PRODUCTION OF SPIRITS

The process of manufacturing spirits can often seem like an arcane and almost random process, but in fact all distilled spirits follow roughly the same patterns in their creation. The myriad diversity all coming from small differences in five main areas; the materials they are made from, yeasts and fermentation, distillation, filtration and maturation. We will go into all of these in depth to help you really understand the magic.

Raw Materials

The most important ingredient in liquor is the most important ingredient in life; the key to aqua vitae is water. In a standard bottle of spirits more than half the content of the bottle is water added at some point after distillation. This means that it plays a massive part in the final taste of a product.

All water is not the same. This point is most obviously demonstrated by blind tasting mineral waters, although their level of contaminants will be under 500 parts per million and the minerals found each will come from a reasonably small set the flavours can be quite different. The mineral level and type mineral define the water's physical and chemical properties and contribute not only to the product through the water added for reduction to bottling strength, but also the water used to produce the original mash discussed below.

In an ideal situation a distiller would have access to a consistant supply of clean, good tasting water, and in historical terms most distilleries locations were defined by this most important of resources, as brands have grown however more and more have had to altre their use of water to cope with expansion. This means that many have had to process a supply of water with less than ideal characteristics. The simplest way to do this is by osmotic filtration to produce a demineralised water, alongside UV sterilisation. De mineralised water cannot bring any taste benefits to the final product apart from consistancy but as many brands know the presence or absence of some minerals is vital to the taste of the final spirit.

- Jack Daniels relies on the high mineral content of the water from their cave spring. This water is filtered through limestone which removes all traces of iron but adds lots of calcium and magnesium in the form of carbonates. This is important for the production of whisky and it is no surprise to learn that the only area of limestone in the whole of the continental US is under Kentucky and Tennessee, the home of 98% of the distilleries
- Finlandia Vodka and 42 Below both have the luxury of being produced in unpolluted areas of the world and therefore can use only particulate filtered water for both distillation and bottle strength reduction, contributing

to the clean flavour. Taste tests have proven that de-ionised water has an unpleasant lack of taste attributed to the utter lack of salinity

- La Mauny use rain water to produce their rums as they believe that the lack of filtration and low metallic mineral content bring an extra vitality to their rum , and continue to use an expensively variable proces for collection
- The famed beers of Pilsen require the softest waters to allow the characteristic clean flavours to develop
- The massive variety of Scotch on the market is defined not only by the astonishing variety of styles of manufacture but also the fact that much of the water is still taken from individual springs, this allows distilleries a few miles apart using the same malt to produce dramatically different whiskies.

The production of Ethanol in all alcoholic beverages relies on the fermentation of sugars through the action of yeast. This process will be dealt with in more detail later, but it is important to understand the raw materials that form the source of these sugars and what effects these differences have on the final product.

Both the European Union and The U.S. Food and Drug administration demand that the sources of ethanol must be based on food grade raw materials. It is possible to obtain ethanol from other sources as it is in essence a very simple alcohol and can be manufactured from almost any hydrocarbon, including mineral oil. Although the ethanol component of the final product will be identical, the limitations of any kind of fractional distillation (around 96% ethanol) mean that the remaining percentage must have basis in a consumable product.

The action of yeast, or more specifically the enzymes, called ferments can be described by the simple equation below. An enzyme can be described simply as an organic catalyst and as such remains unchanged through the reaction.

$$C_6H_{12}O_6 \Rightarrow 2C_2H_5OH + 2CO_2$$

$$\text{Glucose} \Rightarrow \text{Ethanol + Carbon Dioxide}$$

This reaction is a slight simplification because even although glucose is the basic building block of all sugars, and in all organisms the source of energy to convert ADP into ATP (Adenosine triphosphate), all raw materials will have residual maltose, sucrose and other complex sugars that yeasts can also convert. We can however use this model for the understanding of the process and we will refer to sugars all the way through as if they were entirely glucose.

