BJCP STUDY GROUP - SESSION 3

> READ / STUDY - The appropriate / matching section of the new BJCP Study Guide that corresponds to the technical topics / off flavors / flavors / etc. listed below.

- Boiling
- Yeast (and Fermentation)

- Alcoholic (ethanol)
- Solvent (fusel alcohols, acetone, lacquer thinner)
- Sherry-Like
- Acetaldehyde (green apple-like) and Cidery
- Esters (fruity)
- Poor Head Retention
- Sewer-like (mercaptan)
- Sulfur (rotten eggs, burning matches)
- Soapy / Fatty (goaty)
- Yeasty

> READ / STUDY - Style Guidelines - Introduction (all) and the Styles listed below.

9. Scottish and Irish Ale
    - 9A. Scottish Light 60/-
    - 9B. Scottish Heavy 70/-
    - 9C. Scottish Export 80/-
    - 9D. Irish Red Ale
    - 9E. Strong Scotch Ale

11. English Brown Ale
    - 11A. Mild
    - 11B. Southern English Brown Ale
    - 11C. Northern English Brown Ale

8. English Pale Ale
    - 8A. Standard / Ordinary Bitter
    - 8B. Special / Best / Premium Bitter
    - 8C. Extra Special / Strong Bitter (English Pale Ale)

10. American Ale
    - 10A. American Pale Ale
    - 10B. American Amber Ale
    - 10C. American Brown Ale

SESSION 3

> Technical Topic 1

- Boiling, Fining and Chilling Processes. Reasons for each should be discussed, along with potential problems.

Boiling, Fining and Chilling
Compiled by Ron Smith

BOILING

THIS QUESTION "USED TO BE" ON EVERY EXAM - KNOW THIS ANSWER !!!
Q) Provide 5 reasons for boiling wort and explain your answers (note: there are 8 reasons).

Boiling wort is performed for the following reasons:

- Deactivate and destroy mash enzymes
- Kill unwanted microbes
- Reduce wort pH (5.2 ideal)
- Extract hop resins / isomerize alpha acids
- Coagulate proteins, tannins and sulfur compounds in the form of trub(hot break / cold break)
- Form melanoidins and/or caramelize sugars (not desired in all styles)
- Evaporate water / concentrate wort
- Dissipates harsh hop oils, sulfur compounds, ketones, and esters.

To effectively achieve these goals, a "rolling" or "vigorous" boil is required for a minimum of 60 minutes.

- NOTE: Boil (and chill) with the lid off to let unwanted components escape.

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pH - Wort pH will fall from 5.6–5.8 at the start of boiling to around 5.2–5.4 at the end. This is primarily due to the precipitation of calcium phosphate. Calcium ions in brewing water reacts with phosphates from the malt to form calcium phospate and hydrogen ions, which lower wort pH.

This demonstrates the importance of excess calcium ions in the wort after mashing. For this reason, it is sometimes a good idea to add gypsum to the kettle. If your mash pH is fine, but the pH does not drop to at least 5.4 by the end of the boil, add 1/4–1/2 teaspoon of gypsum per five gallons.

FINING

Finings are colloidal gels. They are magnetically charged which attract proteins and yeast. Kettle finings such as Irish Moss or other commercial chemicals are used near the end of the boil to promote hot and cold break formation.

- Note: Isinglass, gelatin and other commercial compounds are used during conditioning to promote yeast flocculation

CHILLING

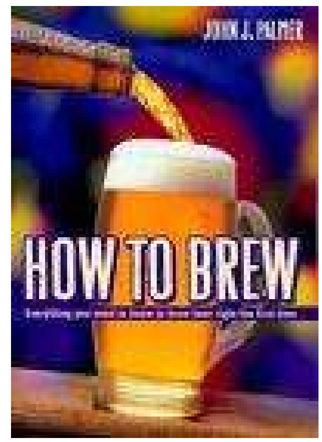
Cooling the freshly boiled wort to proper yeast pitching temperature in a relatively short period of time is critical for the following reasons:

- Extended time between end of boil and chilling can allow proteins to dissolve back into the wort resulting in astringency and/or sulfur / DMS flavors / aromas and create permanent chill haze.

- Extended time at temperatures below 140 degrees Fahrenheit risks contamination by bacteria.

When using an immersion chiller the cold break will form in the kettle and can be left behind when transferring the wort to the fermenter.

When using a counter-flow chiller, the cold break will form in the chiller and will collect in the fermenter. The wort should be allowed to settle (15-30 minutes) and then racked off of the cold break before the end of the lag-phase.



- The following text was taken from John Palmer's book titled How to Brew (used with his permission). This information is on his website at www.howtobrew.com. John does an excellent job of explaining the most important aspects of a subject, in a clear and concise manner. Key points have been highlighted. John's book is excellent, and should be a part of any brewers's library.

Boiling - The "Hot Break"

A foam will start to rise and form a smooth surface. This is good. If the foam suddenly billows over the side, this is a boil-over (Bad). If it looks like it is going to boil over, either lower the heat or spray the surface with water from a spray bottle. The foam is caused by proteins in the wort that coagulate due to the rolling action of the boil. The wort will continue to foam until the protein clumps get heavy enough to sink back into the pot. You will see particles floating around in the wort. It may look like Egg Drop Soup. This is called the Hot break and may take 5-20 minutes to occur, depending on the amount of protein in your extract. Often the first hop addition triggers a great deal of foaming, especially if hop pellets are used. I recommend waiting until the Hot break occurs before doing your first Hop addition and timing the hour. The extra boiling time won't hurt.

Covering the pot with the lid can help with heat retention and help you achieve your boil, but it can also lead to trouble. Murphy's Law has its own brewing corollary: "If it can boil over, it will boil over." Covering the pot and turning your back on it is the quickest way to achieve a boilover. If you cover the pot, watch it like a hawk.

Once you achieve a boil, only partially cover the pot, if at all. Why? Because in wort there are sulfur compounds that evolve and boil off. If they aren't removed during the boil, the can form dimethyl sulfide which contributes a cooked cabbage or corn-like flavor to the beer. If the cover is left on the pot, or left on such that the condensate from the lid can drip back in, then these flavors will have a much greater chance of showing up in the finished beer.

Cooling the Wort
At the end of the boil, it is important to cool the wort quickly. While it is still hot, (above 140°F) bacteria and wild yeasts are inhibited. But it is very susceptible to oxidation damage as it cools. There are also the previously mentioned sulfur compounds that evolve from the wort while it is hot. If the wort is cooled slowly, dimethyl sulfide will continue to be produced in the wort without being boiled off; causing off-flavors in the finished beer. The objective is to rapidly cool the wort to below 80°F before oxidation or contamination can occur.

Rapid cooling also forms the Cold Break. This is composed of another group of proteins that need to be thermally shocked into precipitating out of the wort. Slow cooling will not affect them. Cold break, or rather the lack of it, is the cause of Chill Haze. When a beer is chilled for drinking, these proteins partially precipitate forming a haze. As the beer warms up, the proteins re-dissolve. Only by rapid chilling from near-boiling to room temperature will the Cold Break proteins permanently precipitate and not cause Chill Haze. Chill haze is usually regarded as a cosmetic problem. You cannot taste it. However, chill haze indicates that there is an appreciable level of cold-break-type protein in the beer, which has been linked to long-term stability problems. Hazy beer tends to become stale sooner than non-hazy beer.

BOILING REVIEW: - Review

- Reasons for boiling:
  1) Stops enzymatic activity
  2) Kills bacteria, wild yeast and unwanted microbes
  3) Stabilizes salts for correct boil pH (5.2 - 5.5 is ideal)
  4) Extracts, isomerizes and dissolves hop alpha acids
  5) Coagulates undesired proteins and polyphenols in the hot break (trub)
  6) Carmelizes some sugars and forms melanoidins
  7) Evaporates water, condensing the wort to the proper volume and gravity (about 1 gal / hr)
  8) Evaporates / dissipates undesirable harsh hop oils, sulfur compounds, ketones and esters

- 60 minutes of rolling, vigorous open boil is required (90 min typical for all-grain beers, except Berliner Weisse where hops are added to the mash tun and there is no boil)

- Rapid chilling after the boil is required to reduce the chance of lactobacillus or other bacterial contamination
  - Need to get yeast pitched ASAP once below 140 F
  - Rapid chilling also creates a good cold break to drop out coagulated proteins and polyphenols - The addition of Irish Moss (a fining) can assist this as well (added at the end of the boil)
  - If chilling takes too long, proteins can dissolve back into the wort, resulting in astringency, sulfur, DMS, chill haze, etc.

Also, review the section on Boiling in the BJCP Study Guide.

> **Technical Topic**

- Yeast and fermentation, including characteristics of different yeast strains, bacteria, by-products and relationship to world beer styles. Also discuss fining and carbonation methods.

Yeast

Compiled by Brian Steuerwald and Ron Smith

Yeast is a single-celled living organism classified as a fungus. It is unique in that it can survive either in the presence or absence of oxygen. (Most living organisms can only survive under one of these two conditions.) In oxygen rich environments, yeast typically reproduce. In oxygen depleted environments, they survive by converting sugar into energy needed to sustain the cell in what is called an anaerobic (without oxygen) process. As part of this anaerobic process, alcohol, carbon dioxide, and other byproducts are produced. The entire process of converting sugar to alcohol is what we typically call fermentation.

There are hundreds, if not thousands (they tend to mutate quickly), different strains of yeast. Most are wild yeasts that occur in nature. Some of the wild yeasts strains are well understood but most are not. As for yeast used to produce beer, White Labs and Wyeast combined offer about three dozen strains.

