited options for builds. Now bladed spokes have now fallen out of fashion in favour of aero spokes. These are less aero-dynamic but they are stronger and more stable. Sapim’s CX-ray spokes really are some of the best money can buy, they are one of the strongest, lightest, hardest wearing spokes out there and they are aero-dynamic. They can be used in both downhill wheels and high end race wheels. However their price makes their application less common.

Here is a chart with a technical comparison of Sapim spokes:

<table>
<thead>
<tr>
<th>Type</th>
<th>Weight (x64@260mm)</th>
<th>Strength</th>
<th>Fatigue life (revolutions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leader</td>
<td>428g</td>
<td>1080n/mm²</td>
<td>870,000</td>
</tr>
<tr>
<td>Strong</td>
<td>430g</td>
<td>1400n/mm²</td>
<td>1.6 million</td>
</tr>
<tr>
<td>Race</td>
<td>360g</td>
<td>1350n/mm²</td>
<td>890,000</td>
</tr>
<tr>
<td>Laser</td>
<td>281g</td>
<td>1500n/mm²</td>
<td>1.2 million</td>
</tr>
<tr>
<td>Force</td>
<td>360g</td>
<td>1350n/mm²</td>
<td>2 million</td>
</tr>
<tr>
<td>CX-Ray</td>
<td>278g</td>
<td>1600n/mm²</td>
<td>3.5 million</td>
</tr>
</tbody>
</table>

The fatigue life test was undertaken by Sapim. It involved taking the spoke from a load of 0kg to 90kg and back to 0kg again. With the CX-Ray this could be undertaken over 3.5 million times without the spoke breaking. This extended fatigue life is partly a product of the butting, partly a product of the high grade of steel (adding 8% nickel over the standard stainless steel used in the Race spoke). Finally Sapim say the process of ovalising the spoke adds strength. The Laser is a non-ovalised CX-Ray which is why their weights are so similar.

Front wheels and lacing patterns

When selecting spokes for a wheelset it is important to understand each wheel individually. The front wheel carries less stress than the rear. Therefore it does not need as strong spokes and fewer spokes are required. Sapim Race spokes are appropriate for most front wheels, although Sapim Lasers could be used if weight saving was important or better still CX-Rays. A front wheel can normally be both radially or tangentially laced. Braking must be applied at the rim for radially lacing to be suitable, braking at the hub will cause damage. Radial lacing is where the spokes come out directly from the hub. Tangentially laced spokes normally cross three other spokes before they reach the rim. This has given rise to the term 3X, which is the most common lacing pattern. Many hub manufacturers refuse to warranty products built into radial wheels. There have been instances where the spoke has been pulled straight through the hub flange.
Many wheel builders refuse to build wheels with radial lacing patterns because of the risk of the spoke being pulled through the flange of the hub. However many major wheel manufacturers have moved towards radial front wheels because of aesthetic benefits as well as some weight saving advantages as well as improved stiffness. I have built many wheels with radially laced spokes and none have ever failed at the hub. However, I always point out before building that with the majority of manufacturers, radial lacing invalidates the warranty. I would also discourage the use of radial lacing because it distorts the hubs making for a weaker wheel and it makes for a slightly rougher ride. It is possible to lace radially with heads turned in or heads turned out. I normally lace heads turned out which is less stiff and less likely to damage the hub. However those in pursuit of the stiffest wheel possible may want to go with heads turned in to achieve this.

Dishing and rear wheels

A rear wheel is quite different to a front. It is normally ‘dished’. It also carries a higher proportion of the bicycle’s load. It cannot be completely radially laced because a rear wheel has turning forces exerted upon it from the hub, these would stress and break the hub flange as the spokes are pulled out. Most commonly rear wheels are 3X, although wheels with large numbers of spokes can require 4X or even 5X, others which require particularly short spokes such as Brompton or Rohloff wheels require 2X. Sometimes radial lacing is undertaken on the non drive side which takes a lower proportion of the load. This is done for aesthetic reasons and can help increase stiffness in the wheel.

Dishing occurs on rear wheels with uneven centre to flange measurements, normally there to incorporate external gears. The right hand flange is moved towards the centre line of the hub in order to fit in the cassette or freewheel. This means that the right hand or ‘drive side’ spokes need to be under greater tension than the left hand or ‘non-drive side’ spokes. The tensions on a drive side are more than double that as on the non-drive side and wheelbuilders and manufacturers have been creative in their solutions to this problem.

Sometimes people opt for twice as many spokes on the drive side. Quality rims normally have an allocated direction so this can be an inelegant solution with spokes facing the wrong way in the rim. Another solution which I sometimes use is to have different spokes on the drive side to the non-drive side. The non-drive side will commonly use the same spokes as used on the front wheel. The drive side will have heavier duty spokes an importantly spokes with less flex. This means that the spokes flex more evenly on both drive side and non-drive side. A light duty build could use Sapim Laser spokes for the front and non-drive side and Sapim Race for the drive side. Heavier duty could be Sapim Race for front and non-drive side and Sapim Strong for the drive side. Many wheelbuilders neglect such detail, although it is important for a well balanced wheel. Moreover it does not need to add considerably to the
cost of the build. An important factor to consider before doing this is that sometimes a larger spoke elbow will sit badly in a hub. Considering the quality of the spokes I use as standard, most wheelsets can be laced with the same spokes throughout.

Other considerations

Sapim Laser and CX-Ray spokes are made out of a different grade of steel to all other Sapim Spokes. They contain 8% Nickel. They have been developed in a different way to cope with particularly high tensions, with the CX-Ray rated up to 1600n/mm² approximately 160kgf and the Laser taking up to 1500n/mm². However, these spokes are not recommended for wheels that are built to lower tensions. This causes vibration at the hub and as a result these spokes can failure. Their most common area for failure is at the hub, at the elbow on the non-drive side of the rear wheel. This is the weakest point on the spokes under the lowest tensions. Only use CX-Rays or Lasers on rims that can tolerate higher tensions. Mavic rims have a particularly low tension rating of 90kgf which makes them unsuitable for use with CX-Rays or Lasers.

Certain hubs like Royce hubs have small spoke hole diameters - 2.35mm. This has been done to ensure better support of the spoke in the hub. However, it means that spokes no larger than 2.0mm at the elbow should be used. CX-Rays can be fed through Royce hubs but Sapim Strong spokes or similar are not appropriate on Royce hubs as they have a 2.3mm elbow. Sapim Force spokes should be okay but are not recommended.

Sapim Laser spokes have been rated as unsuitable for use with disc brakes. This is because they are prone to spoke twist. This is a phenomenon where if you tighten spokes the friction between the nipple and spoke causes the spoke to twist or ‘wind up’. This can damage the spoke if it happens too much. Effective lubrication helps with spoke twist, it is worth holding the spoke by hand to see how severe the twist is and you can help prevent the twist by holding this spoke by hand. Sapim CX-Rays by contrast are not prone to spoke twist because you can hold the aero section of the spoke with the CX-Ray spoke holder. This helps to ensure the integrity of the spoke during building and retrueing which is why CX-Rays are suitable for use with disc brakes.

6. Sils Alloy and other Nipples

Nipples are the little screws that hold the spoke into the rim on the wheel. While they may seem like an entirely straightforward selection for your wheels, there is quite a bit more detail to them than you might imagine. Quality nipples come in two major materials. Either nickel coated brass or aluminium alloy. Manufacturers of spokes such as Sapim, Wheelsmith, DT, Alpina all provide nipples with their spokes and in the overwhelming majority of cases you get some sort of nickel coated brass nipples. These are cheap to manufacture and resist corrosion. They come in different lengths to suit different rims. The most common length is 12mm.

The main benefits of alloy nipples are weight saving. However commonly these are made of the 2000 series aluminium which is comparatively weak. They can deform during the build, they can corrode with the elements and seize up to prevent re-truing. Sapim have recently released a new type of nipple. They call it SILS which stands for Sapim Integrated Locking
System. These are made out of 7075 aluminium which is stronger. It also has a unique special anodized coating which resists corrosion.

The new coating also means that these nipples require no lubrication. They are squeal free during the build. Perhaps more importantly they remain tight during use and can be re-trued effortlessly during after-care. Even in high end wheels spokes can work loose leading to a potentially dangerous wheel. Different builders and manufacturers use different approaches to tackle this. Some use no lubricant at all to maximise friction however this can cause damage to the components during the build and inhibits the high tensions required for a stiff wheel. Others use linseed oil to lubricates during the build and then acts like a mild threadlock afterwards. More radical solution include the after-application of a spoke freeze which can be used to either permanently hold the spoke in place – preventing any further truing. Or you can use spoke freeze in conjunction with other lubricants to retain some re-truing potential.

Sils alloy nipples are an excellent solution to this problem. They offer high tensions, low friction, no lubrication required, no corrosion and no loosening - at least in theory. In practice it is best to still apply a little lubricant to the contact between the nipple and the rim. Equally alloy nipples are best suited to eyeleted rims. Non-eyelets rims can damage alloy nipples so ensure that the rim is well finished before using them and lubricant is a good idea.

Another important consideration is Sapim's technology. They have deliberately imperfected the thread on the SILS nipples which is where the locking comes from. This thread is only recommended for use with Sapim spokes. Also, even 7075 aluminium is still softer than brass, so a quality spoke key is required for using SILS or any other type of alloy nipple. One which holds all sides of the nipple simultaneously. There are a number of versions available; they drop down onto the nipple rather than slotting on like a spanner.

There are locking nipples made by other manufacturers as well. DT Swiss have developed one called Pro-lock and Alpina offer a nipple using their ABS technology. The DT Swiss versions are particularly expensive and work similarly to a nylock nut with a nylon insert. The Alpina versions are economically priced but are made out of brass instead of Aluminium.

7. DT Spokes and Other Manufacturers
DT Swiss is the leading manufacturer of high end spokes in the world. They are also more than just a spoke manufacturer. They make complete wheelsets, hub, rims and also suspension systems. However, despite their massive brand presence, I rarely build with them. The simple reason is price. Sapim spokes are much more competitively priced than DT Swiss versions. They are both internationally distributed spokes. They are both used by wheel manufacturers to produce mid and high end products. They both produce stainless steel spokes and they both use their own individually patented cold forging technique for forming the spokes. Sapim’s smaller presence has led people to believe they are a newer entrant to the spoke market than DT Swiss. The Company is actually some 30 years older than DT Swiss, making it the oldest major spoke manufacturer. Despite their age they are still constantly researching new techniques and designs for spokes.
DT Swiss spokes in terms of profile are almost identical to the Sapim range. The DT Swiss equivalent to the Sapim Leader, a basic, plain gauge spoke, is the Champion. This is the most economically priced spoke for both companies, however both companies claim that the steel and processes involved in their manufacture make these spoke superior to other plain gauge spokes on the market.

When it comes to the entry level double butted spokes Sapim have their Race spoke. This is 2mm at the elbow and thread and 1.8mm in the central section. DT Swiss offers their Competition spoke which has the same arrangement. There are key difference between the Competition and the Race spoke. The Competition has a far longer butt at the elbow. This has led to the Competition being slightly heavier than the Race with the Race coming in at 360g for 64 spokes at 260mm DT Swiss are 376g. Interestingly there is a 9 gram difference in weight between the Leader and Champion spoke as well. So the extra weight in the DT spokes is only partly due to the increase butting. The material used is clearly also heavier.

Sapim use two different types of steel in their spoke manufacture. Inox 18(stainless steel coming from the French Inoxiable) which is 18% chromium and Inox 18/8 is 18% chromium, 8% nickel. The Sapim Leader, Race and Strong spokes are made out of Inox 18, whereas the Laser and CX-Ray are made out of Inox 18/8. This makes the Laser and CX-Rays tolerate higher tensions and fail under low tensions. All DT Swiss spokes are made from X5 stainless steel which is the equivalent to 18/10. The 18, 18/8 and 18/10 designations are being phased out when talking about grades of stainless in favour of more precise formula descriptions. However they remain a useful comparison here. Equally, while adding nickel adds strength to the steel, the 10% content is not necessarily a clear indicator that the DT Swiss spokes are better. 18/10 is better at resisting salt water but has a shorter fatigue life. Either way, the materials we are dealing with are less critical than spoke design and manufacturing process. It is from the patented cold forging techniques used by the manufacturers that the steel will gain its key strength. Finally, the Sapim Race/Strong/Leader spokes, which are technically made from the lowest grade of steel, are still exceptionally unlikely to ever break unless damaged.

The Laser is Sapim's light gauge double butted spoke - butted in a 2-1.5-2mm formation. DT Swiss' equivalent is their Revolution spoke. The Revolution spoke could be construed as superior to the Laser from a number of perspectives. Sapim do not rate the Laser as suitable for use with disc brakes, whereas the Revolution is suitable for use with disc brakes. Moreover it is the spoke of choice in a large number of disc brake applications on pre-built wheels. The Revolution is also capable of standing at low tensions, whereas the Laser demands high tension to prevent its failure at the spoke elbow. However, the Laser is capable of handling higher tensions than the Revolution (although the Revolution can in all likelihood handle tensions at least as high as the rim can). The Laser is also considerably cheaper. Unlike the disparity in weight between Sapim and DT for the Competition/Race and Champion/Leader, the weights of the Revolution and Laser are almost identical with the Revolution coming in at a mere 2 grams lighter for 64 spokes at 260mm each.

Sapim's Strong spoke, which is a heavy duty, single butted spoke does not have a direct equivalent in the DT Swiss range. A similar model is their Alpine III spoke. 411g verses 430g means that the Alpine III is a lighter spoke than the Strong. The Alpine III instead of being single butted is triple butted - 2.34-1.8-2 whereas the Strong is 2.34-2. The Force spoke, unavailable in the UK would have served as a similar alternative to the Alpine III in a 2.2-
1.8-2mm butting. Its lack of availability is due to its higher cost than the Strong with minimal gains in strength and the weight saving deemed irrelevant.