There are generally four sources of sugar found in materials used for potable alcohol production. These are:

- Natural Sugars – Found in all fruits and the basis of the production of alcohol in **Brandies.**
- Grain Starch – The energy source for the germination and early life of plants before adequate levels of photosynthesis can be achieved. These form the source for the production of **Whiskies.**
- Plant Starch – The starch held in mature plants as energy storage. This can be further subdivided into Root Stores (sugar beet), Tubers (potatoes) and Stem storage (Agave)
- Sugar cane and its By-products

Each of these sources requires different processes to prepare for fermentation and should be treated separately, even though the end product can end up very similar.

FRUIT

Brandies can be defined as any distilled alcoholic beverage that has its' basis in fruit. There are further clarifications required though, generally splitting fruits up into two categories, these are the fruits that contain high enough concentrations of sugars to ferment unaided and ones that require the addition of sugar to start the process.

Unaided fermentation – Grapes, Stone fruits (apricots, peaches, cherries, plums), apples and pears

When one thinks of brandy one automatically thinks of grape brandies (indeed the word comes from the word brandewijn - burnt wine). Grape wine is certainly the earliest consumed product of fermentation (although mead and beer are close behind). Grapes easily ferment due to the high sugar concentration and the fact that their skin provides a convenient home for yeasts. This means that its' discovery was inevitable and the spread of the vine has of course been based on this happy coincidence alone. In the production of alcoholic beverages the source of the fruit sugar makes a massive difference to the end product, In basic terms this can be illustrated in the difference between wine and cider, cognac and calvados but it is also important to note that fruit variety also plays a part, the difference between Pisco and Cognac is primarily doen to the use of different grapes, pisco uses primarily Muscat and Cognac Ugni Blanc. The Muscat grape is known for its production of sweet wines, Ugni Blanc makes thin acidic dry wines and it is this acidity which means that the wines it produces are low strength and not considered to be particularly fine, but conversely produces brandies of unrivalled complexity. There is a caveat to the grape category and that is the use of the pomace (the skins and residues from squeezing the grapes to produce the basis for wine production.) These 'left-overs' still have enough sugar to ferment, and although their wines are never drunk, the distilled product of these is under various guises, most commonly Marc or Grappa. These are

good examples of distillation being used as a form of purification as well as for increasing the alcoholic conetent.
Stone fruits are used in the production of several spirits the most famous being Kir or Kirshwasser (cherries) or Slivovitz (sljiva plums), in many of the brandies and also the liqueurs using these fruits (from Cherry heering to Amaretto) the stones of the fruits are used as well which bring a characteristic bitterness to the final product.

Aided Fermentation – Raspberries, strawberries, black and red currants,
This is a much smaller category in terms of both production and consumption. The most widely drunk would be framboise eau de vie. Sugar is added to the fruit to raise the concentration that can support natural fermentation. This should not be confused with the method of maceration fruits in high strength alcohol and then distilling the product, or liqueur production

GRAIN
The catch-all term for the seeds of grasses (ranging from small rye seeds all the way up to maize) these are the storage devices of the embryo of the new plant. The mother plant stores up energy to aid the initial growth stages of the offspring. This is stored as insoluable starch, to allow for the seed to remain dormant for a time without degradation. Unfortuanately for the production of alcohol this insolubilty of starch is a major issue.

Producers get around this with a process known as **Malting.** This relies on the fact that the plant must convert the starch to sugar for its' own purposes i.e. growth. The grain is first soaked and then kept at the correct temperature for germination. If the conditions for growth are correctly mimiced the enzymes in the grain begin to convert the starch. The process of growth is arrested by heating to denature the plant just as it begins to produce a shoot and the starch has all been converted. These denatured grains are then ground and ready to begin fermentation when suspended in water.
This malted grain used to be the basis of all grain based spirits and is still used in Scotch and Irish whiskies, and as starter in the manufacture of Bourbon and other American whiskies but has been superceded in the production of vodka with artificially produced enzymes that can be added to milled grain and perform the same starch to sugar reaction.

The process of malting prepares the grain for fermentation but in Malt Scotch the process also adds levels of flavour. When the grain has reached a level of germination that indicates the full conversion of starch the process is arrested by heating. In Irish whisky, Bourbon and other spirits this is done with indirect heat, often steam in an autoclave, whereas in malt whiskies the malt comes into contact with elemnts of the fire and smoke. This toasting process changes the flavour in two ways firstly how heavily toasted the grains are. This is used a lot to change the flavours of beer, but in Scotch the biggest effect comes from the contact with smoke. The peatiness or 'peat reek' of Scotch comes from this contact between the smoke from peat fires and the grain and is still obvious after distillation. This more than any other single taste demonstrates the importance of the raw material in a spirit regardless of the distillation accuracy.