Three characteristics are often used to describe yeast used for fermentation. These characteristics are:
- Apparent Attenuation
- Flocculation Ability
- Optimal Fermentation Temperature

<u>Apparent Attenuation</u> is the extent to which yeast ferments all the sugars in wort during fermentation. It is commonly listed as a percent, in which the numerator is the difference between final and original gravity and denominator is the original gravity. Because the density of ethanol is less than water, when a hydrometer is used to measure this attenuation, it will be measuring the apparent attenuation not the real attenuation (if the alcohol was replaced by water).

<u>Flocculation</u> is the extent to which yeast settles out of the beer after the completion of fermentation. The level of flocculation varies significantly from strain to strain.

<u>Optimal Fermentation Temperature</u>: Yeast behaves differently under different temperatures. To perform optimally (in terms of what the brewer wants in the finally product), some yeasts work better in colder environments and some yeasts work better in warmer environments.

Yeast used in brewing generally falls into one of two genera as outlined in the table below.

Yeast Genus (Common Name and Characteristics)	Ideal Fermentation Temperature	Apparent Attenuation (Alcohol%)	Types of Sugars Fermented
Saccharomyces Cerevisiase (Ale Yeast / Top-Fermenting)	55-75 F	69-89% (12%)	glucose, fructose, maltose, sucrose, maltotriose, xylulose, mannose, and galactose (partially ferments raffinose)
Sacharomyces Carlbergenis or *Sacharomyces Uvarum* (Lager Yeast / Bottom-Fermenting)	46-56 F	67-77% (8%)	glucose, fructose, maltose, sucrose, maltotriose, xylulose, mannose, galactose, and raffinose

As can be seen in the table, ale yeast is called top-fermenting yeast. This is because they tend to clump together during fermentation and rise to the top of the fermenting wort by trapping carbon dioxide. After fermentation they tend to settle out more readily.

Lager yeasts are often referred to as bottom-fermenting yeast because, unlike ale yeast they do not tend to clump together with other yeast cells during fermentation. Consequently, they tend to sink to the bottom of the vessel during fermentation.

The primary difference between the two types of yeast, however, is related to ideal fermentation temperature. Lager yeast performs more optimally under cooler conditions and ale yeast performs more optimally under warmer conditions. (As a side note, lager yeast will ferment just fine under ale-like temperature conditions, but the result will not likely be what the brewer desired). The same cannot generally be said of ale yeasts. Under cooler, lager-like conditions, ale yeast will typically settle out of the wort and go dormant before fermentation is completed.)

In addition, ale yeast tends to attenuate more than lager yeast. Also, lager yeast can more fully ferment the sugar raffinose, which is only partially fermented by ale yeast.

In addition to the two most frequently used types of yeast used in brewing, there are other yeasts and bacteria that can be used in the brewing process…

--- Yeasts of the *Brettanomyces* genus, are used to produce sour flavors and sweaty horse, horse blanket, barnyard-like aromas and flavors in certain beers (particularly some Belgian styles, like Lambic).

--- Bacteria including *Lactobacillus*, Acetobacter, Pediococcus, *Escherichia coli*, *Citrobacter*, and *Enterobacter* produce lactic and/or acetic (vinegar) sourness in some beers (e.g., Berliner Weiss, Witbier, Lambics, Flanders Red, Flanders Brown).

In addition to alcohol and carbon dioxide, yeast also produces several other byproducts during fermentation. Some of these byproducts are desired while others are not. Also, some of the byproducts are metabolized later in the fermentation process while others are not. The most commonly produced byproducts are…

--- Esters
--- Phenols
--- Fusel Alcohols
--- Diacetyl
--- Sulfur Compounds

<u>Esters</u> are produced by yeast combining an organic alcohol and acid. While approximately 90 different esters have been identified in beer, ethyl-acetate, isoamyl-acetate and ethylhexanoate are most commonly above their flavor thresholds. These impart a fruity, sweet aroma to the beer. This is an appropriate aroma for most ales but not lagers. Esters levels can be controlled to some extent by the choice of yeast strain as some produce more esters than others. Similarly, certain yeast strains can produce certain types of ester (e.g., banana esters in Weizens). <u>In general, ester production is increased as the fermentation temperature rises.</u> Higher wort gravity and underaerated wort can also lead to increased ester production.

<u>Phenols</u> presence in beer can be good or bad, depending on the style. In some styles, a peppery, spicy (Belgians), or a clove-like phenol (Weizens) is appropriate. These are usually produced by certain yeast strains and proper temperature control. On the other hand, <u>band-aid</u>, <u>plastic</u>, <u>smokey</u> or <u>medicinal</u> phenol aromas and flavors are more often considered problematic phenols. The cause of undesirable phenols can be complicated. With regard to yeast and fermentation, improper sanitation can introduce

wild yeasts that contribute undesired phenolics, while fermentation temperatures (either too high or too low) can also produce undesired phenols.

Fusel Alcohols are produced by the metabolism of amino acids and tend to add harsher, more solvent-like tones the beer. Fusel alcohols are considered to be a contributor to hangovers and are generally not wanted in beer. Again, higher fermentation temperatures tend to produce this byproduct.

Diacetyl is normally produced by yeast in the early stages of fermentation as an oxidation reaction. It imparts a buttery or butterscotch note to the beer. It is generally undesired (the exception are some Scottish Ales). Fortunately, under good fermentation conditions, the yeast metabolizes the diacetyl to undetectable levels during the latter stages of fermentation. Underpitching yeast, using unhealthy yeast, or an incomplete fermentation can interfere with this natural removal of diacetyl. Some brewers use a diacetyl rest towards the end of fermentation of lagers. This is the process of raising the temperature of the wort up five or ten degrees after about two-thirds of the fermentation has been completed to have the yeast metabolize the diacetyl.

Sulfur Compounds, there are several of these that can be produced by the yeast. One of these is hydrogen sulfide, which smells like rotten eggs. Sulfur aromas tend to be more problematic in lagers. This is based on greater production of sulfur compounds at lower fermenting temperatures and that they are not as easily “scrubbed” off during a lager fermentation that is less vigorous that an ale fermentation. Fortunately, these sulphur compounds generally settle out of the beer during secondary conditioning or lagering.

Fermentation Stages

Fermentation can be divided into several stages. While these stages can each be described separately, the transitions between each are continuous and should not be thought of as distinct phases. The time spent in each phase depends on several factors including the composition of the wort, the environment and the amount of yeast pitched.

Lag Phase: The first phase of the cycle is called the lag phase. During this time the yeast will adapt to the new environment they are now in and begin to make enzymes they will need to grow and ferment the wort. The yeast will be utilizing their internal glycogen reserves of energy for this purpose. The yeast will acclimate itself and assess the dissolved oxygen level, the overall and relative amounts of the amino acids and the overall and relative amounts of sugars present. Some of these amino acids (i.e., peptides) and sugars will be imported into the cell for cell division. With a healthy pitch of yeast, the lag period is relatively brief.

Growth Phase: The growth phase is the next phase. During this phase, the yeast will start to divide by budding to reach the optimal density necessary for the true fermentation. The oxygen that was used to aerate the wort is absorbed during this time to allow the yeast to generate sterols that make the yeast cell wall flexible to reproduce. It has also been proposed that cold trub can provide the unsaturated fatty acids needed for sterol synthesis. Furthermore, it has been proposed that if an adequate amount of yeast has been pitched, such that cell growth is not necessary, then the oxygenation is not necessary. This sterol synthesis is the default pathway used in an all malt wort; however if the wort contains greater than 0.4% glucose then this pathway will not be used and the yeast will instead ferment the glucose, even in the presence of oxygen. This effect is called glucose repression, or the Crabtree effect.

Low Kraeusen Phase of Primary Fermentation: Following the growth phase, the low kraeusen phase of primary fermentation begins. During this time, the yeast begins anaerobic metabolism because all of the oxygen has been used. This phase is characterized by a foam wreath which builds on top of the fermenting wort. The yeast have now completely adapted to the wort conditions and transport of both amino acids and sugars into the cells for metabolism will be very active. This is the phase of fermentation phase when fusel alcohols and diacetyl can be produced.

High Kraeusen Phase of Primary Fermentation: Next, is the high kraeusen phase. During this phase, an ale yeast will have metabolized most of the sugars. On the other hand, a lager yeast may still be in the growth phase while also reducing the extract by four gravity points/day. Lager yeast will be metabolizing most of the sugars during the high kraeusen phase.

Late Kraeusen Phase of Primary Fermentation: Lastly, is the late kraeusen phase. In lager yeasts this can be very important, since it is during this time that the yeast begins to metabolize some of the fermentation by-products they had previously excreted during the low kraeusen phase (i.e., diacetyl).

Flocculation and Conditioning: When the yeast begins to flocculate, the beer is generally racked into a secondary fermenter, which allows for the attenuation of the last remaining extract, usually consisting of the trace sugars. Also removal of the excess yeast and trub will prevent formation of off flavors due to autolysis and/or reactions with trub substrates. For ale styles this period may be very brief, while lager styles may be four to six weeks, or even as long as six months in the case of strong lager styles. It is important during this time to prevent reintroduction of air, since this can lead to oxidation flavors and may introduce contaminants that can infect the beer.

Carbonation: Most often the finish beer needs to be carbonated. This can be accomplished by either bottle-conditioning or forced carbonation. There are several types of bottled conditioning.