The production of the Alpine III by DT was designed purely to be the strongest spoke in the world. Also, by being 2.34mm at the spoke elbow, it can still fit most hubs. This spoke has become popular in trekking and downhill use when strength and longevity are important.

The DT Swiss Aero-lite is their most expensive spoke. It is comparable to the Sapim CX-Ray and they both use a 2.0-0.8x2.3-2.0mm ovalised butting profile. This makes them both equally aerodynamic. The Aero-lite is made from Inox 18/10 whereas the CX-Ray is made from Inox 18/8. The CX-Ray is available in black and silver. The Aero-lite is available in black and white. DT Swiss believes that it is essential with the Aero-lite that they have this coloured coating on them. It is designed to help resist the corrosion. This also means that they should not be laced in a 'warm' pattern unlike the CX-Rays which can be laced in a warm pattern.

The CX-Rays are considerably cheaper than the Aero-lites. They can tolerate higher tensions than the Aero-lites. They are more prone to failure at lower tensions. At 274 grams per 64 spokes at 260mm the Aero-lites are 4 grams lighter than the CX-Rays. For whatever reason, perhaps even just marketing hype, the DT Swiss Aerolites are the spoke of choice on super high end time trial wheels unlike the CX-Ray which extends only to the high end.

DT also offers some different spokes: The Aero-Comp, a heavier bladed spoke, the New Aero, an even heavier bladed spoke, the Aero Speed which is in between the Comp and Aero-lite in weight and is also a bladed spoke. They also do the Alpine; a double butted spoke, heavier gauge than the Competition and finally the Super Comp which is triple butted but similar in gauge to the Competition.

Wheelsmith Spokes

As there is no distribution of Wheelsmith spokes in the UK, I will not provide the same level of detail on their spokes as I have with DT Swiss and Sapim. They are extremely popular in the USA where they are manufactured and are largely considered to be one of the three great spoke manufacturers alongside Sapim and DT Swiss. They are the youngest of the three companies but claim to be the first to perfect mass production of quality stainless steel butted spokes.

Wheelsmith spokes are all made from 304 stainless steel, which is roughly the same as INOX 18/8. They are also cold forged like Sapim and DT Swiss. However, just because Wheelsmith spokes are made out of a similar material as the CX-Ray and Laser spokes, does not mean they perform in the same way. Their manufacturing processes and shape are different. Just like Sapim and DT Swiss they also have designed the profile of their spoke elbows and butting with care. Each manufacturer has carefully researched the profile of their spokes and aimed for the best solution.
Comparing the three brands

Plain gauge: Sapim Leader = DT Swiss Champion = Wheelsmith SS14

Wheelsmith also offer an SS15, stainless steel 15 gauge. So these are still plain gauge but they are 1.8mm thick instead of 2.0mm. This is an interesting spoke because it saves a considerably amount of weight. There is a loss in strength, however there is no real change in price, so it can be an economical way to save weight in a wheelset.

DB14 - similar to the Sapim Race and DT Swiss Competition. However this time in 2-1.7-2mm butting, making it lighter.

DB15 - similar to the Sapim Laser and DT Swiss Revolution. However this time in 1.8-1.55-1.8mm butting. Or there is the XL14 which is the same profile as the Laser and Revolution.

XL15 - essentially a merger between the 15 gauge spoke and the super butted XL14. The butting on this is 1.8-1.475-1.8. This spoke as a result is lighter than the Aero-lite, CX-Ray, Laser and Revolution.

The AE15 is their Aero spoke. Butted quite differently again. 1.8mm-2.2x1.2-1.8mm. So this time again based around the 15 gauge wire rather than 14 gauge.

The DH13 is the same butting profile as the Sapim Strong spoke 2.3-2.0mm

Nipples

Sapim have developed a specific nipple shape called the Polyax nipple. This has been designed so that it can run at more extreme angles than other nipples. They also have their SILS nipples which are mentioned in chapter 6. Wheelsmith nipples have longer threads. It makes for a longer contact with the spoke and also helps to prevent the nipple folding with age. They also use a unique coating on their nipples which they claim is superior to Nickel coating. This is called duristan. It is not independently verified that longer threads are a good idea on nipples. Generally adding threads weakens a material which is why threaded forks are weaker than non-threaded versions. Perhaps the extra threading on the nipple weakens it as much as it strengthens it. Either way, high end nipple failure is unusual and normally a sign than many of the other components are worn too.

Other manufacturers?

Well there are other spoke manufacturers out there. In fact, most spokes that are sold in the world are not branded DT Swiss, Wheelsmith or Sapim. These are high end products. Many more basic products are available and the three giants may have involvement in the manufacturing of these as well but may choose to avoid putting their name by them. Basic spokes come on basic wheels; they will have no stamps and will be manufactured to a particularly low price in the Far East. In all likelihood these spoke cannot be purchased as they are OEM.
Finally, we have Alpina, often mistakenly called A.C.I. spokes. The product is normally marketed as A.C.I. By Alpina. So Belgium have Sapim, Switzerland have DT Swiss, the USA have Wheelsmith and Italy have Alpina. Alpina are a mainly big brand when it comes to motorcycle spokes.

Alpina do make a range of spokes, specialising in aero and bladed spokes. They do not have the brand presence that the other three giants have so their application may not be boasted of.

While most of the range of Alpina spokes are made out of INOX 18/8, in all likelihood you will encounter their 'S' brand spokes and these are made out of INOX 18. The process of their manufacture is different to the other three giants. Their appearance is also different. They feel and look like they are of a lower quality with a brighter and shinier appearance.

It is worth pointing out that the plain gauge version of the A.C.I. spokes have been plagued with failure. In contrast their double butted counterparts have not. These spokes are a slightly unusual butting 2-1.7-2mm. If you are looking to build with Alpina spokes, it is worth paying a little extra to go with the double butted versions.

Alpina have created an interesting nipple called the ABS nipple. This is essentially the same as a nylock nut but it is a nylock nipple. The idea being that it prevents spoke loosening like the Sils nipples but using the nylock system and they used nickel coated brass nipples to improve longevity and reduce their price.

Below is a table listing the manufacturers and their spoke models. The attempt is to contrast the various features of the spokes. So you can see that the heaviest version is the Wheelsmith DH13 (443g) and the lightest is the wheelsmith XL15 (254g). This makes the total potential different for 64 spokes at a length of 260mm - 189g.

Please note that the DT weights have been adjusted from their official publication. 264mm has been converted to 260mm. Wheelsmith spokes have been converted from 262 to 260mm.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Material</th>
<th>Weight (g)</th>
<th>Profile (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sapim</td>
<td>Leader</td>
<td>Inox 18</td>
<td>428</td>
<td>2.0</td>
</tr>
<tr>
<td>Sapim</td>
<td>Race</td>
<td>Inox 18</td>
<td>360</td>
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<td>Strong</td>
<td>Inox 18</td>
<td>430</td>
<td>2.3-2.0</td>
</tr>
<tr>
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<td>Laser</td>
<td>Inox 18/8</td>
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<tr>
<td>Sapim</td>
<td>CX-Ray</td>
<td>Inox 18/8</td>
<td>278</td>
<td>2.0-0.9/2.3-2.0</td>
</tr>
<tr>
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<td>Champion</td>
<td>Inox 18/10</td>
<td>437</td>
<td>2.0</td>
</tr>
<tr>
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<td>Competition</td>
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<td>Revolution</td>
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<td>SS14</td>
<td>Inox 18/8</td>
<td>423</td>
<td>2.0</td>
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</table>
Moving from description to prescription

The intentions of this book were to provide useful information when it comes to selecting components for building bicycle wheels. So far in this chapter a lot of information has been provided that describes the differences between the competing spoke manufactures and little advice has been given to choose between them.

Quite simply, brand choice is not that relevant. Different brands do things slightly differently, however what they all do is manufacture high quality products: DT Swiss manufacturer high quality products with exceptionally low levels of reported failure. Sapim offer significant cost savings over DT Swiss at the time of writing they are between 30 and 50% cheaper. Wheelsmith offer a different range of products with a lot more emphasis put on weight saving. Alpina spokes are exceptionally cheap, around 50% cheaper than Sapim.

If you are building a high end wheel it is worth sticking to one of the three (four if you include Alpina) major manufacturers. If you are looking to build a fairly modest wheel or do an economical rebuild, Alpina offers the best value for money on that. In the past I have used Sapim strong spokes on the drive side rear to strengthen up wheels using Alpina spokes elsewhere. This makes failure a lot less likely and can be a good compromise for price.

What is likely to be the biggest factor in your decision is availability. Wheelsmith spokes are not distributed in the UK, so they are unavailable. Sapim spokes are less well distributed than DT Swiss, so DT Swiss is more widely available. I use Sapim because they are available enough, they are good quality enough, they offer a versatile range and they are well priced. In the USA, Wheelsmith may make more sense, they may be better priced over there than Sapim and they are certainly more widely available.

DT Swiss is probably better quality than Sapim, so if price were no object, then they make sense as a choice. However, the performance increase is unlikely to be noticed which makes their application unnecessary in all but the super-high end. The most obvious DT Swiss spoke to choose over the Sapim equivalent is the Revolution instead of the Laser, particularly if you are looking to run disc brakes.

### 8. High End Hubs

As mentioned in the introduction, Shimano make a great range of benchmark hubs. Shimano are a brand that sells products in large quantities and they go for mainstream markets. If you want a particularly niche hub, it is unlikely to be manufactured by Shimano. Their technology is fairly ordinary, their weights are fairly average, their longevity is
unremarkable however they are good quality and excellent value. One of the few technologies that they almost uniquely use in their hubs is cup and cone bearings. Low quality hubs come with low quality cup and cone bearings however now Shimano are one of the only manufacturers making high end cup and cone bearings. They do this because they believe they have perfected the sealing and cup and cone bearings according to them are faster. For more information on bearings, see chapter 12.

When building a wheel Shimano are a likely candidate for a hub, mainly because of their quality and low price. However if price was irrelevant, Shimano are an unlikely choice. What then would you choose? There are a few features that make a good hub a great hub. Features that hub manufacturers strive for are:

- Low weight
- Low rolling resistance
- Longevity
- Strength
- Aesthetics
- Versatility
- Ability to build into a stiff wheel
- Freehub body engagement

Different high end hubs place different emphasis on each of these features. They also use different techniques and technology to do so. Below are some case studies of some high end hubs and their features which try to achieve some of these features.

Chris King produces a range of impressive hubs. Chris King hubs boast a 5 year warranty. They also use their own unique ring drive system within the freehub body; this gives a high engagement count, as well as quick engagement. Some hubs come with higher engagement counts but that just means more clicks per revolution, you may still have a delay before the engagement kicks in. Chris King believe that their system gives one of the fastest engagements available because of their unique system. Chris King hubs also come in a huge array of colours, one of the biggest ranges available on any hub. They have been famous within the mountain biking world for some time, they are tough and the 5 year warranty is particularly appealing for an aggressive rider.

More recently, Chris King produced the new R45 hub, specifically for road use. This comes with a titanium drive system to replace the former, heavier, stainless version. They have also reduced the engagement count to reduce resistance on the hub. A common criticism of the Ring Drive system was that it slowed the rider down a lot when freewheeling. This is less of a problem in off road applications where the increased engagement speed was deemed a greater benefit. However on road, the rolling resistance reduction is a higher priority. The
R45s are quieter than former Chris King hubs and there is machining on the hub flanges to reduce weight. The bracing angle on Chris King hubs is conducive to a stiff wheel and the static load on the bearings is very high. The front hubs are suitable for radial lacing.

Phil Wood makes some particularly nice hubs as well. These come in heavier than Chris King and they offer lower engagement counts too. Phil Wood produced some of the first sealed cartridge bearings hubs to make servicing easy. They developed what they called the Field Servicable Hub. These were designed so that the owner could service their own hub easily with simple tools. Phil Wood is a smaller, more boutique manufacturer of hubs than Chris King and they lack the same worldwide scale of distribution. They produce more niche hubs to fulfill smaller markets. They have released one version known as the LHS, Last Hub Standing. It is a track hub and is designed to be tougher than anything else out there - although that is far from independently verified.

Phil Wood produces a range of higher flange hubs. These are more traditional and may be chosen for aesthetic reasons. However, high flange hubs do last longer; they are also less prone to wind up, where leading spokes become excessively tight and trailing spokes excessively slack. So using a high flange hub is likely to improve longevity of the whole wheel as well, adding to Phil Wood's credentials for providing long life hubs. Their motto is, 'Build it strong. Keep it simple. Make it work.' The hubs require less regular servicing than Chris King, whose hubs can, sometimes, need fairly regular attention to keep them running at top quality. Phil Wood manufacturer a number of other wheelbuilding parts and tools; they produce a popular, albeit expensive spoke cutting and threading machine, they also produce their own spokes which is unusual for a hub manufacturer. You can also buy Phil Wood bottom brackets which is more common for a hub manufacturer as a bottom bracket bears many similarities to a hub.

Another good manufacturer is Hope. They are not strictly speaking a high end manufacturer, however they do produce some interesting hubs. They are heavier than most performance hubs and their longevity is unexceptional. They have some particularly noisy freehub bodies which can need fairly regular servicing and their bearings are prone to wear. They are made in the UK and they are particularly well priced for their quality. It is hard to find a hub at their price that is as light and strong. They use some exotic alloys to try and achieve this and a busy workshop.