The differences in various grains are represented in the spirits that they produce. Even in vodka the differences between rye, wheat and barley is quite pronounced. Probably the best illustration though is in American whisky where the Mashbill (the ration of grains used in the production) plays a large part in the final taste of the whisky.
The four main grains used in spirit production are:

Barley – 100% of Scotch and Irish Whisky, around 10% of most Bourbon whiskies, Finlandia vodka.
Wheat - Absolut, Stolichnaya and many other Scandinavian and Russian vodkas and also some bourbons e.g. Makers Mark
Rye – Wyborowa and most Polish vodkas, straight rye whisky, Canadian whisky and as a component of most Bourbons
Maize – All Bourbon and Tennessee whisky must be at least 51% maize, corn whisky and some vodkas use maize (Skyy)

As with everything else, modern technology and farming techniques have led to neew varietals of grains being produced. Although the differences in the spirit produced are less obvious than with grape varietals lots of manufacturers express a preference.
In addition neutral grain spirit is used for the manufacture of most gin, some liqueurs and flavoured spirits and is often used in low strength products like PPS

PLANTS
Some plants store large amounts of starch in parts of their systems to allow them grow more effectively. These are generally plants that survive either in Xerophytic conditions or highly seasonal growing areas. They are generally three groups of plants that are used for distillation but we can generalise into two types. The first are species that have starch stores underground. These can be either Root Succulents like the sugar beet or turnip, where the starch store is a swollen part of the root. (they generally have a simple tap-root based system) or Tuberous plants that grow separate starch stores (potatoes and yams) amongst a more complex branched root network. The difference is largely down to the fact that the two sets of species have evolved separately and until Columbus had the atlantic between them. We treat thyem together as both developed the starch stores as a way of achieving the same biological aim.

Potatoes are used in the production of characterful vodkas from Poland, where one particular variety, the Stobrawa is used. It has a very high starch content to maximise the yield of useable sugars. Sugar beet is generally used to make neutral spirit for the lower end of the market and for the production of industrial alcohol.

Whereas the transformation of starch to sugar in grain is based on chemical addition, with potatoes and beets the process is a more simple one based on breaking the long chain starch molecules with heat. The product is 'cooked' in an autoclave or steam oven and the resultant softened pulp further ground and mixed with water to form the basis for fermen tation.

The other type of plant used in the production of alcohol is the leaf succulent. By far the most obvious and common example is the Agave used in Tequila and Mescal production.
A relative of the lily, and not a cactus these plants are native to Mexico and adapted to grow in the Desertlike conditions. The main varieties are Agave Tequiliana Weber (Blue agave – the only one allowed to be used for the manufacture of tequila), Agave Escadin and Agavacea dasyllian. The plants grow two about two metres tall and reach maturity at about 6-8 years. The starch store takes almost the whole stem of the plant, and is surrounded by a crown of long spiky leaves. The stem or heart (pina) is harvested and in a process similar to the roots above is cooked. In tequila this is normally now done in closed oven or autoclave yielding a softened but still fibrous mass with the starch converted. This is then pressed and the resultant sugary liquid (agua miel) is then fermented. The process for mescal differs only in the fact like in Scotch maltings there is contact between the pina and the smoke and fire, which lends a characteristic taste to the spirit.

SUGAR CANE
Sugar cane is a fast growing grass of the genus Saccharum. There are several species used for the production of spirits but all are defined by the huge sugar content of the their sap, which can reach up to 10% concentrations (gomme syrup is only 50%) This means it is a great raw material for distillation as in can be used immediately. The cane grows very quickly and in the tropics can grow all year round, with new areas coming to maturity all the time. This means that rum production is not nearly as seasonal as other spirit types which are mainly produced in temperate regions and rely on stored raw material for winter production, or like Cognac close the distillery for periods of the year

The three main styles of rum are based on different uses of the sugar cane.