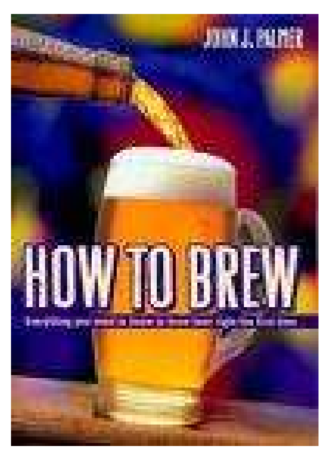
--- If the beer has not been conditioned very long (e.g., 1 to 2 weeks), sugar can be added to the beer and then bottled. The remaining yeast in the beer will be sufficient to begin fermenting the added sugar and produce and adequate level of carbon dioxide in the sealed bottle.

--- If the beer has been conditioned to the point that virtually all the yeast has settled out, then a fresh yeast and sugar combination can be added to the beer and bottled.

--- A third bottle conditioning method is to add freshly fermenting beer, referred to as kraeusening, to the finished beer and bottle.

--- Forced carbonation can be achieved via a kegging system in which carbon dioxide is gradually (or rapidly) introduced into the beer by a pressurized CO^2 tank.

As a final note, yeast cannot live on sugar alone during fermentation. Yeast also needs nitrogen, amino acid, and fatty acids to enable them to live and grow. The primary source for these building blocks is the free amino nitrogen (FAN) and lipids from the malted barley. Moreover, yeast needs calcium and magnesium to produce a healthy fermentation. Zinc also helps increase yeast cell count and vigor.



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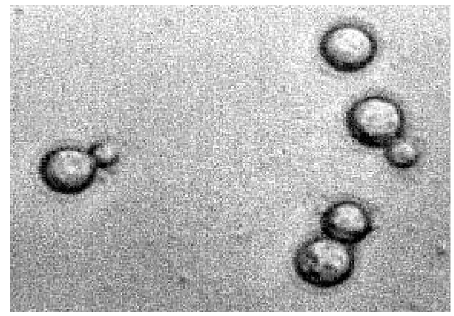
Yeast - What Is It?
There was a time when the role of yeast in brewing was unknown. In the days of the Vikings, each family had their own brewing stick that they used for stirring the wort. These brewing sticks were regarded as family heirlooms because it was the use of that stick that guaranteed that the beer would turn out right. Obviously, those sticks retained the family yeast culture. The

German Beer Purity Law of 1516 - The Reinheitsgebot, listed the only allowable materials for brewing as malt, hops, and water. With the discovery of yeast and its function in the late 1860's by Louis Pasteur, the law had to be amended.

Brewer's Yeast (Saccharomyces cerevisiae) is considered to be a type of fungus. It reproduces asexually by budding- splitting off little daughter cells. Yeast are unusual in that they can live and grow both with or without oxygen. Most micro-organisms can only do one or the other. Yeast can live without oxygen by a process that we refer to as fermentation. The yeast cells take in simple sugars like glucose and maltose and produce carbon dioxide and alcohol as waste products.



Along with converting sugar to ethyl alcohol and carbon dioxide, yeast produce many other compounds, including esters, fusel alcohols, ketones, various phenolics and fatty acids. Esters are the molecular compound responsible for the fruity notes in beer, phenols cause the spicy notes, and in combination with chlorine, medicinal notes. Diacetyl is a ketone compound that can be beneficial in limited amounts. It gives a butter or butterscotch note to the flavor profile of a beer and is desired to a degree in heavier Pale Ales, Scotch Ales and Stouts. Unfortunately, Diacetyl tends to be unstable and can take on stale, raunchy tones due to oxidation as the beer ages. This is particularly true for light lagers, where the presence of diacetyl is considered to be a flaw. Fusel alcohols are heavier molecular weight alcohols and are thought to be a major contributor to hangovers. These alcohols also have low taste thresholds and are often readily apparent as "sharp" notes. Fatty acids, although they take part in the chemical reactions that produce the desired compounds, also tend to oxidize in old beers and produce off-flavors.

Yeast Terminology
The following are some terms that are used to describe yeast behavior.

Attenuation This term is usually given as a percentage to describe the percent of malt sugar that is converted by the yeast strain to ethanol and CO_2. Most yeast strains attenuate in the range of 65 - 80%. More specifically, this range is the "Apparent" attenuation. The apparent attenuation is determined by comparing the Original and Final gravities of the beer. A 1.040 OG that ferments to a 1.010 FG would have an apparent attenuation of 75%.

(From FG = OG - (OG x %) => % att. = (OG-FG)/OG)

The "Real" attenuation is less. Pure ethanol has a gravity of about 0.800. If you had a 1.040 OG beer and got 100% real attenuation, the resulting specific gravity would be about 0.991 (corresponding to about 5% alcohol by weight). The apparent attenuation of this beer would be 122%. The apparent attenuation of a yeast strain will vary depending on the types of sugars in the wort that the yeast is fermenting. Thus the number quoted for a particular yeast is an average. For purposes of discussion, apparent attenuation is ranked as low, medium, and high by the following percentages:

65-70% = Low
71-75% = Medium
76-80% = High

Flocculation This term describes how fast or how well a yeast clumps together and settles to the bottom of the fermenter after fermentation is complete. Different yeast strains clump differently and will settle faster or slower. Some yeasts layers practically "paint" themselves to the bottom of the fermenter while others are ready to swirl up if you so much as sneeze. Highly flocculant yeasts can sometimes settle out before the fermentation is finished, leaving higher than normal levels of diacetyl or even leftover fermentable sugars. Pitching an adequate amount of healthy yeast is the best solution to this potential problem.

Lag Time This term refers to the amount of time that passes from when the yeast is pitched to when the airlock really starts bubbling on the fermenter. A long lagtime (more than 24 hours) indicates that the wort was poorly aerated, not enough yeast was pitched and/or that the yeast was initially in poor shape.

Yeast Types
There are two main types of yeast, ale and lager. Ale yeasts are referred to as top-fermenting because much of the fermentation action takes place at the top of the fermenter, while lager yeasts would seem to prefer the bottom. While many of today's strains like to confound this generalization, there is one important difference, and that is temperature. Ale yeasts like warmer temperatures, going dormant below about 55°F (12°C), while lager yeasts will happily work at 40°F. Using certain lager yeasts at ale temperatures 60-70°F (18-20°C) produces a style of beer that is now termed California Common Beer. Anchor Steam Beer revived this unique 19th century style.

Yeast Forms
Yeast come in two main product forms, dry and liquid. (There is also another form, available as pure cultures on petri dishes or slants, but it is generally used as one would use liquid yeast.) Dry yeast are select, hardy strains that have been dehydrated for storability. There are a lot of yeast cells in a typical 7 gram packet. For best results, it needs to be re-hydrated before it is pitched. For the first-time brewer, a dry ale yeast is highly recommended.

Dry yeast is convenient for the beginning brewer because the packets provide a lot of viable yeast cells, they can be stored for extended periods of time and they can be prepared quickly on brewing day. It is common to use one or two packets (7 - 14 grams) of dried yeast for a typical five gallon batch. This amount of yeast, when properly re-hydrated, provides enough active yeast cells to ensure a strong fermentation. Dry yeast can be stored for extended periods (preferably in the refrigerator) but the packets do degrade with time. This is one of the pitfalls with brewing from the no-name yeast packets taped to the top of a can of malt extract. They are probably more than a year old and may not be very viable. It is better to buy another packet or three of a reputable brewer's yeast that has been kept in the refrigerator at the brewshop. Some leading and reliable brands of dry yeast are DCL Yeast, Yeast Labs (marketed by G.W. Kent, produced by Lallemand of Canada), Cooper's, DanStar (produced by Lallemand), Munton & Fison and Edme.

Dry yeasts are good but the rigor of the dehydration process limits the number of different ale strains that are available and in the case of dry lager yeast, eliminates them almost entirely. A few dry lager yeasts do exist, but popular opinion is that they behave more like ale yeasts than lager. DCL Yeast markets two strains of dry lager yeast, Saflager S-189 and S-23, though only S-23 is currently available in a homebrewing size. The recommended fermentation temperature is 48-59°F. I would advise you to use two packets per 5 gallon batch to be assured of a good pitching rate.

The only thing missing with dry yeast is real individuality, which is where liquid yeasts come in. Many more different strains of yeast are available in liquid form than in dry.

Liquid yeast used to come in 50 ml foil pouches, and did not contain as many yeast cells as in the dry packets. The yeast in these packages needed to be grown in a starter wort to bring the cell counts up to a more useful level. In the past few years, larger 175 ml pouches (Wyeast Labs) and ready-to-pitch tubes (White Labs) have become the most popular forms of liquid yeast packaging and contain enough viable cells to ferment a five gallon batch.

Yeast Strains
There are many different strains of brewer's yeast available nowadays and each strain produces a different flavor profile. Some Belgian strains produce fruity esters that smell like bananas and cherries, some German strains produce phenols that smell strongly of cloves. Those two examples are rather special, most yeasts are not that dominating. But it illustrates how much the choice of yeast can

determine the taste of the beer. In fact, one of the main differences between different beer styles is the strain of yeast that is used.

Most major breweries generally have their own strain of yeast. These yeast strains have evolved with the style of beer being made, particularly if that brewery was a founder of a style, such as Anchor Steam. In fact, yeast readily adapts and evolves to specific brewery conditions, so two breweries producing the same style of beer with the same yeast strain will actually have different yeast cultivars that produce unique beers. Several yeast companies have collected different yeasts from around the world and offer them to home brewers. Some homebrew supply shops have done the same, offering their own brands of many different yeasts.