The reason they are a case study on hubs is because of their exceptional versatility. The front hubs can take quick release, 15mm and 20mm thru axles. They come with removable cups so you can interface them with whatever fork you need. They pioneered this system which has subsequently been copied by a number of other manufacturers. It is perhaps a contributory factor in their comparatively short life span, although a patented sealing system should ensure several thousand miles of aggressive use if you keep them services. Hope also make their hubs in a wide variety of colours and hole counts.
DT Swiss is a manufacturer of hubs, rims, suspension forks and spokes. Everything they make is high quality and made in Switzerland. Their 240s hubs are their more economically priced version, their 190s hubs are their top end version. There are other versions for more rugged applications and others again used in pre-built wheels. The main difference between the 240s and the 190s is the bearings. The 190s come with ceramic bearings for improved life and decreased rolling resistance. DT Swiss use a different engagement system on their freehub bodies which they believe is superior to all others. The engagement count is fairly low but the engagement delay is near non-existent. If you backturn the freehub and hear the click you will feel an instant engagement, however the infrequency of the engagements means there could still be a delay. The 190s hubs are particularly light, especially on the disc brake versions. They are available in 6 bolt disc and center lock unlike most manufacturers. The front road hubs are suitable for radial lacing.

Royce hubs are the last case study. They are made in the UK on a small scale. Royce hubs are by modern standards considered heavy however historically they have been cutting edge. Royce track hubs were used in Chris Boardman’s record breaking hour time trial. Front hubs come in four different flange sizes. Hubs can also be supplied filed to accommodate bladed spokes. Fully titanium shells are also available as special order items. Royce hubs are polished to a mirror finished then clear anodized for longevity. The shells are made of a single piece of aluminium which is then machined to ensure there are no joins and no weak spots. They are available in a screw on freewheel version, Campagnolo and Shimano freehub versions. Royce do offer disc specific hubs but most of the range best suited for road, track and particularly touring use.

The axles on a Royce hub are made of titanium for unparalleled longevity as well as considerable weight saving and improved stiffness. When you purchase a set of Royce hubs you get a certificate of ownership which if you return the counter-part guarantees the spindle for the life of the original purchaser. The engagement count is fairly sluggish on a Royce hub and the standard bearings are a little draggy. There are faster versions available upon request if you wish which have a reduced life span.

Royce hubs are less expensive than some of the others in the case study and their longevity is exceptionally high. They are aesthetically particularly pleasing although they are only available in high polished silver. Royce are a particularly popular choice for classic looking wheels on semi-performance bicycles.

9. Gears
One of the first great breakthroughs in cycling was the advent of the freewheel. This opened up cycling to many more people, it allowed people to have a rest whilst cycling and the bicycles themselves became easier to use. The next great breakthrough was the advent of gears; this revolutionised cycling. It enabled people to access far more terrain. It allowed
them to pedal at a given cadence but vary their speed. They could climb steeper hills and descend faster.

The original gearing systems were developed by Sturmey Archer in 1902. These had worldwide popularity by the 30s. The original design allowed three separate gears; the middle of the three was direct drive, meaning that the external cog would move at the same rate as the hub. The first of the three was 20% easier than direct drive and the third was 25% harder than direct drive. A range of models were released over the years and Sturmey Archer still produces hubs today, although now in Taiwan rather than Nottingham and they are now owned by Sun Race.

The 1950s saw a sea change in gears with the advent of the parallelogram rear derailleur. This was a cable operated gear changing mechanism developed by Tullio Campagnolo. Campagnolo are still in operation today and their design, ownership and manufacture is still almost entirely Italian. Their history started with the advent of the quick release skewer in 1933 and the derailleur was strictly speaking invented in 1948, although that was not the cable operated system that is used today. Later in the 1950s the 'groupset' was born with the Campagnolo Record. This allowed people to buy many matching components under one brand. The Record range is also still around today now also eclipsed by the Campagnolo Super Record.

One important feature of the derailleur was speed. Internally geared hubs lost some of the power input when they were out of direct drive. The externalisation of these gears produced less significant loss of power and these became Tour De France winners.

As the decades wore on systems with greater gear numbers were developed. Five gears is where it had originally started, the five gear system uses a narrower chain than single speed chains which are normally 1/2 x 1/8 inches. The 1/2 x 3/32 chain used in the five speed systems was important to ensure easier shifting. When the 6th gear was added it was the freewheel itself that became larger, having an extra gear tagged onto the end. As gear counts grew they posed a problem for the freewheel system. The inboard bearings were a long way from the frame ends (dropouts). The lever action caused by the rider weight on these bearings made the axles prone to snapping. The freehub body and cassette system was created in response to this.

The freehub body became particularly popular in the 1980s along with the indexed gearing systems. This meant that a calibrated gearing system would have indexed positions for the gears. However, so also began a great rivalry between the Japanese owned Shimano and Italian owned Campagnolo. They have different pull ratios for the gear indexing. They also have different freehub body interfaces. So for a Campagnolo cassette to fit, you need a Campagnolo freehub bodies. Often wheels come with replaceable freehub bodies so they can now be converted between Campagnolo and Shimano fittings.

There has been some variation since then. Shimano initially started with their Uniglide system but have since moved to their Hyperglide technology. The Uniglide had the final cog screw onto the freehub body, whereas the Hyperglide has a lockring which holds all the cogs in place. Some interim freehub bodies could hold both UG and HG cassettes. Another change has been in size; the freehub body has got larger as more gears have been added. Shimano produced a 7 speed HG freehub body which had a maximum carrying capacity of 7 gears. To get 8 gears an 8 speed freehub body needed to be developed. To get to 9 gears a
narrower chain was developed. To get to 10 speed an even narrower chain was developed. Campagnolo have also produced 11 speed cassettes which have an even narrower chain and it has been suggested that 11 speed Shimano is under development.

More recently the American owned Sram have entered the scene. They work on the same freehub body interface as Shimano however all their modern gear shifting works on a different ratio to Shimano. Shimano chains and cassettes are largely compatible with Sram ones, however shifters and derailleurs need to be of a particular brand. Modern shifting ramps on cassettes, chains and chainrings are now used to improve the shifting performance of modern gearing systems. Shimano's patented system is called Hyperglide and more recently Dyna-Sys within the mountain biking world. Campagnolo have developed UltraDrive and Sram have OpenGlide. The popularity of off road applications and the demands it makes has been a major contributor to the success of Sram and Shimano. Campagnolo have had little presence in off road applications. Sram and Shimano have also offered a large number of more economically priced products. As a result Campagnolo have seen a shrinking market share for decades. The growing popularity of the groupset and complex indexing systems has also meant challenges for smaller gear manufacturers which are left with a dwindling market share if they avoid bankruptcy.

Most recently Shimano has developed Di2 which is an electronic shifting for their road racing components. At the point of writing, Campagnolo’s release of their electronic shifting is confirmed yet unavailable. Shimano have released Ultegra Di2 which has made Di2 much more available to the general public. There are no confirmed releases of electronic shifting in off road applications. The success of electronic shifting for Shimano will doubtlessly lead to its growth in the market over the coming years.

More recently hub gears have seen a resurgence along with fixed gear and single speed bicycles. A lot of this is traditional romanticism combined with people looking for simplicity and neatness. Fixed geared bicycles are low maintenance and offer a unique riding experience. Modern parts also allow for significant weight saving making a fixed gear and single speed bicycle lighter than a geared version. Track racing has always been fixed gear and has also grown in popularity recently. The hub gear has become popular for rugged applications, particularly since the development of the Rohloff hub and Shimano’s Alfine 11. For more on this please see the chapter on 'Building with a Rohloff Hub'.

When it comes to making a decision on having internal verses external gears here are the key disadvantages of each system: Internal gears are heavier and lose more power, if they fail, the item may be unservicable. Internal gears tend to be slower at shifting than external versions and the engagement after pedalling is slower. External gears are exposed to the elements which make them more prone to wear. They also require pedalling to shift unlike internal gears.

Internal gears are generally considered appropriate on hard wearing commuter bicycles because of their low maintenance. They are also used in heavier trekking applications and in some longer distance winter cross country applications. External gears are generally popular on economical bicycle and performance bicycles. External gears hold the majority of the market share.
When choosing gear range you can gear calculators to work out gear inches. This can be useful when comparing external and internal gears, or when choosing chainring or cassette ratios.

Adjusting chainline is not normally possible at the hub, unless you are running a single speed conversion kit. Chainline is normally changed at the bottom bracket or by moving the chainring. Bicycle with old gears may have a narrow O.L.D. When you are building any wheel this is a key measurement that needs considering.

10. Dynamo Hubs

Dynamo hubs are not only still available today but they are growing in popularity. While battery technology has improved greatly in recent years, so has bulb technology and dynamo technology. This means that whether you opt for a battery powered or dynamo powered lighting system, you can have better lights than ever before.

Normally when people think of hub dynamo lighting they think of Sturmey Archer dynamo hubs. These produced a small amount of inconsistent power, which only provided significant output at high speeds; speeds which are unlikely to be undertaken with such poor visibility. The lights themselves provided little illumination of the road. However the energy from the hubs was endless, the maintenance was limited and the friction coming from the dynamo systems was less than bottle dynamos.

Hub dynamos have always been more efficient than bottle dynamos, although improvements have been made in those too. Hub dynamos are less prone to failure and damage. Bottle dynamos can also damage tyre walls and can slip providing a flickering light.

Modern LED technology combined with improvements in efficiency of hub dynamos has allowed for some dazzlingly bright lighting systems and ultra low resistance. Better quality dynamo hubs have regulators to prevent surges. Higher quality lights also have stand light facilities so they light remains on even when stationary. Modern technology has also expanded the potential of the dynamo hub, which can now be used to charge mobile telephones, MP3 players and other portable devices.

Disadvantages

There is an added drag to a dynamo hub. This is fundamentally unavoidable because the hub needs to extract energy from the rider in order to power the light. Many of the improvements in the hubs are applicable when there is zero power drain, when a lighting system is active, the drag is perceptible, albeit only slightly. If you turn the axle on a dynamo hub you can feel resistance coming from it. Interestingly if you spin a wheel with a dynamo hub it still spins freely. The explanation for this is that the magnets inside the hub push and then pulls, so you will notice the resistance when you turn the axle but probably overlook the assistance. The overall effect is largely neutralised and the vibration cannot be noticed whilst riding.
A dynamo hub is heavier than a standard hub. There are some lighter versions available but they all have to carry additional equipment inside them so they will always be heavier. However, you save weight by avoiding batteries so there may be no overall weight gain if you need a lighting system.

Price: there are inexpensive dynamo hubs out there but a decent one will be an expensive option. What you are paying for is reliability and a greener lighting solution.

Performance: the absolute top end battery operated lights are brighter than the top end dynamo versions. However these are exceptionally expensive systems and you are unlikely to require a light brighter than the top end dynamo versions.

**Important hubs**

The least expensive version is the Novatec EDH2 – a fairly heavy, fairly slow but solid hub. This is a great alternative for those on a tight budget.

Moving up the range there is the Shimano DH-3n30. This is Shimano’s entry level dynamo hub. A significant upgrade on the Novatec, offering weight saving and reduced resistance, especially when switched off.

The next important hub is the Shimano DH-3n80. This is Shimano’s top end dynamo hub. This offers improved bearings and life span as well as weight saving and significantly reduced rolling resistance, especially when switched off.

Going beyond Shimano we have Schmidt and Son with their Son 28 hub. These are lighter than Shimano as well as offering reduced drag. They can also go 50,000km between servicing.

The top end version is Schmidt and Son’s Son Delux. This is the most recent entrant to the dynamo market and also the most expensive. It is smaller than other dynamos and considerably lighter. It offers less drag too, even than the Schmidt 28. This hub is designed to go with the new generation of lighting systems which require lower power output at low speed. They offer phenomenal illumination. This is the pinnacle of dynamo lighting technology.

Modern dynamo hubs are capable of running with disc brakes which makes them an option for night mountain biking as well.

**11. Building with a Rohloff Hub**

The Rohloff hub is one of the most expensive in the world. Partly because it is manufactured to a high standard but mainly because of what it is expected to do. The Rohloff has 14 internal hub gears. This means you have no need for: external cassette, front mechanism,
rear mechanism, front shifter or more than one front chainring. There is just one simple shifter that can be used stationary or during pedalling. No-one manufactures a hub that has 14 internal gears apart from Rohloff.

The hubs are Made in Germany. The gears are an even 13.6% spacing with a total range of 526%. When using a double or triple chainset at the front on a standard derailleur system, you will find yourself entering into different ranges of gears which do overlap. So when you have 27 gears they are not 27 individual gears. The smallest chainring at the front with the smallest cog at the back is a considerably harder gear than the middle ring at the front and the largest at the back. The Rohloff has a straightforward shift up or down system. There is no complex arranging of gears and there are no ‘inappropriate’ gears like those found with derailleur systems (when the chainline is far out, or problematic rear mechanisms struggling to cope with the range in chain length).

Rohloff hubs do come in at a weighty 1.8kg per hub on average although this varies slightly depending on the version. However there is considerable weight saved by not having a rear cassette or mechanism and so forth. Unfortunately for Rohloff, because of the weight, the hub is an inappropriate choice for any performance application when weight is a factor, particularly when you consider the additional weight as a result of the rotation of the hub. Moreover a Rohloff, like other internally geared hubs has more loss within the system than a conventional derailleur system, except when run in direct drive.

Rohloff are not concerned about this because their key consideration in their engineering was life expectancy and maintenance. Being externally single speed means that the chainline is always perfect putting less strain on your chain and improving its longevity. It also allows for a wider chain which helps to improve life-expectancy. They also have the gears in an oil bath which allows for very irregular service and the oil can be changed without dismantling the hub. The idea behind the Rohloff is essentially you never need to maintain the internals; you can use the hub for tens of thousands of miles before any internal work will need doing.

Another important feature for Rohloff it that the hub builds into a stronger wheel: rear wheels that have external gears are normally dished which means particularly high tensions on one set of spokes and particularly low tensions on the other set. With a Rohloff, the wheel is undished which means all tensions can be even. Rohloff claim that a 32h Rohloff wheel has the equivalent strength to a 40h conventional rear wheel.

Unfortunately for those looking to build with a Rohloff there are a number of Rohloff specific considerations. Rohloff recommends that their hubs be built up with Sapim Race spokes. They will tolerate the use of spokes with similar dimensions such as DT Competitions. Crucially they want a double butted spoke that is of a reasonable mid section and most importantly has a 2mm diameter at the elbow. Their hub shell is drilled in such a way that fatigue would be caused from a larger spoke. Equally anything smaller would be a poor fit.