- Cachaca, the national spirit of Brazil is produced from the whole cane. This is the most simple treatment of the product. Sugar cane is cut and broken up and the husks are placed in a vessel and heated with water. This extracts all the potential sugar from the cellulose husks, and also extracts some of the vegetal matter and flavours. The resultant liquid is then fermented and distilled. The characteristic taste of Cachaca is based on the flavours extracted from this basic cooking process.

- Rhum Agricole, produced in the French Islands of the Caribbean, most notably Martinique uses the free running juice of the sugar cane. The cane is pressed and the resultant liquid is then left to ferment.
- Rum. Often known as English style rum, although encompassing Cuban and South American styles as well as the English speaking Caribbean, the name refers to the historic dominance in rum production based on the English Navy. Rum is produced from molasses, a byproduct of the manufacture of sugar. At one time refined sugar was more expensive than gold, and brought huge profits to the people who could import it back to Europe and the new world. Sugar is refined from the true raw material by simple fractional distillation. Almost all grades of sugar are sold on but the very heaviest and impure fractions remain as a black, pungent liquid, molasses. This molasses is subjected to fermentation, and even with low levels of simple sugar the heat levels of the area allow the fermentation to take place

Fermentation

The process of fermentation occurs naturally in various forms and differs little from other less useful forms of corruption, indeed the word is often used to describe the process of fungal respiration, both anaerobic and aerobic. Yeasts are fungi and the process of fungal growth is harnessed in many areas of food production from the flavouring elements of blue cheese to the sour preservation of products such as yoghurt and pickles like sauerkraut.

The production of alcohol requires a more specific (and correct) definition of fermentation. It is the anaerobic respiration of sugars without oxidation to form an alcohol and carbon dioxide.
This reaction happens under the enzymic catalysis of products of the variety of fungi that come under the category of yeasts. The yeasts benefit in the fact that although not all the energy is released in the reaction they can harness some into the conversion of ADP into ATP and thus grow and reproduce. The reaction above is for the complete conversion of glucose, in all natural cases however different strains of yeast will have slightly different effects and when reacting with more complex sugars and sugar sources different alcohols and other aromatic organic compounds will be created. The reaction is limited by the amount of available sugar but also the hardiness of the yeast. They are in an unfortunate situation that the by products (for them, the product for us) of their respiration – alcohol is poisonous and will kill them above a certain level of concentration, also in a closed system the pH. can change enough to also become unsurvivable. This is true of all yeasts in natural and artificial situations. In many wine and fortified wine applications it is favourable to keep some of the sugars so the action of yeast is often curtailed by the addition of neutral spirit.

Emil Christian Hansen at the Carlsberg Brewery in Copenhagen undertook further study of yeasts and was the first to work out that naturally occurring yeasts are made up of variant strains of the organism. He is credited with the first monoculture strain (Sacchromyces Cerevisiae Carlsbergensis) but more importantly led people to understand the importance of using cultured yeast as opposed to naturally occurring strains for both yield and consistency. Now brewers and distillers will carefully select and store their strain of yeast for its desired effects. A mention should be made of the sour mash process. This was a development of the manufacture of sourdough bread by the pioneers and early settlers to the US. They used a small portion of the dough from a batch of baking to start the yeast culture in the next (levain in France.) James Crow used the same idea with a portion of his unfiltered mash is distilled and added to the next batch to ensure correct growing conditions for the favoured yeast.

There are two types of fermentation and they are responsible for the different aspects of flavour. Aerobic and Anaerobic. These are often described in beers as top fermenting and bottom fermenting. They produce different chemicals ranging from acids to aldehydes and aromatic esters, and vary wildly in the speed of fermentation. Most spirits undergo a 40 -50hour fermentation but many ferment for as long as a week. The length of time is determined by the ratio of top fermenting (quick) and bottom fermenting (slow) yeast action. Most washbacks or fermentation tanks are sealed but those in North America are often open and gently bubbling. Fermentation is now normally carried out in stainless steel but some producers still use cypress or pine fermenters. These were used originally for their antibacterial properties to cut down on the enemy of fermentation – bacteria. These organism fight for the resources and create too many acidic residues.