Dry Yeast Strains
As I mentioned earlier, the dry ale yeast strains tend to be fairly similar, attenuative and clean tasting, performing well for most ale styles. To illustrate with a very broad brush, there are Australian, British and Canadian strains, each producing what can be considered that country's style of pale ale. The Australian type is more woody, the British more fruity, and the Canadian a bit more malty. Fortunately with international interest in homebrewing growing as it is, dry yeast strains and variety are improving. Some of my favorites are Nottingham (DanStar), Whitbread (Yeast Labs), and Cooper's Ale.

Liquid Yeast Strains
There are a lot of liquid yeasts to choose from and in order to keep this simple I will just describe them by general strain. All of the brands of liquid yeast I can think of (Wyeast, White Labs, Yeast Culture Kit Co., Yeast Labs, and Brew-Tek), are of very good quality, and to describe each company offering of a particular strain would be redundant. This is not to say that all of the cultivars of a type are the same; within a strain there will be several cultivars that have different characteristics. You will find that each company's offering will be subtly different due to the conditions under which it was sampled, stored, and grown. You may find that you definitely prefer one company's cultivar over another's. Detailed descriptions of each company's cultivar will be available at your brewshop or on the company's website.

Preparing Liquid Yeast
Liquid yeast is generally perceived as being superior to dry yeast because of the greater variety of yeast strains available. Liquid yeast allows for greater tailoring of the beer to a particular style. However, the amount of yeast in a liquid packet is much less than the amount in the dry. Liquid yeast usually must be pitched to a starter wort before pitching to the main wort in the fermenter. Using a starter gives yeast a head start and increases the population preventing weak fermentations due to under-pitching.

But a starter is not always necessary. These days, several companies offer liquid yeasts that are use-by date coded and are packaged at higher cell counts so that they don't need to be pitched to a starter. Below, I describe how to make a yeast starter, which is meant to build up the cell counts for the 50 ml size smack-pack yeast pouches, and yeast packaged as slants. (A slant is a small tube containing agar or similar growth media and a relatively low number of yeast cells.) Ready-to-pitch yeasts, and and the larger 175 ml smack-packs do not need a starter, depending on their freshness, but it never hurts. (Unless your sanitation is poor!)

Yeast from Commercial Beers
There are many quality microbrewed beers on the market that are bottle conditioned, i.e. naturally carbonated and unfiltered, much the same as homebrewed beers are. The yeast layer from a bottle conditioned beer can be harvested and grown just like the yeast from a liquid yeast packet. This is a common practice among homebrewers because it allows for the use of some special yeast strains in homebrew that would not otherwise be available. This method can be used for cloning some of the specialty styles, such as Belgian Wit, Trappist Ales, or everyone's favorite - Sierra Nevada Pale Ale. Harvesting yeast from a bottle conditioned beer is quite simple.
- Step 1. After opening the bottle, thoroughly clean the bottle neck and opening with sanitizer to prevent

bacterial contamination.
- Step 2. Simply pour the beer into a glass as you would normally, leaving the yeast layer on the bottom of the bottle intact.
- Step 3. Swirl up the sediment with the beer remaining in the bottle and pour the yeast sediment into a prepared starter solution as described in the previous section- Preparing a Liquid Yeast Starter.

For best results, add the sediment from 2-3 bottles and be sure to use the freshest beer you can find. The starter should behave the same as any other liquid yeast pack starter, though it may take longer to build due to the smaller amount of yeast that you start out with. In fact, you may not notice any activity in the starter for the first couple wort additions until the amount of yeast builds to higher levels. Add more wort as necessary to build the yeast slurry to pitching level.

Yeast Nutritional Needs

From a yeast cells point of view, its purpose in life is to grow, eat, and reproduce. Yeast can do all this with or without oxygen, but using oxygen makes the processes easier for the cell. Yeast use oxygen in the biosynthesis of the compounds that make up their cell membranes that allow them to process sugars for food and grow. Being able to process food and grow more efficiently allows them to reproduce more effectively also. Without oxygen, yeast cannot reproduce as fast. Therefore, to ensure a good fermentation, we need to provide the yeast with sufficient oxygen to allow them to grow quickly and reproduce when they are first pitched to the fermenter. Once they have reproduced to sufficient numbers, we can let them get on with turning our wort into beer.

Nutrients

Yeast cannot live on sugar alone. Yeast also need nitrogen, and amino and fatty acids to enable them to live and grow. The primary source for these building blocks is the free amino nitrogen (FAN) and lipids from the malted barley. Refined sugars like table sugar, corn sugar or candy sugar do not contain any of these nutrients. And, it is common for extracts (especially kit extracts targeted toward a particular style) to be thinned with refined sugars to lighten the color or reduce the cost of production. An all-malt beer has all the nutrition that the yeast will need for a good fermentation, but all-extract beers may not have sufficient FAN to promote adequate growth. Since malt extract is commonly used for yeast starters, it is always a good idea to add some yeast nutrients to ensure good yeast growth.

If you use ion-exchanged softened water for brewing, the water may not have adequate calcium, magnesium, and zinc for some of the yeast's metabolic paths. Magnesium plays a vital role in cellular metabolism and its function can be inhibited by a preponderance of calcium in the wort. Brewers adding calcium salts for water chemistry adjustment may want to include magnesium salts as part of the addition if they experience fermentation problems. Usually the wort supplies all the necessary mineral requirements of the yeast, except for zinc which is often deficient or in a non-assimilable form. Additions of zinc can greatly improve the cell count and vigor of the starter, but adding too much will cause the yeast to produce excessive by-products and cause off-flavors. Zinc acts as a catalyst and tends to carry over into the succeeding generation—therefore it is probably better to add it to either the starter or the main wort but not both. The nutrient pouches in the Wyeast smack-packs already contain zinc in addition to other nutrients. For best performance, zinc levels should be between 0.1-0.3 mg/l, with 0.5 mg/l being maximum. If you experience stuck fermentations or low attenuation, and you have eliminated other variables such as: temperature, low pitching rate, poor aeration, poor FAN, age, etc., then lack of necessary minerals may be a significant factor.

You will see three types of yeast nutrients on the market that can supplement a wort that is high in refined sugars or adjuncts.

- Di-ammonium Phosphate - This is strictly a nitrogen supplement that can take the place of a lack of FAN.
- Yeast Hulls - This is essentially dead yeast, the carcasses of which act as agglomeration sites and contain some useful residual lipids.

- Yeast Nutrient or Energizer - The name can vary, but the intent is a mixture of di-ammonium phosphate, yeast hulls, biotin and vitamins. These mixtures are a more complete dietary supplement for the yeast and what I recommend.
- Servomyces (tm) - This product from Lallemand is similar to yeast hulls but differs by having a useful amount of rapidly assimilable zinc, which is an essential enzyme co-factor for yeast health. This product falls within the provisions of the Rheinheitsgebot.

Oxygen
Yeast need oxygen to synthesize sterols and unsaturated fatty acids for cell membrane biosynthesis. Without aeration, fermentations tend to be underattenuated because oxygen availability is a limiting factor for yeast growth—the yeast stop budding when sterol levels become depleted. Higher gravity worts need more yeast for proper fermentation, and thus need more oxygen, but the higher gravity makes it more difficult to dissolve oxygen in the first place. Boiling the wort drives out the dissolved oxygen normally present, so aeration of some sort is needed prior to fermentation. Proper aeration of the wort can be accomplished several ways:

- shaking the container, e.g. the starter jar
- pouring the cooled wort into the fermenter so it splashes,
- using a bronze or stainless steel airstone with an aquarium air pump and using it to bubble air into the fermenter for an hour.

Aeration is Good, Oxidation is Bad
The yeast is the most significant factor in determining the quality of a fermentation. Oxygen can be the most significant factor in determining the quality of the yeast. Oxygen is both your friend and your enemy. It is important to understand when which is which.

You should not aerate when the wort is hot, or even warm. Aeration of hot wort will cause the oxygen to chemically bind to various wort compounds. Over time, these compounds will break down, freeing atomic oxygen back into the beer where it can oxidize the alcohols and hop compounds producing off-flavors and aromas like wet cardboard or sherry-like flavors. The generally accepted temperature cutoff for preventing hot wort oxidation is 80°F.

Oxidation of your wort can happen in several ways. The first is by splashing or aerating the wort while it is hot. Other beginning-brewing books advocate pouring the hot wort after the boil into cold water in the fermenter to cool it and add oxygen for the yeast. Unfortunately the wort may still be hot enough to oxidize when it picks up oxygen from the splashing. Pouring it down the side of the bucket to minimize splashing doesn't really help either since this increases the surface area of the wort exposed to the air. Thus it is important to cool the wort rapidly to below 80°F to prevent oxidation, and then aerate it to provide the dissolved oxygen that the yeast need. Cooling rapidly between 90 and 140°F is important because this temperature region is ideal for bacterial growth to establish itself in the wort.

In addition, if oxygen is introduced after primary fermentation has started, it may cause the yeast to produce more of the early fermentation byproducts, like diacetyl. However, some strains of yeast respond very well to "open" fermentations (where the fermenter is open to the air) without producing off-flavors. But even for those yeast strains, aeration or even exposure to oxygen after fermentation is complete can lead to staling of the beer. During racking to a secondary fermenter or to the bottling bucket, it is very important to prevent gurgling or splashing. Keep the siphon flowing smoothly by placing the outlet of the siphon hose below the surface of the rising beer. Decrease the difference in height between the two containers when you begin. This will slow the siphon rate at first and prevent turbulence and aeration until the outlet is beneath the surface.

To summarize, you want to pitch a sufficient amount of healthy yeast, preferably grown in a starter that matches your intended fermentation conditions. You want to cool the wort to fermentation temperature and then aerate the wort to provide the oxygen that the yeast need to grow and reproduce. Then you want to protect the beer from oxygen once the fermentation is complete to prevent oxidation and staling.