They have also specified that the spokes need to be laced in a two cross pattern (1x on smaller than 26” wheels). The size of the hub means that three cross lacing would have the spokes come out of the hub at an extreme angle which can cause wear on them. Additionally, when the spoke meets the rim it is at a considerable angle and this causes the spoke to bend
and in time fatigue. Because of this particular problem Rigida have made a Rohloff specific rim called the Andra 30. These are a hugely tough rim and importantly are drilled so as to prevent kinked spokes. These rims have to be laced in a particular way because not only is each hole side specific, it is directional as well. This is the only rim recommended by Rohloff in their builds and it is only available in 26”. However if you are building a 700c wheel, the angle is less severe and a conventional rim can be used.

Another important consideration when building with a Rohloff is to be careful when stressing the axle. If the axle receives too strong a force it will go out of alignment causing the bearings to lock up. This could occur when the wheel is being stressed or when seating spokes properly. Heed caution when undertaking these necessary steps.

One last Rohloff specific trait is that the leading spoke needs to be facing inwards, in contrast to the trailing spoke which needs to be facing outwards. It is also important that the spokes to not cross over the hub cap fixing screws. Diagrams are available on Rohloff’s website.

What about the Alfine 11?
The Alfine 11 has only recently been released, so at this point they could all be recalled unlike the Rohloff hubs that have stood the test of time. However this is unlikely, especially considering the time the Shimano spent developing it. They have moved away from the technology that they used in the Alfine 8 in favour of Rohloff’s oil bath system. They have also made a hub that is less than half the price of the Rohloff. It is also a little bit lighter than the Rohloff and smaller. It also comes with a fairly standard rapid fire shifter. This uses a normal cable and shifts in the same way that modern Shimano MTB shifters do.

By contrast, it has 11 rather than 14 gears, with a range of 408.5% which is less than the Rohloff. The Rohloff also shifts in even 13.6% increments, whereas the Alfine has a particularly easy first gear (effectively a bail out gear) followed by a jump to second where it proceeds in fairly even increments of a similar percentage to the Rohloff hub.

The Rohloff hub does offer more than the Alfine, however the price disparity has made the Alfine 11 popular. It comes as standard on a large number of bicycle unlike the Rohloff which is generally an expensive retro-fit. The large PCD of the Alfine requires a 2x lacing pattern as well, however Shimano’s literature on the Alfine states otherwise. Do not lace an Alfine 11 hub in a 3x or 4x lacing pattern. This will lead to spoke failure.


The advent of bearings significantly improved the rolling resistance of a wheel. There was a time when wheels would simply sit on a greased axle. The grease itself would need to act like the bearings to reduce the friction. This system was stiff and prone to wear but it was easy to manufacturer.
The basic principle of any bearing is you have balls sitting between two surfaces. These balls roll and allow one surface to freely pass over the other. There are a few obvious factors that will affect quality here. There is the quality of the surfaces; these will need to be curved and smooth. A rough surface will be gritty and sticky and one that has imperfections in the curve will have tight spots and slack spots. Equally the balls themselves need to be strong but also need to be good spheres. If they themselves are imperfect they will lead to tight spots and slack spots. A good bearing will have near perfect spheres for balls passing over a lubricated, hard, polished, round bearing surface. This will allow for free running and each of the bearings should bear the load equally.

Some bearings have the balls running in grooves in the races, whereas others are held together in a cup and cone system. The cup and cone system has been the most popular in cycling applications and until fairly recently was the only system used. The cup and cone system works by having a cup which cradles the balls on their outside and will be an integral part of the hubs shell and a cone which pushes the balls into the cup from the inside. The cone is threaded onto the axle. So the bearing is supported on one side from the axle and the other side from the hub shell. If you remove one of the cones the axle can be completely removed from the hub and all the balls will fall out.

The cone will need to be loaded at an optimal pressure. Too tight and the bearings will grind away at each other and the wheel will not spin freely. Too slack and you will be able to feel play in the wheel. You can do this by holding the tyre and moving it side to side. Play in the wheel will mean that the balls are taking it in turns to hold the burden of the wheel which will damage them. They will also run along an inappropriate course. Normally a locking nut will sit next to the cones to prevent them from loosening or tightening themselves. Specialist spanners called cone spanners are used for this task. It is important when you are doing this on a rear wheel that you lock the cone on the drive side first. This can be fed into the wheel and then you can load the non drive side afterwards. The freehub body on the rear wheel normally prevents access to the cone and so it cannot be locked in place after installation. It can then work itself tight and destroy the hub.

All bearings need to be properly lubricated. Lubricants when old can dry out and they can also be washed away by water, so heavy rain and cleaning can be particularly harsh on bearings. Ceramic hybrid bearings (bearings with ceramic balls) are generally 'lubricated for life' and they are particular about what lubrication is used if more is required. The quantity of lubricant is also normally specified. If you are looking to lubricate a ceramic bearing, please refer to the manufacturer's instructions. Ceramic bearings are uncommon in bicycle applications, generally only found in very high end wheels and bottom brackets. Normally, steel balls are used and these do need lubricating fairly regularly.

Balls will have a grade; the universal measurement for the tolerance of the eccentricity of a bearing will be its ABEC rating ranging from ABEC 1 to ABEC 9. ABEC 1 allows eccentricity to within 0.0075mm, whereas ABEC 9 allows eccentricity to within 0.0012mm. The bearings grade may also be given a value. The lower the value, the higher the grade, typically you will find replacement bicycle ball bearings to be somewhere between 300 and 100. The grade is determined by a number of factors: sphericity, diameter variation, diameter tolerance and surface roughness. Grade 100 will need to have sphericity within 0.0025mm, diameter variation within 0.0025mm, diameter tolerance +/-0.0381 and surface roughness of 0.127 micrometers.
When you replace balls ensure they are the same size as previously used and ideally at least as high a grade. Replace all the balls or none at all. When replacing steel balls on a hub it is best to use quite a thick lubricant. Lithium grease can be used to improve rolling resistance but can be more easily dispersed by water. Oil will provide extremely fast rolling but will be dispersed faster still. It is worth taking time to examine the bearing surfaces to ensure the integrity. If they are blemished or worn unevenly this is likely to be caused by loose running. It may mean that they cannot be loaded properly anymore. They may always either feel tight or loose. Sometimes the bearing cup has completely collapsed or is badly worn in which case it would be dangerous to continue riding. The hub will need to be replaced.

1991 saw Phil Wood create his third generation of hub complete with its FSA axle. This was a revolution in hub design because it provided a Field Servicable Axle. The idea behind this is that using simple tools the user could now service their own hubs. Previously Phil Wood had bonded bearings into the hub shell, whereas now they could be removed with a tool. Phil Wood used a sealed cartridge bearing which would come out as a complete unit. Since then the sealed cartridge bearing has become extremely popular in better quality hubs. Used by almost all high end manufacturers.

So, are sealed cartridge bearings better then? Well, not necessarily. The great advantage of most sealed cartridge bearings is their easy installation and removal. However this is still dependent on the hub manufacturer using a system that allows for easy installation and removal. On many hubs the bearings will need to be pressed in and out of the shell. This can be a difficult process and may require the use of a bearing press. The bearing press is an expensive piece of equipment and is certainly not 'field servicable'. However if the physical installation and removal of the cartridge is straightforward, you then have a complete cartridge bearing to work with. This is easier than handling a large number of tiny balls which need to be kept immaculate.

A common misconception is that sealed cartridge bearings are better sealed than cup and cone versions. Sealed cartridge bearings do contain their own sealing system. You cannot see the balls if you hold the unit, you will only see a seal sitting between the two races. However this is not a perfect seal. Also, if the seal on this bearing is tighter, the bearing will normally run slower as a result. The friction delivered by the seal on the races slows the movement of the bearings. Normally, hubs using sealed cartridge bearings will have addition systems in place to protect the bearing. This makes the bearings integrated seal the last line of defence for the bearing, rather than the only defence. So the quality of the sealing on a bearing on a sealed cartridge bearing hub is actually determined by the quality of the sealing system used, not by the type of bearing used.

Equally, with cup and cone bearings, there are many different systems can be used for sealing them. Often non-contact systems are used on higher end products because they improve rolling resistance. Equally labyrinth systems can be used because it makes it particularly difficult for water to reach the bearings.

Another disadvantage of sealed cartridge systems is they are normally more expensive and they are less widely available. Most cycle shops will carry spare ball bearings for servicing hubs. However few will carry a range of sealed cartridge units for servicing sealed cartridge hubs. These units can be fairly expensive as well whereas the cost of ball bearings individually is negligible. It is important to consider this point that we are comparing the ball with the complete sealed cartridge unit. Yes ball bearings are cheaper than sealed
cartridge units, but the balls are only one of three parts to a complete bearing whereas the sealed cartridge unit is a complete bearing. If you only sought to replace the balls in a cup and cone bearing, the part cost would be negligible. However if you also required replacement cones for the bearing the cost rises considerably. Cones are also not widely available and some simply cannot be sourced. They are also specific to that make and model of hub. Finally, if the cup has gone on a cup and cone hub then the hub has to be disregarded, whereas if a sealed cartridge bearing is completely worn out the whole unit can be replaced and the wheel will become fully functional again.

One great advantage of sealed cartridge bearings is there is less risk of user error. If a cup and cone bearing is improperly loaded it can damage the bearing surfaces and can completely destroy the hub. A sealed cartridge bearing comes already preloaded so there is a reduced sensitivity to their installation. When you install a sealed cartridge bearing it is important to press on the outer race of the bearing. Pressing the inner race can cause the bearing to go out of alignment and become damaged. Sometimes it is impossible to remove a cartridge bearing without pressing the inner race, however if you are removing it, you are probably replacing it anyway so there is no problem.

Campagnolo and Shimano used to both vehemently believe in cup and cone bearings. Campagnolo have subsequently started using sealed cartridge bearings in some of their hubs. Shimano by contrast still use cup and cone on all versions of their hubs. Shimano are prepared to use cartridge bearings where they feel their application is appropriate - for example in their bottom brackets. However they believe that their cup and cone systems are superior and so use them even in their Dura Ace and XTR hubs. They even use them on their thru axle versions. They believe that it improves longevity and also provides less drag than cartridge bearings.

It is true that cartridge bearings often provide more drag than properly set up cup and cone versions. However there are cartridge bearings that are available with faster seals which roll significantly better. It is also possible to reduce the rolling resistance by installing ceramic balls in cartridge systems. These produce less heat, reduced friction and have improved longevity. Ambrosio Filorosso cartridge system offers exceptionally low rolling resistance which appears to somewhat undermine the argument of the die hard cup and cone advocates.

Bearing drag is a serious consideration when it comes to selecting bearings. Before we address it directly, we need to see a key difference between bearing drag and seal drag. Bearing drag has become quite a hot topic since the advent of ceramic bearings which reduce drag. However the drag of the bearings is normally significantly less than the drag of the seals.

Bicycle Science says that the drag of a clean, lubricated and properly aligned and adjusted ball bearing tiny. The friction coefficient is approximately equal to 0.0015 which is the ratio between the resistive force generated in the bearing divided by the load it is carrying. This is approximately 100 times smaller than the resistance offered by a tyre, making this a fairly minor consideration.

The bearing seal offers many times this resistive force, so a hub with fast bearings will build into a faster wheel. However, reducing the rolling resistance of a ball bearing will entail improving the accuracy of its manufacture, which will also improve the life span of the
bearing. By contrast reducing the friction of the seal is likely to reduce the effectiveness of the seal and as a result, reduce the life span of the wheel.

So, when choosing fast seals (if available) you may want to consider the style of riding you are opting for. Indoor track racing lends itself to fast seals. Winter commuting lends itself to slower, more effective seals.

A final consideration when it comes to bearings is their size, quantity and location. These are fairly straightforward cases. You can decide which is most appropriate based upon their advantages and disadvantages.

Front wheels have two bearings. If you move these two bearings further out they will improve the stiffness strength of the axle. The load on the axle comes from the forks, the closer to the forks the bearing is located, the less of a moment is exerted on the axle. The weight is delivered almost immediately from the fork ends, to the bearing and then to the flange and spokes and then to the rim. The bearing will normally sit below the flange of the hub as this is where the load is being delivered. If these flanges are further apart they also improve the stiffness of the wheel. However, by moving the bearings further out, you also make them more exposed to the elements. External bottom brackets were developed to improve stiffness, save weight and reduce the rolling resistance over the standard square taper versions. The bearings are bigger and further out. However they are also more exposed and this has reduced their longevity. As a result, bottom bracket shells have now expanded as well to cover the external bottom bracket which is now still bigger but once again inside the frame.

Rear wheels sometimes have two bearings others have three and some as many as four. The greater the number of bearings, the greater the strength of the hub and the less stress is put on each of the bearings. Their wear will be improved as a result. Often bearings are put underneath each flange and also at the end of the freehub body. The disadvantages of this are that it increasing the rolling resistance and also the central bearings can be more difficult to reach, depending upon the system used. Normally the freehub body is also easy to remove providing easy access to the additional bearings. It is perfectly reasonable to have fast seals on inner bearings as these are more protected than the outer versions.

13. Wheel Size Choice
Currently there are two main sizes for wheels (children’s bicycles aside). They are known as 26 inch (normally for mountain bike) and 700c (normally for road, hybrid or touring use). Often these can equate to being a similar size when you consider how much bigger a 26 inch mountain tyre is and how slender a 700c racing tyre can be. That makes a 29er, which is a mountain bike width tyre on a 700c diameter rim look and feel very large, even though the diameter of the rim is the same as a standard road rim.