Distillation

Distillation or more correctly fractional distillation is the process of purification through the action of heating a substance to a gaseous form and then selectively condensing the required component (fraction). The are other forms of separation that are used in the production of beverage alcohol, most notably freeze concentration used in the production of Applejack, a process where an alcoholic mixture is concentrated by allowing it to freeze (which the water component does first) and removing the ice. This method has similarities to distillation and although it relies on the same science we will concentrate on the standard form. If the process only required to separate water from ethanol this could be done accurately in a still as simple as this with just one distillation, up to an accuracy of 96% pure. This is the maximum purity achievable in RTP (room temperature and pressure) distillation due to the fact that water and ethanol form an azeotrope. Put simply this means that the mixture at this specific point has the same potential in its liquid and gaseous states, if you boil 96/4% mixture the gas given off is at 96/4% as well. In industrial uses other techniques are used to get the extra percent but none have been certified for use in beverage alcohol, an all are prohibitively expensive.

Distillation as a practical process has been around for thousands of years with practical knowledge resurfacing after the dark ages with the Moors. They used the process for the production of essences for perfumes but the skills were swiftly transferred to the rest of Western Europe. The techniques have been polished and adapted to the present day, with increasing accuracy in measurement and construction better results can be obtained but until the invention of the continuous still by Robert Stein in 1826 and the subsequent perfection of the idea by Aeneas Coffey in 1831 the concept had remained very similar.

Pot Distillation

The original form of still is used for the production of some brands of almost all types of spirit and can be traced back to simple apparatus like the picture above. The style of modern pot stills came into use in the 16th century, with the use of copper. A still is divided into three parts. The kettle or base is the vessel where the liquid is heated, the neck or swan neck is the hurdle over which the vapours have to travel and the lyne arm or line pipe is the path to the condenser and collection.

The fermented wash (sometimes known as distiller's or small beer) is placed in the still and then heated, usually with a water jacket or steam pipes as direct heat will burn some of the particulate matter to the sides of the vessel making it harder to clean (some still have a system of flails called rummagers to stop this happening). As the liquid starts to vapourise the distiller will collect the resulting liquid. This first distillation occurs in what is known as the wash still. It takes a distillate from 7-9% alcohol from fermentation of the raw materials and takes it up to around 21 -29 %. These liquids are known as low wines.

These are then placed in a second still, sometimes called the spirit still and are redistilled. The results of this second distillation are separated into three categories. The Heads or Foreshots contain high alcohols and aromatics and are recycled back into the system. The next part is the heart, the spirit that will actually be used, and the last are the Tails or Feints. These contain the heaviest components of the mixture and are generally also redistilled or discarded. The hearts of the distillation represent around 20-30% of the total run and it is the art of the distiller to pick his cut points to gain the best flavours. The liquid coming off the second distillation will vary between 52%(tequila) and 70%(whisky and cognac) ABV. Some distillers, most notably in Ireland distil a third time. This allows a lighter and purer spirit of around 80% to be produced)
There are many factors changing the way a still works that have notable effects on the resultant liquid.

- Size of still. The size of still affects the amount of contact the liquid has with the copper walls. In the conditions of a still with increased heat copper acts as a catalyst for a host of organic reactions that change the components of the liquid. The smaller the still the more copper contact

- The heat source. To make the most spirit the still should run as fast as possible but a better result occurs with gentle heating. This means a compromise must be made
- The shape of the neck. A long neck will produce a lighter spirit, as it is more difficult for heavy molecules to pass over the swan neck. A short still will make a deeper, heavier spirit. Moreover the shape defines a further reaction called reflux. This is similar to the action of a continuous still where liquid that has condensed before reaching the swan neck falls back and strips molecules from the rising vapour, making a lighter end product.
- Mini reflux reactions can take place if the still has any irregularities, creating micro climatic distillation inside the still. These little understood reactions have a large effect on the spirit

The pot still requires on artistry of the master distiller based on both interpretation of technical data and also experience and as it is a batch process the still must be run, stopped and cleaned between batches. This is both labour intensive and time consuming and the limiting factor in volume production. The continuous still came around to get around both of these points.

Continuous Still

A continuous still is a double columnar device to take the guesswork and inefficiency out of the production of spirits. The system is designed to allow exact fractions to be removed from a sample automatically reducing the need for an experienced master distiller, and because the process runs continuously and can be recharged the inefficiency of a stop start operation is removed.