Fermentation - Some Misconceptions
In this chapter, we will discuss fermentation - how the yeast turns wort into beer. As important as the yeast process is to achieving a good batch, it is also the one that is most often taken for granted by beginning brewers. A lot of thought will be given to the recipe: which malts, which hops, but often the yeast choice will be whatever was taped to the top of the kit. Even if some consideration is given to the brand of yeast and the type, very often the conditions to which the yeast is pitched are not planned or controlled. The brewer cools the wort, aerates it a bit, and then pitches his yeast and waits for it to do its thing.

It has been common for brewing texts to over-emphasize the "lagtime" - the period of time after pitching the yeast before the foamy head appeared in the fermentor. This lagtime was the benchmark that everyone would use to gage the health of their yeast and the vigor of the fermentation. While it is a notable indicator, the lagtime accounts for a combination of pre-fermentation processes that have a great deal to do with the quality of the total fermentation, but that individually are not well represented by time.

A very short lagtime, for example, does not guarantee an exemplary fermentation and an outstanding beer. A short lagtime only means that initial conditions were favorable for growth and metabolism. It says nothing about the total amount of nutrients in the wort or how the rest of the fermentation will progress.

The latter stages of fermentation may also appear to finish more quickly when in fact the process was not super-efficient, but rather, incomplete. The point is that speed does not necessarily correlate with quality. Of course, under optimal conditions a fermentation would be more efficient and thus take less time. But it is better to pay attention to the fermentation conditions and getting the process right, rather than to a rigid time schedule.

Factors for a Good Fermentation
Let's review the preparations from the previous chapters that will help us consistently achieve a good fermentation. There are three principal factors that determine fermentation activity and results: Yeast, Wort Nutrients and Temperature.

Yeast Factors
The first step to achieving a good fermentation is to pitch enough yeast. The yeast can be grown via yeast starters or it can be harvested from previous fermentations. When yeast is harvested from a previous fermentation, it should be taken from the primary yeast cake and preferably from the upper layer of the cake or from the secondary. This yeast will have the optimum characteristics for re-pitching. In either case, you should target pitching at least 1/3 cup (75 ml) of yeast slurry to a typical 5 gallon batch of ale or 2/3 cup of slurry for lagers. For stronger beers, OG > 1.050, more yeast should be pitched to ensure optimum fermentations. For very strong beers like doppelbocks and barleywines, at least 1 cup of slurry should be pitched.

The yeast that is obtained from a healthy starter or recently from a prior fermentation will have good vitality and adapt readily to the new wort. With good levels of aeration and nutrients, the yeast will quickly multiply to the numbers necessary for an exemplary fermentation.

Wort Factors
There are two considerations that are needed to ensure that the wort has been properly prepared to support a good fermentation. The first is oxygen supplied via aeration. The methods for aerating the wort were covered in Chapter 6- Yeast. The role of oxygen in yeast growth will be discussed further in the Adaptation Phase section later in this chapter.

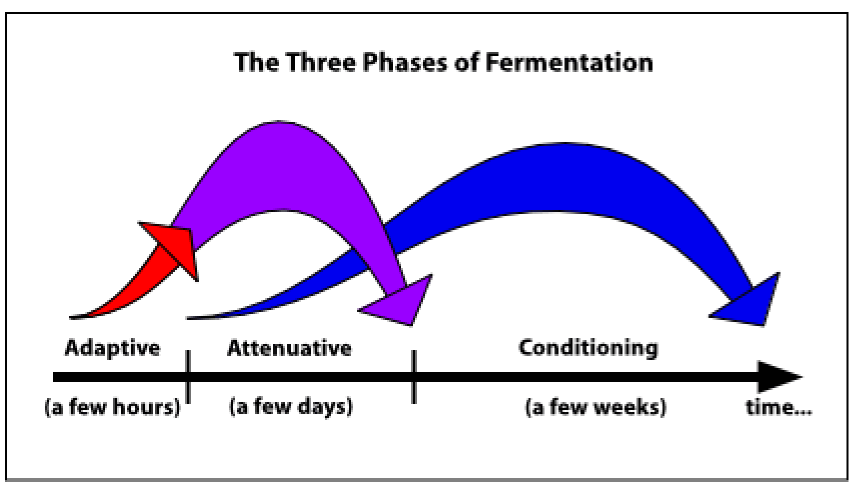
The second consideration is the level of amino acid nutrients in the wort, specifically referred to as Free Amino Nitrogen or FAN. Malted barley normally supplies all of the FAN and nutrients that the yeast need to grow and adapt to the fermentation environment. However, if the recipe incorporates large amounts of adjuncts (e.g. corn, rice, unmalted wheat, unmalted barley), or refined sugars, then the wort may not have the minimum levels of nutrients necessary for the yeast to build strong cells. It is always advisable to add some yeast nutrient powder to worts that are made exclusively from light extracts because these extracts are typically thinned with corn sugar.

In addition, brewers should be aware that in a wort that contains a high percentage of refined sugar (~50%), the yeast will sometimes lose the ability to secrete the enzymes that allow them to ferment maltose. They will adapt themselves right out of a job!

Temperature Factors
The third factor for a good fermentation is temperature. Yeast are greatly affected by temperature; too cold and they go dormant, too hot (more than 10°F above the nominal range) and they indulge in an orgy of fermentation that often cannot be cleaned up by conditioning. High temperatures encourage the production of fusel alcohols - heavier alcohols that can have harsh solvent-like flavors. Many of these fusels esterify during secondary fermentation, but in large amounts these esters can dominate the beer's flavor. Excessively banana-tasting beers are one example of high esters due to high temperature fermentation.

High temperatures can also lead to excessive levels of diacetyl. A common mistake that homebrewers make is pitching the yeast when the wort has not been chilled enough, and is still relatively warm. If the wort is, e.g. 90¡F, when the yeast is pitched and slowly cools to room temperature during primary fermentation, more diacetyl will be produced in the early stages than the yeast can reabsorb during the secondary stage. Furthermore, primary fermentation is an exothermic process. The internal temperature of the fermentor can be as much as 10F above ambient conditions, just due to yeast activity. This is one good reason to keep the fermentor in the proper temperature range; so that with a normal vigorous fermentation, the beer turns out as intended, even if it was warmer than the surroundings.

Brewing in the summertime is a definite problem if you don't have a way to keep the fermentor cool. My friend Scott showed me a neat trick though, he would immerse (not completely) his fermentors in a spare bathtup during the summer. The water in the tub was slow to warm during the day even though temperatures would be in the 90's, and at night the water would be slow to cool, even when the temperature dropped to 45 F. In this way he was able to moderate his fermentation temperature between 60-70 F, and the beer turned out great. I have used this method myself with wash tubs and had great success.



Re-defining Fermentation
The fermentation of malt sugars into beer is a complicated biochemical process. It is more than just the conversion of sugar to alcohol, which can be regarded as the primary activity. Total fermentation is better defined as three phases, the Adaptation or Lagtime phase, the Primary or Attenuative phase and a Secondary or Conditioning phase. The yeast do not end Phase 2 before beginning Phase 3, the processes occur in parallel, but the conditioning processes occur more slowly. As the majority of simple sugars are consumed, more and more of the yeast will transition to eating the larger, more complex

sugars and early yeast by-products. This is why beer (and wine) improves with age to a degree, as long as they are on the yeast. Beer that has been filtered or pasteurized will not benefit from aging.

Lagtime or Adaptation Phase
Immediately after pitching, the yeast start adjusting to the wort conditions and undergo a period of high growth. The yeast use any available oxygen in the wort to facilitate their growth processes. They can use other methods to adapt and grow in the absence of oxygen, but they can do it much more efficiently with oxygen. Under normal conditions, the yeast should proceed through the adaptation phase and begin primary fermentation within 12 hours. If 24 hours pass without apparent activity, then a new batch of yeast should probably be pitched.

At the beginning of the adaptation phase, the yeast take stock of the sugars, FAN and other nutrients present, and figure out what enzymes and other attributes it needs to adapt to the environment. The yeast use their own glycogen reserves, oxygen, and wort lipids to synthesize sterols to build up their cell membranes. The sterols are known to be critical for enabling the cell membrane to be permeable to wort sugars and other wort nutrients. Sterols can also be produced by the yeast under poor oxygen conditions from lipids found in wort trub, but that pathway is much less efficient.

Once the cell walls are permeable, the yeast can start metabolizing the amino nitrogen and sugars in the wort for food. Like every animal, the goal of life for the yeast cell is to reproduce. Yeast reproduce asexually by "budding". Daughter cells split off from the parent cell. The reproduction process takes a lot of energy and aerobic metabolic processes are more efficient than anaerobic. Thus, an oxygen-rich wort shortens the adaptation phase, and allows the yeast to quickly reproduce to levels that will ensure a good fermentation. When the oxygen is used up, the yeast switch metabolic pathways and begin what we consider to be fermentation - the anaerobic metabolism of sugar to alcohol. This pathway is less energy efficient, so the yeast cannot reproduce as proficiently as during the adaptation phase.

The key to a good fermentation is lots of strong healthy yeast- yeast that can get the job done before going dormant due to depleted resources, rising alcohol levels, and old age. As noted, the reproduction rate is slower without oxygen. At some point in the fermentation cycle of the beer, the rate of yeast reproduction is going to fall behind the rate of yeast dormancy. By providing optimum conditions for yeast growth and reproduction in the wort initially, we can ensure that this rate transition will not occur until after the beer has become fully attenuated.