This standardisation has made making wheels more straightforward. Wheel builders and manufacturers can offer more options and more price points for a given function. However, there are a number of bicycles out there that pre-date this standardisation. There are even a few using current line bicycles using old fashioned sizes today still. This is
normally done to keep the bicycle in line with tradition (for example Pashleys). Some people even believe that the standard wheel sizes are simply wrong and opt for something different. 650b and 650c are increasingly popular sizes for this reason.

When it comes to understanding wheels we need to be clear what we are working with. The clearest measure is the ISO (international organisation for standardisation). The ISO of a 26 inch wheel is 559mm, if the tyre fitted were 37mm wide which this would make the full ISO measurement 559 x 37 which is approximately equal to what would be commonly be called 26 by 1.5. So what that means is that the bead seat diameter, the measurement between where the bead of the tyre sits is 559mm. The ISO of a 700c is 622, so the bead seat diameter is 622mm. When we are talking about rim sizes only the first portion of the ISO is relevant (the big number). If we are talking about tyre sizes, both are relevant because this describes the width as well as the diameter.

Before standardisation, tyre sizes had different names. Some of them overlapped. Some of them sounded similar but were radically different for example modern 26 inch is a lot smaller than 26x1 3/8. Here are some important sizes for comparison:

559 – 26 inch (Standard mountain bike)  
571 – 26×1, 26×1 3/4, 650c (sometimes used in modern small racing bicycles)  
584 – 26×1 1/2, 650b (sometimes used in modern Cyclocross)  
587 – 700D  
590 – 26×1 3/8 (E.A.3), 650a (common in old town bicycles)  
597 – 26x1 1/4, 26x1 3/8 (S-6)  
599 – 26x1.25, 26x1.375 (not to be confused with standard MTB)  
622 – 700c (Standard road/touring bike/most modern hybrids)  
630 – 27×1, 27×1 1/7, 27×1 ¼ (common in old touring and racing bicycles)  
635 – 28×1 1/2

There are other sizes available smaller than 559 although they are mostly on children’s bicycles. Some of these sizes are more readily available than others. 590 rims, for example, are relatively common, whereas 587 rims are particularly unusual. If you could only source a rim in 590, you could rebuild the wheels this way. You are unlikely to have any issues with brake reach, you are unlikely to notice any perceptible difference or have any problems with mudguard clearance. However, it is impossible to fit a 587 tyre onto a 590 rim. It will not 'stretch' like an innertube will.

If you had a bicycle with an ISO of 587, you will, in all likelihood, need to change the tyre size in use on the bicycle. If a wheel of this diameter has failed at the rim, you can rebuild a wheel with new spokes on potentially the existing hub with a 590 rim and save the bicycle this way. If the hub or spokes have failed these could potentially be replaced and the original rim salvaged. The important thing is that a bicycle with 587 rims can have new wheels built for it. The tyres will need replacing as well as the rim but the bicycle will ride and appearance will be the same as they ever were. You may also need to undertake such a repair if you find it impossible to source tyres in the relevant size. Hubs with traditional internal gears, drum brakes and narrow spacing are still available today. There is a wide range of heritage style hubs available from Sturmey Archer.
14. The Benefits of Eyelets

The most basic wheels use rims that are single walled and non-eyeleted. These are normally the weakest, flexiest rims. It is a basic profile that they adopt which is badly optimised for strength and stiffness. They cannot handle the tensions that a decent wheel can and as a result they are weak.

However, contrary to common belief, they are not necessarily heavy. They are only single walled, their humble design while flexible and weak does not require a large amount of material. While some rims are made of exotic materials, most, irrespective of their quality are all made out of the same material; 6061 aluminium. This is a particularly versatile and good value alloy of aluminium that is used in a huge number of applications. So, when it comes to making a rim stronger, normally its strength has come from a strong shape, more than from a strong material.

When you move up the wheel scale in terms of quality you will normally now get a sleeve jointed, double walled, eyeleted rim. This is then seen as a mark of quality. Eyelets on single walled rims are exceptionally rare, so if you see eyelets, you can pretty much guarantee they are double walled. The double walled rim has two separate levels, one that holds the spoke and one above it which holds the rim tape and the inner tube sits against. The shape of a double walled rim is inherently a lot stronger and a lot stiffer. They are less prone to going out of true as a result. They will also normally come with a machined side wall (one which has grooves running along its length) which help to improve braking performance. Often these rims are actually slightly heavier than the single walled versions as their extrusion is fairly thick. However at this comparatively low end of the spectrum, strength is more of a concern than weight saving.

There are no high quality single walled rims. The single walled design is a weak shape. It is done purely on the basis of cost. Sometimes you will see single walled rims on trials bikes and this is done deliberately, where the rim needs to be particularly wide and ideally light weight. Sometimes this single walled rim is also drilled out in between the spoke holes to save further weight. You can then see the rim tape bulging through these holes.

As double walled rims are higher quality and eyelets are an excellent indicator of a double walled rim, people tend to associate eyelets with quality as well. Equally, some of the highest quality rims out there do have eyelets, so this perception is accurate to an extent. However, the use of eyelets is more complicated than a simple trend between high and low quality rims. There are a number of instances when eyelets are not used on high quality rims.

Carbon fibre rims are manufactured without eyelets. Deep section, aero aluminium rims come without eyelets and some ultra light weight boxier section rims come without eyelets.

Why then are eyelets used? What are the benefits? Before answering this we need to understand the difference between two types of eyelets. There is the single eyelet and the double eyelet. The single eyelet sits only on the inner most wall of the rim, where the nipple will be sitting. Double eyelets sit on both walls and have a solid tube linking the two of them.

When you add eyelets to a rim you generally add weight and strength although this may only be a small amount of weight. The single eyelet is lighter than the double eyelet but the double eyelet is also stronger than the single eyelet. What the single eyelet does is act a bit
like a washer; it allows the load of the spoke to be spread over a greater area in the rim.
What the double eyelet does is the same but on both walls of the rim.

A big reason why double eyelets are used on intermediate quality wheels is related to their manufacturing. When you are lacing up a wheel with a single walled rim you can easily pop the nipple onto the spoke threads by hand or machine. When you are lacing a wheel with a double walled rim, it is possible to lose the nipple in between the two walls. Time is then lost in attempting to get that nipple out again, which on certain rims can be quite difficult. However, when you use double eyelets, it is impossible to lose the nipple between the two walls of the rim. That is sealed off from where you insert the nipple. There are specialist tools that can be used to help minimise this problem. However use of these tools is also time consuming. As a result, building with double eyelets is easier and can be done faster and costs less.

You may think that this makes the application of eyelets fairly straightforward. They should always be used on lower quality rims where strength is more of an issue than weight. They will not be used when weight is more of an issue than strength, particularly on the lightest wheels. However, you would be mistaken as this is still an over simplification. The lightest rims out there are box section tubular rims. Yet, these rims almost always have double eyelets. By contrast, deep section, aero rims are far heavier and yet these never have eyelets. Why is this?

Well, when we are talking about box section tubular rims here, we are talking about aluminium versions. The profile on these is particularly small i.e. the distance between the two walls is particularly short. Moreover, the extrusion of the rim is exceptionally thin in order to save weight. As a result of the extrusion being so thin, it is hard for the inner wall to support the spoke without failure, so double eyelets are an easy way to add strength where it is needed. By contrast the deep section rim is particularly tough and the distance between the two walls is particularly large. Adding a double eyelet would add a lot of weight as the eyelet would need to be big and also add strength to an already inherently strong and heavy design. Another crucial reason is the shape of the rim. If you are installing an eyelet into a rim the section that you install it into needs to be fairly flat. However, one of the great advantages of the aero rim is its aero-dynamic properties. If you flattened the section of the rim in the centre in order to install eyelets, you would lose some of those aerodynamic properties. This would defeat the purpose of choosing an aero rim.

There are also boxier section rims or mid section rims that use no eyelets at all. Adding single eyelets would add little weight to this design, so one may wonder why their application is omitted. Well, when you install an eyelet into a rim you need to drill the rim out bigger than if you left them out. The act of drilling of a bigger hole will in itself create a weak spot in the rim. So the gain in strength offered by the single eyelet is partly lost in the modification of the rim required for its installation.

At this point our understanding of eyelets has become considerably clearer. Double eyelets add a lot of strength. All eyelets need to be installed on a flat surface. Single eyelets add little strength so you will normally find double eyelets in box section rims and no eyelets in aero rims. However, this makes the single eyelet appear redundant. If it adds so little strength, why would we ever use it? Well, the main reason it to do with tension. When you bring a wheel up to full tension the nipple will become more difficult to turn. If the friction is too great then the top can come off the nipple or it can be crushed by the key. The friction is
mostly coming from the contact between the nipple and the rim. When the rim is drilled there will be burrs and the surface will be rough which then offers a lot of friction. The eyelet is pressed in a bit like a rivet and the contact surface is smooth, clean and ideally shaped for seating a nipple on. As a result the friction is reduced and the wheel will tension up easier. This is more relevant when using aluminium nipples which are softer than nickel coated brass versions. The soft aluminium can become damaged under high tension on a non-lubricated, non-eyeleted surface.

15. Tubular Verses Clincher
Clincher rims take clincher tyres, tubular rims take tubular tyres. You cannot put a clincher tyre on a tubular rim or a tubular tyre on a clincher rim. The two are completely distinct. A tubular is rolled onto the rim which is concave in shape. Often cement or adhesive tape is used during this process to prevent the tubular from rolling off while riding. A clincher tyre is normally run with an inner tube inside it. Normally the tyre has a wire bead which hooks round a hook in the rim securing the tyre when it is under pressure.

Some low quality rims have no hook bead. The result of this is that the tyre can blow off the rim if run at higher pressures. It is also possible sometimes to run a clincher tyre without an inner tube. This is called tubeless. More details are available on tubeless systems in chapter 22.

Because tubulars roll onto the rim and are not secured by hooking onto it, there is no risk that they will pop off the rim. Similarly, clincher tyres run at high pressure put a lot of strain on the section of the rim they hook into. This can fail if pressures are too high and often the rim will have a maximum tyre pressure rating. All this means that tubulars can normally be run at much higher pressure than clinchers. These higher pressures mean that the contact area between the road and tyre is reduced and so then is the rolling resistance.

Similarly a tubular tyre is a completely sealed unit. A tubular rim is a more simple shape; it needs no sides to support the tyre. As a result tubular rims are normally lighter than clincher rims. Similar tubular tyres are normally lighter than a clincher tyre with an inner tube. This reduction in weight means that the overall wheelset is lighter and as a result will spin up faster and climb hills better.

The deflection that a tubular tyre is able to make is less constrained by the profile of the rim. So if run at a comparable pressure to a clincher tyre, it should offer improved grip and comfort. However, in spite of all these advantages boasted by the tubular system over the clincher system, tubular systems are extremely unpopular. Why is this?

The answer is simple. Punctures. If you get a puncture on a clincher tyre it can be one of two things. It could be pinch flat, where the innertube has been pinched from high impacts on low pressures or it could be from something sharp penetrating the tyre and inner tube. Sometimes that sharp thing is actually part of the rim, if the rim tape is improperly fitted or if the rim has sharp edges. However mostly it is a piece of glass or grit or a thorn penetrating the tyre from the outside. With a clincher tyre you can then either replace or repair the inner tube and as long as the sharp thing is removed, the puncture will be fixed. However, with a tubular, the solution is more complex.
When you have a puncture on a tubular you can do one of two things. You can insert a sealant through the valve in the hope that it will fill the hole made by the sharp thing (which will need to have been removed). Alternatively you can replace the whole tubular. If this is being fitted with cement, this cement will need to dry. Tubulars can be extremely difficult to remove if cement or tape is used, or can roll off during cornering if no tape or cement is used. So the best time to use tubular rims and tyres is when you are in a race and you have a support car which has a completely new wheel with tubular fitted at pressure. This can be swapped out quickly and prevents you from carrying round a completely new tubular. The weight of the replacement tubular would also, in all likelihood, override the weight saving in running a tubular system over a clincher system.

Tubulars are regularly used in competitive cycling because you can avoid the practical problems and take advantage of the benefits of running a tubular. However, they are less popular than they previously were because of significant advances in clincher tyres and inner tubes. Clincher tyre weights have come down significantly, as have clincher rims and inner tubes. Moreover modern tubeless systems do away with inner tubes altogether allowing for further weight saving.

Tubulars may also be used in more controlled environments. They are common during track racing for example. Punctures are unusual when cycling in a velodrome because the track itself is pristine. Furthermore, if a puncture does occur, you are within the velodrome where the bicycle can be serviced rather than fifty miles away from home.

16. Making Wheels Strong and Durable
You may think that strength is always a good thing. However strength comes at a cost. Normally it is weight. These are two considerations that you need to think carefully about. If you are a lean racing cyclist, shaving off weight will be a big priority for you. However if you are a touring cyclist, already carrying 40kg luggage, saving 1kg in your bicycle at the cost of some strength is going to be an unwise sacrifice.

Strength and quality are common partners. The lowest quality parts are normally the weakest, they are made from low quality materials in basic shapes using basic techniques to low tolerances. However, there are some excellent value parts out there that are strong. Here are some examples of factors affecting strength:

- If you have a product that is produced with high tolerances then when parts are fitted together they will be a snug fit. A loose fit will lead to movement and if parts move against one another they wear away at one another. This will hinder the durability. Furthermore high tolerances will mean that if two surfaces come into contact, their contact can be even and consistent. A low tolerance may mean that a small portion of the surface is in contact and as a result shares a high proportion of that load. This will in time fatigue and break.

- Material selection – fatigue life. Certain materials have inferior fatigue life to others. However this depends on whether they are expected to regularly flex. Aluminium has an inferior fatigue life to steel – if you take a thin rod of each aluminium and steel and bend them back and forth the aluminium will break far sooner. The aluminium may also be badly damaged from the initial bending, whereas steel can normally be
‘bent back’ without losing a significant amount of its strength. The fatigue life of a product may be irrelevant for product selection, other factors such as weight or stiffness may be considerably more relevant.