The continuous still consists of two columns, the rectifier and the analyser. The system uses heat very efficiently but quite confusingly. The initial stage involves heating the wash in the rectifier – in a closed system. This removes the need for a separate heat exchanger. This is the transferred in to the Analyser at the top of the column. The analyser has a series of copper plates with holes to allow vapour to rise and liquid to fall. The heated wash meets steam that is pumped into the bottom of the analyser. This steam strips the molecules from the wash and at each baffle plate a mini distillation is in effect taking place. The steam continues to rise along with the alcohol molecules it has stripped from the wash. This vapour then proceeds to the rectifier where it rises up through more baffle plates until it starts to condense. Each baffle plate can be accessed as each represents a fraction of the original liquid with a very specific condensing point. The still allows the removal of the high alcohols and the heavy elements are immediately separated in the analyser. This means that not only is there controllability there is increased efficiency.

Most people consider the use of the continuous still primarily for white spirits and grain whisky but because you can choose the level of accuracy and define a range of fractions spirits including Armagnac and most bourbon can come from a style of continuous still, just the come off at less high proof.

Filtration

Filtration in some form has been used since the earliest production of alcohol. At it’s most simple the concept of removing unwanted material from a given sample is the easiest way to improve the quality of a wine or spirit. From earliest recoded times, animal skins, and woven cloth fibres have been used as mechanical filters, but the by far the most important advance was the use of activated carbon in filtration.

Filtration can be of two types, mechanical and chemical. Mechanical filtration works very much on the principle of a household sieve, but of course on a much smaller scale. Water and Ethanol are small molecules, whereas much of the contaminant matter that would occur in a sample of beverage alcohol would be much bigger, especially some of the heavier congeners and fusel oils that bring off tastes to a spirit. Mechanical filtration can remove these simply by making the filter ‘holes’ smaller than the unwanted chemicals.

One of the easiest ways to construct this level of filtration, far before the technology required to manufacture a molecular grid is to ape nature and use a compacted system of granular material to act as the sieve. This approach can be seen across the production of white spirits, from the use of quartz sand by Bacardi, Flint in Siberian Vodka, Diamond dust etc. The choice of the material matters little. All that is important is the fact that it is inert and very fine. As a liquid slowly leaches through the compressed bank of granular material the largest molecules get left behind, as they cannot pass through the smallest spaces. The efficiency of such filtration is defined by the pressure the liquid is at and the size of the particles in the filter, and much less about the actual material, diamond being no better than quartz sand for this purpose. Mechanical filtration has been promoted as an important part of the manufacture of many modern premium and super premium vodkas, with many dubious statements used to give uniqueness to this essentially mundane procedure.

Chill filtering is another process that is commonly used to mechanically filter spirits. The solubility of a liquid changes with its’ temperature, the colder a liquid is the less soluable material can it hold. Also the ability for larger molecules to remain in suspension reduced. This material will then sink to the bottom of the vessel due to its’ higher density where it can be removed. This is most commonly used to remove tartrates from whisky, but as these are related to flavour components some people say that chill filtration reduces the flavour. The same process is used to make ‘Ice’ beers and their flavour is noticeably lighter and less good than the originals

The other, and far more important type of filtration is chemical filtration. This is used to actively remove specific unwanted chemicals. The earliest known examples of these where used in the fining of wines. They were used to remove sediment by coagulation of the material and then subsequent gravity based

filtration. Early fining agents were substances noted to cause coagulation in particular chemicals, milk casein being an obvious example, although extracts of fish guts and animal gelatine was also used. This addition of a fining agent works well for wine but the molecules in spirits are in smaller concentrations that can make chemical fining an expensively inefficient process.
In the 1870's a chemist working for Smirnoff in Moscow noted the particular ability of activated charcoal for filtration. He of course invented nothing new, alchemists had been using charcoal for hundreds of years but his, and coincidentally of the other side of the world Don Fecundo Bacardi's development was how to market a thoroughly filtered alcoholic beverage.