Worts that are underpitched or poorly aerated will ferment slowly or incompletely due to lack of viable yeast. Experienced brewers make a big point about aerating the wort and building up a yeast starter because these practices virtually guarantee enough yeast to do the job well.

Primary or Attenuative Phase
The primary or attenuative phase is marked by a time of vigorous fermentation when the gravity of the beer drops by 2/3-3/4 of the original gravity (OG). The majority of the attenuation occurs during the primary phase, and can last anywhere from 2-6 days for ales, or 4-10 days for lagers, depending on conditions.

A head of foamy krausen will form on top of the beer. The foam consists of yeast and wort proteins and is a light creamy color, with islands of green-brown gunk that collect and tend to adhere to the sides of the fermentor. The gunk is composed of extraneous wort protein, hop resins, and dead yeast. These compounds are very bitter and if stirred back into the wort, would result in harsh aftertastes. Fortunately these compounds are relatively insoluble and are typically removed by adhering to the sides of the fermentor as the krausen subsides. Harsh aftertastes are rarely, if ever, a problem.

As the primary phase winds down, a majority of the yeast start settling out and the krausen starts to subside. If you are going to transfer the beer off of the trub and primary yeast cake, this is the proper time to do so. Take care to avoid aerating the beer during the transfer. At this point in the fermentation process, any exposure to oxygen will only contribute to staling reactions in the beer, or worse, expose it to contamination.

Many canned kits will advise bottling the beer after one week or after the krausen has subsided. This is not a good idea because the beer has not yet gone through the Conditioning phase. At this time the beer would taste a bit rough around the edges (e.g. yeasty flavors, buttery tones, green apple flavors) but these off-flavors will disappear after a few weeks of conditioning.

Secondary or Conditioning Phase
The reactions that take place during the conditioning phase are primarily a function of the yeast. The vigorous primary stage is over, the majority of the wort sugars have been converted to alcohol, and a lot of the yeast cells are going dormant - but some are still active.

The Secondary Phase allows for the slow reduction of the remaining fermentables. The yeast have eaten most all of the easily fermentable sugars and now start to turn their attention elsewhere. The yeast start to work on the heavier sugars like maltotriose. Also, the yeast clean up some of the byproducts they produced during the fast-paced primary phase. But this stage has its dark side too.

Under some conditions, the yeast will also consume some of the compounds in the trub. The "fermentation" of these compounds can produce several off-flavors. In addition, the dormant yeast on the bottom of the fermentor begin excreting more amino and fatty acids. Leaving the post-primary beer on the trub and yeast cake for too long (more than about three weeks) will tend to result in soapy flavors becoming evident. Further, after very long times the yeast begin to die and break down - autolysis, which produces yeasty or rubbery/fatty/meaty flavors and aromas. For these reasons, it can be important to get the beer off of the trub and dormant yeast during the conditioning phase.

There has been a lot of controversy within the homebrewing community on the value of racking beers, particularly ales, to secondary fermentors. Many seasoned homebrewers have declared that there is no real taste benefit and that the dangers of contamination and the cost in additional time are not worth what little benefit there may be. While I will agree that for a new brewer's first, low gravity, pale beer that the risks probably outweigh the benefits; I have always argued that through careful transfer, secondary fermentation is beneficial to nearly all beer styles. But for now, I will advise new brewers to only use a single fermentor until they have gained some experience with racking and sanitation.

Leaving an ale beer in the primary fermentor for a total of 2-3 weeks (instead of just the one week most canned kits recommend), will provide time for the conditioning reactions and improve the beer. This extra time will also let more sediment settle out before bottling, resulting in a clearer beer and easier pouring. And, three weeks in the primary fermentor is usually not enough time for off-flavors to occur.

Conditioning Processes
The conditioning process is a function of the yeast. The vigorous, primary stage is over, the majority of the wort sugars have been converted to alcohol, and a lot of the yeast are going dormant; but there is still yeast activity. During the earlier phases, many different compounds were produced by the yeast in addition to ethanol and CO_2, e.g., acetaldehyde, esters, amino acids, ketones- diacetyl, pentanedione, dimethyl sulfide, etc. Once the easy food is gone, the yeast start re-processing these by-products. Diacetyl and pentanedione are two ketones that have buttery and honey-like flavors. These compounds are considered flaws when present in large amounts and can cause flavor stability problems during storage. Acetaldehyde is an aldehyde that has a pronounced green apple smell and taste. It is an intermediate compound in the production of ethanol. The yeast reduce these compounds during the later stages of fermentation.

The yeast also produce an array of fusel alcohols during primary fermentation in addition to ethanol. Fusels are higher molecular weight alcohols that often give harsh solvent-like tastes to beer. During secondary fermentation, the yeast convert these alcohols to more pleasant tasting fruity esters. Warmer temperatures encourage ester production.

Towards the end of secondary fermentation, the suspended yeast flocculates (settles out) and the beer clears. High molecular weight proteins also settle out during this stage. Tannin/phenol compounds will bind with the proteins and also settle out, greatly smoothing the taste of the beer. This process can be helped by chilling the beer, very similar to the lagering process. In the case of ales, this process is referred to as Cold Conditioning, and is a popular practice at most brewpubs and microbreweries. Cold conditioning for a week clears the beer with or without the use of finings. Fining agents, such as isinglass (fish bladders), Polyclar (plastic dust), and gelatin, are added to the fermentor to help speed the flocculation process and promote the settling of haze forming proteins and tannins. While much of the emphasis on using finings is to combat aesthetic chill haze, the real benefit of dropping those compounds is to improve the taste and stability of the beer.

Using Secondary Fermentors

Using a two stage fermentation requires a good understanding of the fermentation process. At any time, racking the beer can adversely affect it because of potential oxygen exposure and contamination risk. Racking the beer away from the krausen/yeastbed before the Primary fermentation phase has completed can result in a stuck (incomplete) fermentation and a final gravity that is too high.

It is important to minimize the amount of headspace in the secondary fermentor to minimize the exposure to oxygen until the headspace can be purged by the still-fermenting beer. For this reason, plastic buckets do not make good secondary fermentors unless the beer is transferred just as the primary phase is starting to slow and is still bubbling steadily. Five gallon glass carboys make the best secondary fermentors. Plastic carboys do not work well because they are too oxygen permeable, causing staling.

The following is a general procedure for using a secondary fermentor.

1. Allow the Primary Fermentation stage to wind down. This will be 2 - 6 days (4 - 10 days for lagers) after pitching when the bubbling rate drops off dramatically to about 1-5 per minute. The krausen will have started to settle back into the beer.
2. Using a sanitized siphon (no sucking or splashing!), rack the beer off the trub into a another clean fermentor and affix an airlock. The beer should still be fairly cloudy with suspended yeast.

Racking from the primary may be done at any time after primary fermentation has more-or-less completed. (Although if it has been more than 3 weeks, you may as well bottle.) Most brewers will notice a brief increase in activity after racking, but then all activity may cease. This is very normal, it is not additional primary fermentation per se, but just dissolved carbon dioxide coming out of solution due to the disturbance. Fermentation (conditioning) is still taking place, so just leave it alone. A minimum useful time in the secondary fermentor is two weeks. Overly long times in the secondary (for light ales-more than 6 weeks) may require the addition of fresh yeast at bottling time for good carbonation. Always use the same strain as the original. This situation is usually not a concern. See the next chapter and the Recommended Reading Appendix for related information on lager brewing.

Different beer styles benefit from different lengths of conditioning. Generally, the higher the Original Gravity, the longer the conditioning time to reach peak flavor. Small beers like 1.035 Pale Ales will reach peak flavor within a couple weeks of bottling. Stronger/more complex ales, like Stouts, may require a month or more. Very strong beers like Doppelbocks and Barleywines will require 6 months to a year before they condition to their peak flavor. (If oxidation doesn't take its toll first. I have had some pretty awful year old barleywines.) This conditioning can be done in either the secondary fermentor or the bottle, but the two methods do produce different results. It is up to you to determine how long to give each phase to produce your intended beer. When bottling your first few batches, its always a good idea to set aside a six pack in the corner of the basement and leave it for a time. It is enlightening to taste a homebrewed beer that has had two months to bottle condition and compare it to what the batch initially tasted like.

Secondary Fermentor vs. Bottle Conditioning
Conditioning is a function of the yeast, therefore it is logical that the greater yeast mass in the fermentor is more effective at conditioning than the smaller amount of suspended yeast in the bottle. This is why I recommend that you give your beer more time in the fermentor before bottling. When you add the priming sugar and bottle your beer, the yeast go through the same three stages of fermentation as the main batch, including the production of byproducts. If the beer is bottled early, i.e. 1 week old, then that small amount of yeast in the bottle has to do the double task of conditioning the priming byproducts as well as those from the main ferment. You could very well end up with an off-flavored batch.

Do not be confused, I am not saying that bottle conditioning is bad, it is different. Studies have shown that priming and bottle conditioning is a very unique form of fermentation due to the oxygen present in the head space of the bottle. Additional fermentables have been added to the beer to produce the carbonation, and this results in very different ester profiles than those that are normally produced in the main fermentor. In some styles, like Belgian Strong Ale, bottle conditioning and the resultant flavors are the hallmark of the style. These styles cannot be produced with the same flavors via kegging.

For the best results, the beer should be given time in a secondary fermentor before priming and bottling. Even if the yeast have flocculated and the beer has cleared, there are still active yeast in suspension that will ferment the priming sugar and carbonate the beer.

Summary
Hopefully this chapter has helped you understand what fermentation is and how it works. You need to have sufficient yeast and the right conditions for them to work under to achieve the best possible beer. The next chapter will use this information to walk you through fermenting your first batch.