- Exotic materials. Normally with bicycle parts the materials concerned are metals. These metals are almost without exception alloys of metals i.e. a cocktail of metals blended together to give a new material with unique qualities. High tensile steel is an example of a basic alloy that may be used in the cycling industry. Despite its name it is a comparatively weak steel composed of inexpensive metals. Chromoly steels are more exotic and contain chrome and molybdenum as well as high quantities of carbon. There is still a great variety to chromoly steels with their strength varying greatly. Often more exotic materials are more difficult to manufacture or may also be difficult to work with when formed. They may contain other materials that are themselves expensive. A basic comparison of Aluminium, Titanium and Steel is often inadequate when evaluating the quality of the materials involved. Often it is a case of whether they are fit for purpose and whether they are high quality alloy of these materials. Other materials such as carbon fibre and magnesium may be used to improve strength and/or save weight.

- Shape is important when making something strong. Certain shapes are fundamentally strong, like the egg for example. The load it can tolerate is remarkably high given the strength and quantity of the material. Many strong shapes such as the egg are irrelevant here because the shape of the product is already largely determined. However, given that framework, shapes can be improved to enhance strength. Take for example the shape of a basic rim; it will be a single walled extrusion of material. A more advanced shape is the double walled rim. If you took a particular amount of aluminium and extruded it into a single walled rim it would have considerably less strength than if that same material were share between two rims, whereas the weight would be identical. The extra wall could also accommodate more material and enhance the strength further but with a weight penalty. Extra corners and shaping to the rim can also enhance the strength or stiffness of it. There may also be additional internal lattices of material.

- Advanced techniques may be employed to improve the strength or overall quality of a product. All metal rims are an extruded piece of material which is folded round into a circle and joined. This joint varies. The basic joint will be a sleeve joint, the rim will have sockets which rods are inserted into which joins the two ends of the rim. A stronger but more complex joint is when the rim is pinned in place. This is a more secure joint as sleeve joints can move, particularly when spoke tension is removed. Beyond this rims are welded together, this weld may be ground down to remove excess material. A welded rim will be stronger because the rim is physically bonded. This is also normally allows for a more balanced rim because sleeve joints in material are heavier around the joint which reduces the stability of the wheel when spinning. Other advanced techniques may make a product superior but perhaps no stronger, for example a machined sidewall has no real strength gains but it will improve braking quality and disperse heat during braking better. If you are running disc brakes there is no need for a braking surface on the rim. This will save weight and improve strength because machining a braking surface will weaken it. Moreover the rim looses strength every time you brake as material is removed. Eventually so much
material will be removed that the rim is worn out. Using the wheel beyond this point is dangerous as the side wall will eventually collapse. Exotic techniques may also be used in the development of the material; they may be cold forged or tempered to improve their strength. So two chemically identical materials may have radically different strength.

- After treatment. Various treatment processes can be employed to improve the durability of a product. A traditional technique used would be chroming. This adds a layer of chrome to steel to prevent it from rusting. This has now fallen out of favour because stainless steels have become more commonplace and chrome does eventually peel away from the steel leaving it exposed to rust. Painting is another way of improving longevity with powder coating becoming popular now as a more durable alternative. Metals are also often anodised which add a further layer to them which is extra durable designed to protect the product from mechanical damage and weathering.

- Putting materials together. Certain materials work well together, others are less compatible. Aluminium and steel can be unhappy companions together, for example an aluminium seat post in a steel frame. This will need to be greased to prevent the seat post from seizing in place. By contrast, brass has a natural lubricating quality and can help prevent items from seizing up over time. This makes brass nipples a popular choice on wheels as the brass helps prevent the nipple from seizing in place on the spoke.

- Build quality. In this sense we are talking about the quality of the wheel build. A wheel that has been badly built will last less long than a wheel that has been well built. Sometimes a wheel may have been damaged during its build, if perhaps certain spokes were taken to an exceptionally high tension too early or if components were physically damaged during the build. However mostly builds can be corrected in retrospect. Bad work can normally be undone.

- Braking systems. As mentioned before rim brakes wear away at rims. So non-rim brake systems are more durable than rim brake versions, although normally there is a weight penalty with this. Drum brakes would traditionally be fitted on ‘town bicycles’ designed to be low performance bicycles which would do fairly high mileage and would receive little maintenance. Drum brakes also carry the advantage of working equally well in wet conditions whereas rim brakes work less well when wet. A more modern alternative is disc brakes which can also provide greatly improved braking performance. They are also lighter than drum versions. They are normally more expensive than rim brakes and it is worth paying for a quality version. There are low quality disc brakes on the market but in this instance better it would be better to stick with an equally priced rim brake which will work far better. Disc brakes can be difficult to set up and their failure can require complex and/or expensive maintenance. Their complete replacement can be expensive so they are not always popular on touring or trekking bicycles. Often a brake which can be repaired at the roadside is a more popular alternative, where parts are universal and easily sourced worldwide. Increasingly mechanical disc brakes are becoming popular for these applications as their maintenance is more straightforward but their performance and durability is better than rim brakes.
Other considerations:

What do we mean by strong? It sounds like a simple concept but there are a number of factors to strength. It is not always possible to describe one material as stronger than another. Wood for example has a grain, making it better at resisting certain forces, the grain may be split with relative ease but splitting through grains is much more challenging. Strength may also be tensile which means its ability to carry load, but it may also be compressive; the materials ability to resist compression. There is also shear strength; shear strength is a materials ability to resist tearing apart by crossing forces. So choosing an appropriate material requires knowledge of which forces are likely to be exerted upon it and that materials ability to resist those particular stresses.

Strength to weight is also an interesting factor, sometimes known as specific strength. The tensile strength of steel is generally higher than titanium and considerably higher than aluminium. That is to say steel of a given thickness can support a greater load than aluminium or titanium. However it has generally a lower strength to weight ratio than titanium and is not significantly higher than aluminium. Steel is denser than titanium and considerably denser than aluminium. A particular volume of steel will weigh more than titanium and considerably more than aluminium. Selecting these materials for use then depends on what is required for their application.

Certain parts need to be strong but are perhaps small, so their heaviness is unlikely to be a problem. A bolt is an example of such an item. Hub axles and bearings are similar in this capacity. By contrast a rim is a large item which requires comparatively little strength so a weaker but considerably lighter material such as aluminium is normally used.

Maintenance

A component such as a drum brake is a good choice if you want low maintenance and longevity. Cars use prop shafts because of their high lifespan, whereas a bicycle uses a chain because it is versatile for shifting gears and is considerably lighter than a prop shaft. The life of a chain is sufficient that its replacement has limited inconvenience. The extra weight of a prop shaft would generally be considered a greater inconvenience. So sometimes a product which requires higher maintenance is a sensible solution.

Other parts, such as certain hub bearings, may last a particularly long time if regularly maintained. The bearings themselves could perhaps be replaced to extend the life further. So in this instance the total lifespan of the product is high, as long as regular maintenance is undertaken. This again may be preferable to a more durable system which has reduced performance.

Equally, products with high life spans can be exceptionally expensive, perhaps many times more than a more basic product. This additional expensive may not equate to an equivalent gain in life span. Sometimes it is prudent to opt for a more disposable and more economical product in pursuit of better value for money. Making limited gains in quality for a considerably increased price is known as the law of diminishing marginal returns. This is equally relevant in the next chapter on weight saving. Often to gain small amount of quality, a great deal of extra money needs to be spent. Sometimes this performance increase is valuable, often it is excessive.
Emphasising quality where it is needed

When building a custom wheel you can choose each part individually. This is advantageous when trying to gain the best value for money or the longest lasting product for you. Tungsten carbide coatings on braking surfaces can greatly improve the life of a wheelset. The wear on a rim provided by braking is a common way for a wheelset to fail. However a tungsten carbide coated rim would be superfluous if disc brakes were being used. This would provide no increase in longevity.

Someone who cycles long distances in flat rural areas is likely to wear out bearings before any other component. If these are not serviceable or replaceable this could mean the end of the life of the wheelset. However, someone who is cycling with rim brakes in winding, wet, mountain country is likely to wear out rims first because of their increased braking. So if you have some spare money to spend on improving one component, it is worth considering which one is most likely to fail. Moreover, it is pointless investing additional money in a particular component if it will outlast all others by a margin anyway and its reuse is impractical.

17. Saving Weight and its Side Effects

Weight saving in a motorised vehicle is important but often far less important than the price of the item. If you had the option of buying two car batteries, one was 20% lighter than the other but also 20% more expensive, you are unlikely to opt for the lighter version.

By contrast, saving weight on a man-powered vehicle is exceptionally important. However, it is best to think of it as the end goal - the final consideration to satisfy. If product A is lighter than product B but product A is unaffordable whereas B is affordable, B becomes the only option. If A is 20% lighter than B but also 20% weaker, unless B is over-engineered anyway, you are unlikely to choose the lighter product. Product failure is normally considered to be a greater disadvantage than a weight penalty.

Nevertheless, there are now many regulations governing the required strength of certain products. So, while certain products may carry a rider weight limit or a load limit, you are unlikely to find a product which will fail from lack of strength anymore. The shortcoming is likely to affect longevity instead of strength.

When it comes to saving weight, often a sacrifice is comfort or the general ‘feel’ of a product. Consider a light weight but uncomfortable saddle; this is a poor choice for all but the most competitive cyclist, determined to remove all excess grams. Equally, foam grips are lighter than quality lock-on rubber versions. However foam grips have a nastier feel to them; they are also less grippy which is somewhat fundamental in a grip. Certain other products may be light and strong enough, however they flex as a result of the material reduction, the flex may worsen the feel of the product it may also lead to power loss.

A degree of flex is often considered to be a good thing on a bicycle, particularly in certain areas. The flex in a fork is unlikely to significantly hinder rider output, yet it will cushion harsh surfaces well. Box section rims flex more than deep section versions, however this makes them popular for long distance cycling when high power output is less relevant and
comfort is a greater consideration. By contrast flex in a head tube or around the bottom bracket will make the bicycle slower without significant comfort gains.

Shaving weight off of a bicycle will make an enormous difference to the way it rides. A heavy bicycle will be slow to accelerate, difficult to manoeuvre and make hill climbing more challenging. Also, when it comes to wheels you have centrifugal force to consider. A wheel has a greater mass in virtue of its rotation. As an experiment to demonstrate this, try holding a wheel by its two axe stubs and moving them around. The process will feel quite easy. Repeat this with the wheel rotating at speed, it will resist the movement and appear to have a mind of its own. There greater the weight at the extremity of the rim, the greater the extent this is a phenomenon. So if you want to save weight in a wheel, purely from the perspective of weight saving, the tyre should be the highest priority, then the inner tube, then the rim tape, then rim, nipples, spokes and finally the hub.

Another consideration with saving weight is the weight of the person. If you have a 27lb bicycle and a 270lb rider, shaving 3lbs from the bicycle will not make a deeply significant difference to the ride, there will only have been around a 1% overall weight saving in the bicycle and rider, if that were in the wheels along it may act more like 2%. However it is possible that as a consequence of this weight saving, a lot of strength will have been lost and so the bicycle may fail under the weight of the rider. By contrast a rider weighing around 110lbs would notice a big difference if the bicycles weight was reduced their overall weight saving would be around 2.2%, if that weight saving were in the wheels it could act more like 4.4%.

Equally when it comes to wheels, saving weight often increases flex in the wheels. A 270lb rider is likely to be a powerful rider. A 110lb rider is likely to be considerably less powerful. Therefore the flex they will feel from the wheels will be different. A 270lb rider would be better off with a stiffer stronger set of wheels. A 110lb rider would benefit from a lighter set, even if that came at a cost to some strength and stiffness.

There are a lot of road racing wheels out that that have 20 spokes in the front wheel laced radially and 24 spokes in the rear, laced tangentially onto a deep section rim (approximately 30mm). The misconception made about this set is that it is light and fast. It may be accurately believe that they are weak. These wheels are often built like this because they look similar to wheels used in competition; however their appearance is the only real similarity.

There are a number of reasons why these beliefs are normally inaccurate. When it comes to weight in wheelsets normally the largest proportion is held in the rims - often about 1kg. The second highest proportion is held in the hubs, approximately 600g and the lowest is normally the spokes and nipples, approximately 400g. If you remove just over 30% of the spokes you will save about 125g on my example wheel. However, as a result of removing the spokes, a lot more is demanded of each of the remaining spokes and a lot more is demanded on the rim which has a longer unsupported section.

This brings us to the second part. The deep section rims used in these wheelsets will carry aerodynamic advantages as well as being stiffer. However they will also be heavier and are probably being used to counter the strength lost by removing spokes. A fairly light 30mm section rim may weigh 600g, whereas a fairly light box section rim will weight approximately 450g. So if instead of removing 30% of the spokes we had gone with a box section rim we would have saved 300g instead of a mere 125g. Sometimes, to make matters worse, further
weight loss is made in the hubs to bring down the overall weight. This is sometimes done by removing seals on bearings and sometimes by using weaker and lighter materials. The result is a weak wheelset with a heavy rim and so almost no performance gain whatsoever, particularly as losing spokes will also make the wheels flex more, undermining some of the stiffness gained by the deep section rim.

I want to give the right impression here. A quality light weight road wheelset will have a reduced spoke count. However there are a number of things to consider about this wheelset. It will feature: a rim with a very high strength/weight ratio. The lightest sets will be a boxier section rather than an aero section. They will have exceptionally strong spokes, each of which is capable of supporting many times that of a basic spoke. They will also have hubs made out of exotic materials including ceramic bearings, perhaps titanium axles, carbon fibre inserts and so forth. Also, these wheelsets will probably be designed for people who still do not weigh 270lbs. They often have a rider weight limit of 90kg (198lbs).

Fundamentally when it comes to making a product lighter, there are a limited number of tools at your disposal. You can change a material and opt for one which is stronger; as a result you could thin the material without losing strength. You can similarly work a material stronger in the manufacturing process, tempering could be an example of doing this.