Activated Carbon (Charcoal) is produced from organic sources, in the most simple terms hydrocarbons that make up organic matter are reduced to their carbon component through the slow burning of raw material. This forms charcoal. This can then be activated further on contact with air or for the best effects pure oxygen. Activated charcoal at a microscopic level shows a huge number of folds and convolutions giving it a huge surface area to weight ratio. This allows a huge number of chemical reactions to take place all over its' surface. The key is that charcoal efficiently adsorbs other some hydrocarbons while acting inertly to most minerals, Adsorption is a process of chemical binding to sites on the surface of the charcoal. Technically it isn't a chemical reaction as both the carbon and the impurity remain unchanged but it acts as one because the bond between them removes the chemical from active circulation. This process is vital in the chemical industry as well as the production of spirit

We can split filtration in to three areas

- Filtration of water supply. All spirit manufacturers have to filter their water supply to a certain extent, differences occur only down to the availability of a clean water source. From simple mechanical filtration in the case of Finlandia to total deionisation by distillation or UV treatment in SKYY distillers ensure a consistent and consistently clean water to add to both the distillation process and for reducing to bottling strength. Most manufacturers go to the expense of deionisation not for taste reasons but to ensure consistent mineral levels and absence of any corrupting environmental pollutants, This will become more and more necessary in our dirty world

- Filtration before aging. This is an uncommon process as most filtered spirits are un-aged but there is one notable exception. Tennessee whisky is characterised by the Lincoln County Process. This is the filtration of spirit through sweet maple charcoal before barrel aging. The spirit is dripped through large vats of ground charcoal that has been made in the open air. This charcoal not only has the filtering effect, but due to the speed of the burn will have some remnants of maple wood also. The spirit proceeds through the vat and takes on some of the flavours of the maple while being stripped of many of the harshest notes in the original spirit.

The process accelerates the production of a smoother whisky, while others have to rely solely on contact with their aging barrel to mellow the spirit

- Filtration before bottling. If a spirit has been aged like Bacardi Carta Blanca, or un-aged like vodka, the process of charcoal filtration before bottling is all about making the spirit as fine, smooth and pure as possible. Multiple filtrations are often used with a combination of mechanical and charcoal methods. Charcoal can effectively remove colour at this stage but not always, as referenced by Gentleman Jack which retains its' colour even after a second filtration. Chill filtering is used here also to remove matter, although this is more to produce a product with a more consistent appearance.

Maturation

One of the most magical aspects of alcohol production happens in the months and years after distillation. Raw new make spirit is often known as Moonshine and is a harsh and uncomplicated product. It is then placed into oak barrels and after due period emerges as a brown, mellow and complex spirit.

The process of barrel aging has been known about for hundreds of years, but understood for far less. The first drinks to benefit from this extra aging where probably wines and fortified wines taken aboard ships on the earliest voyages to India and the Far East. These wines where kept at the bottom of the hold as ballast and consumed throughout the voyage, we can be sure that some difference was noted between first sip and last. Unfortunately though the storage of a product before sale costs the producer money and the concept of improving the wines and spirits in this way didn't immediately catch on due to the cost. It took until the late 17^{th} century for European commerce to be stable enough to have merchants stocking maturing spirits and a market that would consume them. Probably the brandies of Cognac were the first to be recognised as benefiting from their time in wood but soon after followed the increase in both whisky and rum.

Barrel aging is a mysterious process relying on a variety of variables, and, when discussing the aging of a particular brand or sample it is often illustrative to look at the myriad factors that affect it. Aging in wood allows for four things. Oxidation of aromatic chemicals in an extremely slow and controlled manner; change in alcoholic strength due to evaporation; filtration in much the same way as activated charcoal works in other systems and addition of flavours that are originally present in the cask itself. All four of these processes are happening in every stored barrel of spirits in the world but it is the varying degrees of each process that creates the astonishing variety of final tastes. When investigating a spirit it is easiest to examine each factor to understand the particular aging process.