How Much Alcohol Will There Be?
This is a common question. While there are various laboratory techniques that can be employed to determine it precisely, there is a simple way to estimate it. The easiest is to use a "triple scale hydrometer" which has a percent alcohol by volume scale right on it. You subtract the respective percentages that correspond to your OG and FG, and there you have it.

If you don't have this type of hydrometer, the following table based on the work of Balling should satisfy your curiosity. To use the table, look for the intersection of your OG (columns) and your FG (rows). This number is your approximate percentage of alcohol by volume.

Table - Percent Alcohol by Volume (ABV) From Original and Final Gravity

	1.030	1.035	1.040	1.045	1.050	1.055	1.060	1.065	1.070	1.075
0.998	4.1	4.8	5.4	6.1	6.8	7.4	8.1	8.7	9.4	10.1
1.000	3.9	4.5	5.2	5.8	6.5	7.1	7.8	8.5	9.1	9.8
1.002	3.6	4.2	4.9	5.6	6.2	6.9	7.5	8.2	8.9	9.5
1.004	3.3	4.0	4.6	5.3	5.9	6.6	7.3	7.9	8.6	9.3
1.006	3.1	3.7	4.4	5.0	5.7	6.3	7.0	7.7	8.3	9.0
1.008	2.8	3.5	4.1	4.8	5.4	6.1	6.7	7.4	8.0	8.7
1.010	2.6	3.2	3.8	4.5	5.1	5.8	6.5	7.1	7.8	8.4
1.012	2.3	2.9	3.6	4.2	4.9	5.5	6.2	6.8	7.5	8.2
1.014	2.0	2.7	3.3	4.0	4.6	5.3	5.9	6.6	7.2	7.9
1.016	1.8	2.4	3.1	3.7	4.4	5.0	5.7	6.3	7.0	7.6
1.018	1.5	2.2	2.8	3.4	4.1	4.7	5.4	6.0	6.7	7.3
1.020	1.3	1.9	2.5	3.2	3.8	4.5	5.1	5.8	6.4	7.1
1.022	1.0	1.6	2.3	2.9	3.6	4.2	4.9	5.5	6.2	6.8
1.024	0.8	1.4	2.0	2.7	3.3	4.0	4.6	5.2	5.9	6.5

Next, we will discuss how brewing and fermenting lager beer differs from ales.

What is Different for Brewing Lager Beers

Lager Beer - Yeast Differences
What makes lager beer different from ale beer, you ask?
Well, the main difference is temperature. Make that temperature and time. No, there's three: Temperature, Time and Yeast. Let's start with yeast. As discussed in Chapter 6 - Yeast, lager yeasts like lower fermentation temperatures. Lager yeast produce less fruity esters than ale yeasts but can produce more sulfur compounds during primary fermentation. Many first time lager brewers are astonished by the rotten egg smell coming from their fermentors, sometimes letting it convince them that the batch is infected and causing them to dump it. Don't do it! Fortunately, these compounds continue to vent during the conditioning (lagering) phase and the chemical precursors of other odious compounds are gradually eaten up by the yeast. A previously rank smelling beer that is properly lagered will be sulfur-free and delicious at bottling time. Speaking of Time...

Lager Beer - Additional Time
The lower fermentation temperature decreases the rate at which the yeast work and lengthens both the primary and secondary fermentation times. The primary phase for ales is often 2 - 5 days, but 1 - 3 weeks is normal for a lager. As mentioned in the previous chapter, the primary and conditioning phases of fermentation happen concurrently, but the conditioning phase takes longer. This is especially true with lager yeasts. The defining character of a lager beer is a clean, crisp taste without ale fruitiness. Obviously those rotten egg odors don't belong either. The time that it takes for these compounds to be processed by the yeast can be several weeks to a few months. It depends on the malts used, the yeast strain, and the temperature at which conditioning occurs.

Lager Beer - Lower Temperatures
Lager comes from the German word "lagern" which means to store. A lager beer is in cold storage while it ages in the conditioning phase. Temperature influences lagers in two ways. During primary fermentation, the cooler temperature (45-55 °F) prevents the formation of fruity esters by the yeast. In addition to producing fewer byproducts during the primary phase, the yeast uses the long conditioning phase to finish off residual sugars and metabolize other compounds that may give rise to off-flavors and aromas. Unfortunately, this long time with the beer in contact with the yeast can be a problem. The problem is autolysis, i.e. yeast-suicide, which can produce terrible off-flavors in the beer.

Lager Beer - Autolysis
When a yeast cell dies, it ruptures - releasing several off-flavors into the beer. When you have a large yeast mass on the bottom of the fermentor, you have a large potential for off-flavors due to autolysis. If this ever happens to you, you will know it. The smell is one you will never forget. It happened to me one time when my wife was making paper as a hobby. She used boiled rice as the glue to hold the shredded paper together. After the rice had been boiled until it became a paste, the paper making was called off that weekend and the pot of rice paste was set aside on the counter top. A wild yeast must have got a hold of it during the next couple days (I remember it bubbling) and the pot was ignored in the days that followed. A busy week went by along with another busy weekend and the unintentional Sake experiment still sat there forgotten. The following weekend, my wife was once again ready to try making paper. I picked up the pot and lifted the lid to see what had happened to it. My knees buckled. My wife turned green and ran to the door coughing and choking. The stench was appalling! It was heinous! The noxious aftermath of a late night of cheap beer and pickled eggs would be refreshing compared to the absolute stench of autolysis. I hope I never have to smell it again. Luckily, the propensity of yeast to autolyze is decreased by a decrease in activity and a decrease in total yeast mass. What this means to a brewer is that racking to a secondary fermenter to get the beer off the dead yeast and lowering the temperature for the long cold storage allows the beer to condition without much risk of autolysis. At a minimum, a beer that has experienced autolysis will have a burnt rubber taste and smell and will probably be undrinkable. At worst it will be unapproachable. As a final note on this subject, I should mention that by brewing with healthy yeast in a well-prepared wort, many experienced brewers, myself included, have been able to leave a beer in the primary fermenter for several months without any evidence of autolysis. Autolysis is not inevitable, but it is lurking.

Lager Beer - Yeast Starters and Diacetyl Rests
There are two other items that are significant in brewing a good lager beer and I will describe them briefly. These are Yeast Pitching and the Diacetyl Rest. Lager brewing is best described in a book of its own and fortunately someone has done just that. See the Recommended Reading section in the appendices for more information. Because of the cooler temperatures, the yeast is less active at first. The best way to ensure a strong, healthy lager fermentation is to pitch a much larger yeast starter than you would for an ale. Where you would pitch a one quart starter solution of liquid yeast for an ale, you would use a 2 or 3 quart starter for a lager. This is the equivalent of about 1/2 to 3/4 cup of yeast slurry. In addition, the pitching temperature should be the same as the fermentation temperature to prevent thermally shocking the yeast. In other words, you will need to chill the wort down to 45 - 55 °F before pitching the yeast. The yeast starter should also have been brought down to this temperature range while it was fermenting. A good way to do this is to pitch the yeast packet into a pint of wort at 60 °F, let that ferment for a day, cool it 5 degrees to 55°F and add another pint of aerated, cool wort. Let this also ferment for a day, and cool and pitch a third and even fourth time until you have built up 2 quarts or more of yeast starter that is comfortable at 45 -55 °F. I recommend that you pour off the excess liquid and only pitch the slurry to avoid some off-flavors from that much starter beer. Some brewers pitch their yeast when the wort is warmer and slowly lower the temperature of the whole fermenter gradually over the course of several days until they have reached the optimum temperature for their yeast strain. This method works, and works well, but tends to produce more diacetyl (a buttery-flavored ketone) than the previous method. As the temperature drops the yeast become less active and are less inclined to consume the diacetyl that they initially produced. The result is a buttery/butterscotch flavor in the lager, which is totally out of style. Some amount of diacetyl is considered good in other styles such as dark

ales and stouts, but is considered a flaw in lagers. To remove any diacetyl that may be present after primary fermentation, a diacetyl rest may be used. This rest at the end of primary fermentation consists of raising the temperature of the beer to 55-60 °F for 24 - 48 hours before cooling it down for the lagering period. This makes the yeast more active and allows them to eat up the diacetyl before downshifting into lagering mode. Some yeast strains produce less diacetyl than others; a diacetyl rest is needed only if the pitching or fermentation conditions warrant it.

Lager Beer - When to Lager
It takes experience for a brewer to know when primary fermentation is winding down and the beer is ready to be transferred. If you insist on brewing a lager for your very first beer, you are going to be flying blind. You can play it safe by waiting several weeks for the primary phase to completely finish (no more bubbling) and rack then, but you will have missed your opportunity for a diacetyl rest. As discussed in the previous chapter, you should rack to a secondary when the krausen has started to fall back in. The bubbling in the airlock will have slowed dramatically to 1 or 4 bubbles per minute, and a hydrometer reading should indicate that the beer is 3/4 of the way to the terminal gravity. Knowing when to rack takes experience, it's as simple as that. I like to ferment and lager in glass carboys because the glass allows me to see the activity in the beer. During primary fermentation, there are clumps of yeast and trub rising and falling in the beer and it's bubbling like crazy- it literally looks like there is someone stirring it with a stick. When you see that kind of activity slow down, and things start settling towards the bottom, you know the primary phase is over and it's safe to rack. The lagering temperature and duration are affected by both the primary fermentation temperature and the yeast strain. These are the four primary factors that determine the final character of the beer. Some general guidelines for fermentation times and temperatures are listed below:

--- Check the yeast package information for recommended fermentation temperature(s).
--- The temperature difference between the primary phase and the lager phase should be roughly 10°F.
--- Nominal lagering times are 3 - 4 weeks at 45°F, 5 - 6 weeks at 40°F, or 7 - 8 weeks at 35°F.
--- Stronger beers need to be lagered longer.
--- Nothing is absolute. Brewing is both a science and an art.