Another technique is altering the shape of the material. The most basic version of this is butting; this is used on spokes and frame tubing. The process of butting adds material at the ends where stress is exerted and removes it from areas that carry low stress. This often gives a helpful flex to the thinned section which removes some strain from the areas with greater material. A butted spoke or tube will in all likelihood be stronger than a plain gauge version despite using less material. So in this instance weight saving has been advantageous all round. A more advanced version of this which is used in more expensive modern aluminium frames is hydroforming. This uses hot oils to shape the tube more precisely. The shape is engineered precisely to distribute material where it is need and remove it from where it is superfluous. These processes are often expensive and will add to the cost of the product, some costs are in manufacture, others simply in the engineering of the shapes.

Another way that products are altered is by machining out where excess material is not required. This may be done with a CNC machine or perhaps simply drilled out. This will have no effect on the strength of the product and will offer weight saving. It will add to the cost of manufacture but in this instance you are simply paying for the weight saving.

On a hub you can reduce the PCD of the hub flange to save weight; this is a way of simply changing the design of a product to make it lighter. However this will place a greater strain on a smaller amount of material on the flange. The hub flange will be stronger if the hole count is lower as there will be more material, however reducing spokes will also reduce strength. Furthermore, if you reduce the flange size you also make the wheel more prone to wind up if there are forces coming from the hub. This is only applicable on rear wheels or wheels with braking at the hub. The turning force on the hub will slacken trailing spokes and tighten leading spokes.

A common way of saving weight in a wheel is to thin the extrusion of the rim. If you do this the rim will become weaker. Potentially the material is superfluous and the rims strength with be adequate even after thinning. By thinning the braking surface you will reduce the
lifespan of the rim. There are fewer miles of braking in the braking surface so you have in this instance opted for performance over longevity.

Adding eyelets to a rim will add weight, however it also adds strength. In the instance of an aluminium box section tubular rim double eyelets are popular because of the increased strength they offer and the particularly thin extrusions of the rim. They can offer a lighter weight version than a non-eyeleted rim because of the extra thin extrusion that they allow.

Another technique would be to change the profile of the rim to make it shallower. You can also reduce the height of the sides, particularly if a braking surface is not required. However, reducing the height of the sides will add flex to the rim, so as before you need to consider rider power output if opting for a rim such as this. Reducing the height can also help with the sealing of a tubeless system which is likely to provide further weight saving.

Tubular rims are lighter because there is no need to support a tyre bead. However tubular tyres are considerably less practical than clincher versions. Tyre and inner tube choice can also be excellent ways of saving weight in a wheelset and can be done without changing wheels, so light weight summer tyres and tubes can be used and heavier duty winter or commuter tyre can be fitted for increased longevity and puncture resistance. Tubeless systems are also a lighter alternative and can offer improved puncture protection as well, however their sealant will go off and the tyres are more prone to damage without the internal support of the inner tube.

18. Why Different Valve Types
There are actually three different valve types in common usage on bicycle wheels. This is in contrast to cars which only have one. The three types are Presta, Schrader and Woods.

The Woods valve is normally omitted from consideration and people will often tell you there are only two types. The woods valve is the valve of choice in Holland. It is best suited to a type of pump uncommon elsewhere in the world.

You can replace the valve core and in a woods valve making it a serviceable item. So in a way it is a great valve. However the interface with common, modern pumps makes them irritating. You often have to use an adapter, if for example you were using a smart head and this is annoying and can be an imperfect fit.

Then we have Schrader. We are normally told that Presta is a high pressure valve, probably because they are the valve of choice on racers which take high pressure. This leads people to believe that Schrader valves cannot handle high pressure. A myth which is easily dispelled when you service an air filled suspension fork. Even the high pressure versions use a Schrader valve; this is because you can screw on a Schrader adapter more easily in a recessed valve bed. The Schrader valve is also, cheaper to produce. It also does not have the cap that you unscrew, which can break off. It is also the valve of choice in the developing world so a Schrader valve makes more sense on a trek around the world.

So, if the Schrader valve is so good. Why would you ever want to use a presta valve. They are associated with high quality. The answer is because when you drill a big Schrader hole in a thin rim extrusion it damages it, it is also less aerodynamic.
19. Using Washers

A washer is a round piece of material designed to sit between nuts bolts and the things they are attached to. It can be used for a number of different applications, often to prevent items from loosening or to prevent them from damaging one another. They can also act as a spacer. Using washers can also make it easier to apply torque. If the washer is larger than the nut or bolt it also helps to spread the load exerted by the nut/bolt over a greater area.

There are three types of washers used in bicycle wheels. There are two types of nipple washer and there is the spoke washer. The nipple washers come in oval and round versions. They are seldom used in wheel building applications now, yet when they are relevant, they are invaluable.

The spoke washer sits between the head of the spoke and the hub flange. In this instance it is acting as a spacer. The profiles of spokes have changed over the years and they have moved towards a tighter fit at the elbow. Previously the fit was far looser which meant that high quality wheels would normally be built with spoke washers. Now, they are more likely to be used either with old hubs and components or on electric bicycles. Electric hubs have large drillings and are designed to take larger spokes. If larger spokes are unavailable, washers help to improve the fit in the flange. It is worth using a single butted spoke in this instance like the Sapim Strong spoke to improve the fit further. Some older internally geared hubs also have large drillings which lend themselves to the application of spoke washers.

Nipple washers sit between the rim and the nipple. They can be used for a number of reasons. Historically, oval washers would be used on steel rims to help spread the load of the spoke over a greater area. Steel rims had thin extrusions to prevent excessive weight and benefited from the reinforcement around the spoke holes. It is a sensible system because then material is placed where it most needed, the same principle that inspired hydroforming or butting. However modern rims are designed either for use without washers or with eyelets which serve a similar function. A double eyelet is a more advanced way of spreading the stress from the spoke than the humble washer.

Hand built wheels with single walled rims are rare, but on occasion necessary, perhaps because of limited availability in a particular size. In this instance, it is normally best to use a round washer. It is best to also use a 14mm nipple because the extra spacing makes the nipple a little short. Single walled rims are not designed to take the tensions that modern wheels use. Higher tensions make a better quality wheel. By using the washer the rim can tolerate higher tensions without damage. The load is better supported and the nipple will not grind away at the rim, removing important material. As a result the nipples will turn more freely, will be less prone to loosening and the wheel can be stronger, stiffer and more stable.

20. Carbon Fibre verses Aluminium Rims

Carbon fibre is unlike a lot of materials when it comes to building. Carbon, is not a metal, it is not forged or machine or carved. It is more like fabric, literally like a net of carbon fibres. Working with such a material is a lot more complex than working with metal.

Aluminium rims are made by extruding aluminium through a former. You then gain the profile of the rim. This is then folded round into a circle and then held into shape by a
number of different techniques, it could be a sleeve joint, it could be pinned or on high end rims it is generally welded. Irrespective of the joining process, the rim will always have a joint. This is normally both a weak spot in the rim and a heavy spot in the rim. The rim is then drilled and largely sometimes eyelets are inserted for extra strength. Sometimes the holes are chamfered which has structural benefits as well as aesthetic. The rim is normally given a hard anodising and then logos are applied.

Carbon fibre is inherently a far stronger material than Aluminium. It is also (if engineered correctly) stronger than steel and titanium as well. It is also light weight so its strength to weight ratio is excellent. This is why it is used in high performance products across various sectors. Formula one cars and performance sports cars have a number of carbon fibre parts.

Carbon fibre products are made in a number of ways. Sometimes sheets are wrapped over formers, sometimes moulds are used. There is also a good deal of variation in the quality of the carbon fibre itself. Engineering these products takes a lot of skill, testing and time. Their development is expensive. As is the initial costs of their production.

A carbon fibre rim can be a jointless system, one which possesses even weight and strength throughout. Carbon fibre rim sections need to be designed much more carefully. The design behind them is essential, early rims were strong on one direction but not in another, reports of stones hitting rims which then shattered came about. Early versions could hold only low tensions as well.

Carbon fibre rims are now made almost exclusively in China. This is a reflection of their high costs of production, so their development is in the lowest cost country that is also well kitted up to high tech industry.

So, if carbon fibre can be engineered into any shape. It can be stiffer, stronger, lighter and more aerodynamic than its aluminium counterparts. Why then is it application rare? There are a number of reasons governing this. Some people distrust carbon fibre because of its history. Other people distrust it because of its lack of history. The aesthetic is also different and fashion does govern the cycling industry to an extent. However the biggest reason by far is price. A basic carbon fibre rim is still around five times that of a basic aluminium rim and approximately 50% more than a high end aluminium rim. A high end carbon rim is approximately ten times that of a high end aluminium rim. So, with such a high price tag, the market for carbon fibre is small.

An additional disadvantage with carbon fibre rims is the added difficulty of building with them. Most of the carbon fibre rims you will see will be deep section versions. The reason for this is because that is where they excel most over their aluminium counterparts. Deeper section rims are stiffer and more aerodynamic, however the extra material adds weight. The superior strength to weight ratio of carbon fibre lends itself to these performance applications.

Deep section rims are difficult to build with. Physically feeding the nipples onto the spokes is difficult because it is hard to find the drilling in the rim. The carbon fibre material also offers a lot more friction than aluminium or an eyelet. As a result a lot of lubrication is required. It is best to lubricate the spoke threads with a lot of thick oil and apply a lot of thick oil between the nipple and rim. For best results this needs to be done before any real tension has been added to the build. Additional oil may need to be added during the build as well. This makes
for a slow and expensive build process which further adds to the cost of carbon fibre wheelsets.

Zipp have developed a special rim profile to maximise their aerodynamics. It has been heavily patented and is able to offer significant aerodynamic advantages. This is an example of a particularly high performance carbon fibre rim. The quality of the carbon fibre used in these rims is also of a higher quality than basic versions and the design of the weave is also complex and highly engineered. In the mountain biking world DT Swiss have developed two carbon fibre versions, these have been able to offer weight saving, strength gains and longevity improvements.

If you are running carbon fibre rims with disc brakes or another hub based brake there are no specific modifications required. However, if you are looking to run rim brakes you will need to use specialist pads designed for carbon fibre rims. The problem with standard pads is they melt onto carbon rims and are also less effective. Carbon dissipates heat less than aluminium so the pads are prone to overheating.

21. Building with Wooden Rims

Wooden rims?
Velocity make a deep V rim with a wooden image design. However, it is possible to buy rims that are entirely made of wood. The most major manufacturer today is Ghisallo. Ghisallo wooden rims come in a range of different designs, suitable for different purposes. There are clincher and tubular versions available, different drilling, different sizes as well as different stains.

Practicalities of building with wood
When it comes to building with a wooden rim, you have to consider that building with wood makes a different sort of rim to one made with metal. The Ghisallo rims are solid wood, which makes the thickness of the rim considerable, far more than you would find on an alloy or steel rim. This means that building with Ghisallos requires much longer nipples. However Ghisallo helpfully supplies all rims with appropriate nipples. Additionally, the wood cannot be placed in direct contact with a nipple; the nipple will eat inelegantly into the rim. A special washer is required to separate the two, which also comes with the rim. Finally, the wood requires time to settle into tension. This means that a wheel built with a wooden rim needs to be done over a period of time. The wheel is brought up to a low tension, trued, rounded, dished, and then left. You then add another layer of tension, true, round, dish and leave. This process is repeated several times. It is possible to build over only a few hours; however it is better to build over a whole day, better still to build over a few days. A wooden rim is also more sensitive to tensions so the precise use of a spoke key is required.

Advantages
All Ghisallo rims are made up from a multi-layer beech ply. This means that the rim can be
made directly round a former and no specialist bending of the wood is required. Metal rims are normally joined in one of two ways. Either they have a sleeve joint which only loosely holds the rim together. This is found on cheaper rims and can lead to a bulge at the joint; this commonly results in a high point that cannot be removed without uneven tensions on the wheel. The alternative is a welded joint, which is better; however it will remain a weak part of the wheel. You are unlikely to have problems as a result of either of these joining methods; however it does present Ghisallo’s seamless system as an appealing alternative.

Ghisallo offers one particular model called the Corsa. This, weighing only 320g per rim, comes in as one of the lightest on the market. Lighter than any aluminium clincher rim on the market. It also comes with an aerodynamic profile.

A steel bicycle frame will offer a natural suspension system because of flex within the material. An aluminium or carbon fibre frame by comparison will probably be stiffer but harsher to ride. Those who extol the virtues of the steel cushioning may find similar benefit to a wooden rim. The wood has a natural flex to it which makes for a softer ride. Some of the heavier duty Ghisallo rims have been used in amateur classic-themed grass track racing. The natural spring makes for a more comfortable ride.

The main reason why anyone buys Ghisallo rims is aesthetic. They look fantastic. The finish is great, they have an unmistakable traditional charm and finesse and will provide a real talking point on any bicycle. They best suit a classically themed machine, one to be used on sunny Sundays or may appeal to those kitting out an unusual ‘fixie’. Ghisallo are poorly suited to any competitive cycling or commuting.

Disadvantages
A fast wheel will be a combination of stiffness and lightness. While Ghisallos compete well on weight, they fall down dramatically on stiffness. The wood bends and flexes in a way which absorbs the rider's power. It can also lead to binding brakes on hard cornering.

Ghisallos come with a lacquer coating on them to protect the wood from the elements. It has been reported that this coating can wear away surprisingly quickly. The lacquer will need to be reapplied to prevent doing serious damage to the rim. A modest rider may only need to do this once a season; heavier use will require more regular maintenance. Performance will be better if rim brakes are avoided. It is important to note that proper maintenance of Ghisallos will offer good life expectancy; they do not require annual replacement.

You cannot use normal brake pads on a Ghisallo. The issue is with the pad not the rim. They melt. So a carbon specific set of pads are required on rim brakes.