- The Type of Wood. A barrel can be made from anything, but for periods longer than that of any spirit manufacture oak has been the most sought after material. This is due to the fact that it is hard and durable, but not so hard as to be inflexible or too difficult to work, plentiful, and because it has a natural resistance to decay when properly cured. Within the large Oak family there are specific genii that are particularly sought after. Typically the tight grain of the European oak that grows in The Limousin was seen as the best for aging cognac – but then only by the French, and in Cognac there are strict adherents to the Troncais forest, with wider pored oaks. Also the best Armagnacs are aged in Monlezun black oak, which they swear matches the earthy contents best. Scotch whisky was traditionally aged in Spanish red oak, often reusing sherry casks and the Americans use varietals of American White oak, which has a tight straight grain with small pores. Whichever wood is used will change the characteristics of the whisky and also the speed of aging. Scotch manufacturers are no experimenting with the influences that the different styles bring.
- The size of the barrel. Barrels under various names go from 60ltr all the way up to nearly 1000ltr. As any mathematician knows the surface area increases by the square and volume by a power of three. This means that the surface area to volume ratio is highest in small barrels. This in turn means that spirit aged in a small barrel has more contact with the surface of the wood and therefore gains aged characteristics more quickly than spirit in a larger barrel.
- The age of the barrel. Making a barrel is an expensive and skilled task and they last for a long time. This means that they can theoretically be used again and again. The first fill however will gain more influence from the wood and have more filtration effects from it than subsequent fills where the ability has been partially used up. Bourbon manufacturers can only use their barrels once, but other types of sprits can use older barrels that influence both the speed of aging and also the amount of sweet wood compounds and oak tannins enter the spirit.
- The degree of char or toast. When the cooper is making the barrels he heats the staves over a fire to give them the flexibility to bend into the correct shape. This char creates a thin layer of active charcoal and also concentrates the sweet wood compounds in a layer just beyond the char. Cognac and Sherry manufacturers traditionally only lightly char their barrels, and then re-char to refresh them when maintaining them through the life span. This extends the barrels life to many even fills. Bourbon manufacturers char much more heavily as they want to fully access the vanillins and tannins inherent in the oak. They char to 3 levels, light, medium and alligator, the last due to the cracked skin of the heavily charred surface. These differences in char change the speed of aging but also affect the colour and taste of the spirit.
- The Climate. Spirits are aged in locations from the far north of Scotland to the deep south of Kentucky and Tennessee, and of course the climate of these locations is vastly different. The concept of effective wood aging

relies on movement of spirit in and out of the wood, this is caused by expansion and contraction of the liquid caused by temperature change. A large change in daily temperature brings on the quickest aging, so whiskies aged in temperate but hot climates age faster than tropically aged rums because the difference between day and night temperatures is greater, while in Scotland aging is very slow as the temperature change is smaller and the maximum temperature, which, although not having as much of effect as the change also influences the speed.

- The conditions of Aging. The size, location and style of aging house can have effects on the aging process both by influencing the local micro-climate (even to the level of different areas of the warehouse) and also the level of efficiency and waste. The Angel's Share is the spirit that evaporates away during aging and the levels of this are defined not only by temperature but also by local humidity, the more humid the smaller the loss. Retaining humidity therefore is a good way of reducing waste, but also means that the temperature in the closed system will have less variation. It is this balance that requires consideration from every manufacturer to gain the correct compromise. Other strange effects can occur due to the location of the aging houses, particularly if they are near the sea of in windy locations, a good reference wood be the salty whiskies of Laphroaig which gain character from the fact that wind blown salinity affects the whole process
- The length of time. This ranges from as little as a couple of months in some Reposado Tequila to half a century in some Malt Whiskies and Cognacs. This variable is a function of all the rest of the factors but once the system for a manufacturer is developed this is the one that can be most easily changed. Most experts agree there are optimum ages for different spirit styles but as all the other effects are so variable the rules are made to be broken. Everyone agrees though that there is a level above which wood flavours begin to over dominate and produce acrid notes in the final spirit.

A small mention must be made of the Solera system. This is a system of aging developed for Sherry but is also used in Spanish brandy and some rums. It involves using a barrel matrix to produce an age/blend system. The new make spirit is put into the first barrel of a series, of which half the original contents have been transferred to the next in sequence, and so on. This system allows the producer to gain the effects of aging in a shorter time as the final sample has not only product aged for the length of time the whole system takes to run but also a component of every product that has been through before in the lifetime of the Solera. This means that very complex spirits can be easily generated.