Ghisallos carry a considerable price tag. The price tag reflects the huge amount of labour required for their construction. They are hand glued; hand stained and then lacquered many times. A specialist machine is then required to drill the holes. While the price tag makes sense considering construction obstacles, it offers poor value for money when you consider longevity and performance.
Conclusion

Ghisallos can only play a small part in the world of bicycle wheels. They are hard to build with, they require regular maintenance, they are expensive and they flex a lot. However, if you want a traditional looking wheel, avoiding metal altogether is a marvellous move, something that we are lucky to still be able to do today. Ghisallo have been making rims since the 1940s so the brand carries pedigree, buying a pair means investing in real, traditional Italian craftsmanship. For those who enjoy a good collection of bicycles, a pair of Ghisallos on a traditional bike will be a worthwhile addition.

For further details please visit: http://www.cerchiinlegnoghisallo.com

22. Choosing Tyres and Tubes

Based in Finland, Wheel Energy is a company to know about when you are choosing tyres and tubes. There is a lot of mysticism shrouding tyres and Wheel Energy are attempting to cut through it. They put different tyres of different styles through rigorous testing to try and establish objectively what makes a good tyre.

Are tyres worth all that attention?

Tyres make one of the biggest differences of any component on a bicycle. A tyre upgrade is normally worth considering if making a wheel upgrade. The only real exception is if top quality tyres are already in use.

As mentioned in the chapter on saving weight, the tyre will make the greatest difference in weight saving because of its rotational weight. Additionally tyres will affect rolling resistance which makes a considerable difference. Why then, are they so important? Well, your style of cycling is irrelevant, tyres are absolutely essential. Different cycling styles lend themselves to different tyre choices. Downhill mountain biking requires wide, tough tyres with a lot of grip. Cross Country summer racing requires wide, tough tyres with a lot of grip, whereas Cross Country winter racing benefits from narrower nobbly tyres, preferably with long protruding nobbles that are widely spaced. This allows for fast riding and the nobbles penetrate through the mud to access surfaces beneath that offer superior grip. Road racing tyres require little or no tread pattern, especially in summer conditions. They will also be particularly narrow.

It is worth experimenting with tyres a bit to get the best tyre for you. The conditions you cycle in will affect your tyre needs. How much puncture protection do you require? Will you be cycling in wet conditions? Will you be cornering at speed? Will the tyres be used on or off road, or both? Are you a heavy rider? Do you prefer speed or comfort? What is your skill level? What is your budget?

A basic tyre will have little consideration given to the tread pattern. It will be designed to mimic better quality tyres as well as be based on what is cheap and easy to manufacture. Companies like Maxxis place a big emphasis on tread pattern. As a result their tread patterns are heavily patented. Maxxis realise that tread patterns make a big difference to the
quality of the ride, particularly in off road applications where Maxxis specialise. A good tread pattern will help to balance speed against grip. It may be designed to deflect away water (although aquaplaning is not a concern for cyclists, especially on narrower tyres).

Continental offers a range of tyres at a range of price points. However, the tread pattern variety is limited across the range and is fixed for the riding style. The difference in quality comes from the quality of the rubber compound used. Basic tyres use a basic compound, whereas their high end tyres use Continental’s heavily patented Black Chilli compound. This offers superior longevity, grip and improves rolling resistance.

Changing your tyres can make an enormous difference to your bicycle. However there are a huge variety of tyres out there. By the time that this is published, there will doubtless be many more. They are launched continuously. However, there is still some universal advice that can be given when it comes to selecting tyres.

Rubber compound: the compound used to make a tyre varies. It plays a major part in the grip and rolling resistance of a tyre. It will also affect longevity. A decent compound takes research money to develop and is normally expensive to produce because of the material costs. A decent compound will offer low rolling resistance, long life, plenty of grip in wet and dry conditions.

If you are looking for a good training tyre, often a basic tyre is required with a lot of material, the idea of a training tyre is to save you money, the performance is saved for competition. Training tyres are most appropriate with turbo trainers which are very heavy on tyre wear but tyre performance is unimportant.

TPI stands for threads per inch. If you increase the number of threads the tyre, generally the more supple it is but generally this offers inferior puncture protection. However, research from Wheel Energy has shown this is not a linear relationship, often there is an optimal TPI count for your riding style and more threads may not guarantee superior rolling resistance.

There is a hypothesis extolled by a number of tyre manufacturers that wider tyres roll better than narrower versions. This has been backed up by research from Wheel Energy. However, this seems odd because anecdotal evidence normally suggests the contrary. However we need to understand this phenomenon carefully. While bigger tyres are supposed to roll better this is tested by fixing the variables bar tyre width. This includes pressure. So a 32c tyre at 90psi will roll better on a rolling machine than a 23c tyre at 90psi. However, a 32c tyre at 90psi will deflect less and have a smaller contact area than a 23c tyre at the same pressure.

Where the experiment falls down is reality verses theory. A 32c tyre will be maxed out at 90psi, if it can even tolerate it. Moreover the rim may not be able to support a 32c tyre at 90psi. By contrast, a 23c tyre may be at the minimum recommended pressure at 90psi with a maximum that may be in excess of 145psi. So a 23c tyre at 145psi will roll better than a 32c tyre at 90psi. So a 23c tyre has the potential to be faster. In addition, a 23c tyre at 90psi will be more comfortable than a 32c tyre at 90psi. So to gain comfort from a wider tyre you will need to run it at a lower pressure.

Finally, a 23c tyre is 9mm narrower than a 32c tyre and as a result will have superior aerodynamics to a 32c tyre. Aerodynamics is particularly important in tyres because of their rotation. Depending on their location within their rotation cycle they may be moving up to
twice the speed as the bicycle into the wind. Aerodynamic resistance has an exponential relationship with speed. So this is another reason why a larger tyre is slower than a narrower version.

Puncture protection is a major consideration with tyres. It is also a matter of personal preference and function of the bicycle. A bicycle that is designed for commuting has a high need for puncture protection, particularly if you are making time critical journeys. Whereas a bicycle used for racing has far less need for puncture protection and track racing less still. Changing a puncture may not be a major concern for you, few tyres, particularly performance tyres, are overly reliable and taking a repair kit and/or a spare tube is prudent. However a small performance penalty can offer significant puncture frequency reduction.

Often puncture protection and performance can come together, however it increases the cost of the tyre. Complex puncture protective layers are brought in using exotic materials and expensive rubber compounds.

The vast majority of punctures occur towards the end of the life of a tyre. Often tyres are replaced not because of they have become dangerous but because punctures have become too frequent.

There are tyres on the market that offer near perfect puncture protection. In the majority of cases punctures will not occur during the life of the product. However the performance loss from using these tyres is noticeable. They are sluggish, stiff (in a bad way) and they are heavy. As we saw before, saving weight in tyres is the most important area on a bicycle so the extra weight is particularly noticeable. Nevertheless puncture ‘proof’ tyres remain a popular choice for those who find punctures particularly inconvenient.

Tubeless systems on clinchers tyres have grown in popularity recently. Normally these can be retrofitted to any wheelset. Although some wheelsets are better than others for using these tubeless kits. They work by installing a specialist valve core instead of a tube, along with a special rim tape. The tyre is then filled with a sealant which fills any small air gaps. When properly installed a tubeless system can then automatically repair some punctures, similarly to slime inner tubes. Unlike slime inner tubes, tubeless systems are lighter than innertubes. So this can be a good way to save weight and improve puncture protection simultaneously. The lack of inner tubes also helps the movement of the tyre which reduces the rolling resistance.

With this win-win-win situation, you may question why tubeless systems are not always used? There are a number of disadvantages to tubeless systems:

- They are a little difficult to install. The process takes a little time and you need to be thorough when installing the sealant.

- The sealant will expire after time and will then need replacing. So you will need to maintain a tubeless system.

- The kit itself is fairly expensive, although the price may drop with time. There are costs involved in maintaining a tubeless system as well.

- Ideally tubeless systems need to be run with tubeless tyres. While it is possible to fit a tubeless system to a standard tyre the sealing is better on a tubeless ready one.
Additionally standard tyres, particularly light weight ones are prone to tearing if used without an inner tube. Tubeless ready tyres have reinforced sidewalls to help prevent this.

- The extra reinforcement required in tubeless systems and the weight of the sealant makes the weight savings narrow over a light tyre and innertube combination.

An alternative to a tubeless system with sealant, some tyres and wheelsets use the UST system. This does not require sealant as a sufficient seal is made between the tyre and rim. The rim itself is sealed, i.e. there are no holes for feeding in nipples, so there is no need for rim tape either. This is a particularly light system, however it does not have the puncture protective advantages gained by using sealant. It also makes maintenance of the wheelset particularly difficult as replacing nipples requires patience and specialist tooling.

23. Closing thoughts

A good quality product should last a long time. Spending more money on quality can be better value than buying several lower quality products which last for a shorter amount of time. As you pay more and more for products you run into the law of diminishing returns. You have to pay endlessly growing sums for small incremental improvements. This may be worthwhile if you are looking to win a race, however if you are on a budget, there is often a critical point, beyond which it is not worth spending more.

I hope this book has given you insight into finding the right product at the right price for you. Sometimes it is nice to pay more for something truly special. Perhaps only to get the look just so. However there is an additional element to value and that is maintenance. If you are spending a little more money on a wheelset, it is worth looking after it. That includes making regular checks and appropriate repairs. If there has been a failure, hopefully now you can undertake an appropriate repair and understand the cause of the failure. A quality wheelset that is well maintained should last tens of thousands of reliable miles.
**Glossary**

**Axle** A central spindle that goes through the centre of the hub.

**Ball bearing** These are balls that are located in between two surfaces which allows on surface to move smoothly over the other.

**Bearing** A part which allows free movement between two parts. One part will attach to the inner race of the bearing, one to the outer, the balls in the centre allow these races to pass over one another freely.

**Bearing Race** These are surfaces which the ball bearings rest on. They can pass freely over one another as they roll over the ball bearings.

**Cassette** A set of cogs that slides onto a freehub body and is then locked in place. This allows the cyclist to access a range of different gears.

**Clincher** In contrast to tubular tyres, clincher tyres hook onto a rim. Normally an inner tube is inside which is inflated with air.

**Derailleur** A mechanism which shifts the chain between cogs on either a freewheel or cassette located on the rear wheel. Front derailleurs allows a similar process to be undertaken on the front chainrings.

**Dishing** The centring of a rim on the hub.

**Dishing tool** A tool used to ensure the rim is correctly centred on the hub.

**Dynamo hub** A special hub containing magnets and coils of wire can be used to generate electricity, normally used for lighting. Bottle dynamos can also be used on tyres.

**Flange** In wheelbuilding the flanges of a hub are the proud parts which are drilled out to hole spokes.

**Freehub body** Sitting on the right hand side of certain rear hubs. The freehub body is is a carrier for a cassette. It also allows the used to freewheel by engaging only in one direction.

**Freewheel** A system that pre-dates the freehub body/cassette system. A freewheel screw onto a rear hub. It allows the user to stop pedaling whilst riding because the freewheel engages only in one direction.

**Hub** Located in the centre of the wheel the hub attaches the wheel to the frame of the bicycle. The hub contains bearings which allow the wheel to move freely. It will be drilled out so that spokes can be laced between the hub and the rim at the edge of the wheel.

**Inner tube** Situated inside of the tyre and made out of Butyl or Latex, the inner tube is filled with air that acts as a cushion inside the tyre. It helps to protect the bicycle as well as having a dampening effect of any impact.

**I.S.O.** An international standard measure of rim diameter.
**Lubricant** A fluid or gel-like substance normally used to protect metal surfaces from damaging one another. The lubricant allows freer movement and can also protect against oxidation.

**Nipple** Nipples are internally threaded and are screwed onto the threads at the end of the spoke. They are normally located by the rim and allow the wheel to be laced together and tensioned.

**Nipple Driver** A specialist tool used to quickly preloading a nipple onto a spoke thread.

**Nipple Grip** A specialist tool used for holding a nipple so that it can be fed through a deep section rim onto spoke threads.

**PCD** Pitch circle diameter. The diameter between two opposing points in a circle, used in wheelbuilding to describe the distance between opposite hole drillings on one flange of a hub.

**Quick Release Skewer** A device that allows for removal of a wheel via a lever. No tools are required for this removal.

**Rim** Normally made out of metal or carbon fibre, this is the outermost part of a naked wheel i.e. a wheel without inner tube and tyre. It is held in place by spokes and supports the tyre or tubular which contacts with the ground.

**Rust** A product of the oxidation of iron or steel. The oxidation of these materials is inelegant and undermines their structural integrity.

**O.L.D.** Overlock dimension. The distance between the locking nuts on a rear axle. Sometimes known as the axle spacing.

**Spoke** Normally made of steel, these strips of wire have a head at one end which is normally located in the hub and they are threaded at the opposite end. The nipple is screwed onto the spoke to hold it in place. As this is tightened the wheel gains strength and the hub can remain suspended in the rim or as the hub is fixed to the wheel, the rim will remain fixed around it.

**Spoke Key** A tool used for tightening nipples onto spoke threads.

**Tension** The force under which an item is held. In wheel building spokes are tensioned to ensure that the rim remains in place around the hub.

**Tension Meter** A tool used

**Thru Axle** A system used in heavier duty off-road applications. Instead of a quick release skewer or nutted wheel, a sold tube is pushed through the fork ends and wheel for a firmer interface.

**Truing** Ensuring that the rim runs straight on a wheel. Adjusting spoke tension allows you to correct run out which would lead to brake binding or weakness in the wheel.

**Truing stand** A device used for holding a wheel when building or repairing it. Normally with various dials or indicators used to true and round a wheel.
**Tubular** A tubular is like a tyre but coming as a completely sealed unit. This is rolled onto a specialist rim. No inner tubes are used with tubulars.

**Tyre** Made out of rubber the tyre sits on the rim of a bicycle wheel. It provides grip and cushioning for the wheel.

**Washer** Washers are placed in between two parts that are held together. Their application is varied. For more details, see the chapter on 'using washers'.

**Wheel** Get a real definition