A common question is, "If the beer will lager faster at higher temperatures, why would anyone lager at the low temperature?" Two reasons: first, in the days before refrigeration when lager beers were developed, icehouses were the common storage method - it's tradition. Second, the colder lagering temperatures seem to produce a smoother beer than warmer temperatures. This would seem to be due to the additional precipitation and settling of extraneous proteins (like chill haze) and tannins that occur at lower temperatures.

Lager Beer - When / If It Freezes - Should I Add More Yeast?
When your lager freezes, chances are the yeast has been impaired. If you are towards the beginning of the lagering cycle, then there may not be enough yeast activity after it thaws to properly complete the attenuation and condition the beer. You should probably add new yeast. If you are at the end of the lagering cycle, and were planning on priming and bottle conditioning it, then you should probably add more yeast also. If you are planning on kegging it and force carbonating (like I was), then you don’t have to worry about it. I say “probably” because some yeast will survive. Even if the beer freezes completely for a short time, typically 20% of cells will remain active. The questions are: 20% of how many, and just how active? Therefore, you should probably add new yeast. The yeast you add to the fermenter should be of the same strain as the original yeast. If you are using yeast from a ready-to-pitch package, then that quantity is probably sufficient and you can pour it right in and swirl it around to mix it evenly. Because you are not trying to conduct a primary fermentation and are not concerned about a fast start, you do not need to build up the count any further, nor do you need to acclimate it to the lagering temperature first. The yeast will acclimate over several days and finish the fermentation cycle. If your yeast came from a small smack-pack or slant, then you may want to build up the cell count by pitching to a starter wort first. And you may want to conduct that starter at your primary fermentation temperature to help the yeast acclimate to the lagering cycle. As noted above, these steps

are probably not necessary, but it never hurts to stack the odds in your favor. You can either pitch the starter at full krausen or wait for it to ferment out before adding it. The small amount of primary fermentation byproducts that you add to the beer by pitching at full krausen will not affect the flavor significantly.

Lager Beer - Maintaining Lager Temperature

Temperature controllers are very handy for use with a spare refrigerator to maintain a constant brewing temperature. They work by plugging into the wall outlet and plugging the fridge into it. A temperature probe is run inside the fridge and it governs the on/off cycling of the compressor to maintain a narrow temperature range. Here in Southern California, I use it to maintain 65°F in the summertime for brewing ales. Check your local homebrew supply shop or some of the larger mail order suppliers for one of the newer controllers. Some controllers will also operate a separate heating circuit (usually in conjunction with a heat lamp) for cold weather brewing conditions. Meanwhile, my frozen Vienna lagered for 6 weeks at 34°F. I placed blocks of ice next to the carboy instead of relying on the refrigerator for temperature control. In fact, insulated Ice Boxes are a good way to control temperature for lagering. Because of the alcohol present, the beer actually freezes at several degrees below normal. Depending on the time of year and your ambient temperature, an insulated box is a very convenient way to lager. If it freezes, just warm it back up, swirl up the fermenter to rouse the yeast and let it continue lagering. My frozen lager went on to take first place in two separate contests in the Vienna/Oktoberfest category.

Lager Beer - Bottling

See the next chapter, Priming and Bottling, for information on how the bottling and carbonating of lager beers can differ from ale beers.

Lager Beer - Brewing American Lager Beer

A lot of people want to know how to brew their favorite American light lager beer, like Bud, Miller, or Coors. First thing I will tell you is that it is difficult to do. Why? Because these beers are brewed using all-grain methods that incorporate rice or corn (maize) as about 30% of the fermentables. The rice or corn must be cooked to fully solubilize the starch and then added to the mash so that the enzymes can convert the starches to fermentable sugars. See Chapters 12—What is Malted Grain, and 14—How the Mash Works, for more info. Second, there is no room in the light body of these beers for any off-flavors to hide—off-flavors stand out. Your sanitation, yeast handling, and fermentation control must be rigorous for this type of beer to turn out right. The professional brewers at Bud, Miller, and Coors are very good at what they do—turning out a light beer, decade after decade, that tastes exactly the same. Though come to think of it, bottled water companies do that too... Lastly, as an extract brewer, you can really only do rice-type lagers. Rice extract is available in both syrup and powder form, and will produce a decent Heineken or Budweiser clone. Corn syrup and corn sugar have had their corn character stripped away and will not produce a good extract based corn-type lager like Miller or Coors. To brew this type of beer, refer to the recipe in Chapter 19—Some of My Favorite Beer Styles and Recipes, for the Classic American Pilsner recipe, "Your Father's Mustache," and reduce the OG and IBUs to the guidelines below. The methods described in the "YFM" recipe can be used to brew a typical American lager using flaked corn or corn grits.

Lager Beer - Fermentation Schedule

2 weeks at 50°F in primary fermenter. Rack and lager at 40°F for 4 weeks.
Prime, and store bottles at room temperature.

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Yeast-Related Problems:

Symptom: I added the yeast 2 days ago and nothing is happening:

Cause 1: Leaky Bucket Lack of fermentation can be due to several things. If the airlock is not bubbling, it may be due to a poor seal between the lid and the bucket. Fermentation may be taking place but the CO_2 is not coming out through the airlock.

Cure: This is not a real problem; it won't affect the batch. Fix the seal or get a new lid next time.

Cause 2: Bad Yeast When a batch is not fermenting , the most common problem is with the yeast. If dry yeast has been properly packaged and stored, it should be fully viable for up to two years. However, if you are using a yeast package that came taped to the top of a dusty can of malt extract, then the yeast may be too old or may have been subjected to poor storage conditions, and will not work for you. Yeast need to be treated with care and be given the proper growing conditions. Dry yeast are de-hydrated, they're parched, they're in no condition to start work. They need some nice warm water to get re-hydrated in, some time to do some stretching, maybe an appetizer, and then they will be ready to tackle a full wort. If the dry yeast is just sprinkled onto the surface of the wort, some of the yeast will be up to the challenge, but most won't.

Cure: Re-hydration of yeast in plain water is strongly recommended because of the principles of osmosis. In a wort with a high concentration of dissolved sugar, the water that the yeast needs cannot be drawn across the cell membrane to wet it. The water is instead locked up in the wort, hydrating the sugars. A friend of mine, who insists on remaining nameless, was misled by the term, "pitching", and for his first batch attempted to forcibly throw each granule of dried yeast into the wort so that it would be wetted. That batch didn't turn out very well. Likewise, liquid yeast cultures also need their breakfast routine. They have been kept in a refrigerator and need to be warmed and fed before there will be enough active yeast to do the job properly. There are a lot more yeast cells in a dry yeast packet than in a liquid packet. The liquid packet needs to be grown in a starter to produce enough cells to take on the job of a full five gallon wort. Both liquid and dry yeast cultures will have a lag time from when they are pitched until they start fermenting in earnest. Aeration, the process of dissolving oxygen into the wort, provides the yeast with the oxygen they need to greatly boost their growth rate and make enough yeast cells to do the job properly.

Cause 3: Too Cold The fermentation conditions may be too cold for an otherwise healthy yeast population. Ale yeast tend to go dormant below 60¡F. If the yeast were re-hydrated in really warm water (105¡F) and then pitched to a much cooler wort (65¡F), the large difference in temperature can thermally shock the yeast and cause a longer lag time as they adjust. Or in some cases, that otherwise normal ale fermentation temperature could cause those warm-acclimated yeast to call it quits.

Cure: Try warming the fermentor by 5¡F; it may make all the difference.

Cause 4: Improper Sanitation Sanitation can be carried too far some times. When you were preparing the warm water for rehydrating or boiling your yeast starter, did you cool it to the proper temperature range? If the water is too cold (below 80¡F) the yeast will be sluggish and have a hard time getting rehydrated. If it is too hot (above 105¡F) then the yeast are going to get scalded, and refuse to have anything to do with you and your wort. Also, if you added the yeast to the Starter wort and then boiled it, well, they're dead.

Cure: Pitch new yeast.

Symptom: I added the yeast yesterday and it bubbled all day but is slowing down/stopped today.

Cause 1: Lack of Preparation As I stated in the section above, yeast that are improperly prepared, whether from lack of re-hydration, lack of numbers (i.e. lack of Starter), or lack of aeration, will often fail to finish the job.

Cure: Pitch new yeast.

Cause 2: Too Cold Temperature can also be a major factor for fermentation performance. If the temperature of the room where the fermentor is cools down, even only 5 ¡F overnight, then the yeast can be slowed dramatically.

Cure: Always strive to keep the fermentation temperature constant, the yeast will thank you for it.

Cause 3: Too Warm The flip side of the coin could be that the temperature was warm, e.g. 75¡F, and

the yeast got the job done ahead of schedule. This often happens when a lot of yeast is pitched, the primary fermentation can be complete within 48 hours. This is not necessarily a good thing, as ferments above 70¡F tend to produce a lot of esters and phenolics that just don't taste right. The beer will still be good, just not as good as it could have been. It will depend on your tastes and the yeast strain.
Cure: Always strive to keep the fermentation temperature within the recommended range, the yeast will thank you for it.

Symptom: It won't stop bubbling.
Cause 1: Cool Temperatures A beer that has been continually fermenting(bubbling) for a long time (more than a week for ales, more than 3 weeks for lagers) may not have something wrong with it. It is often due to the fermentation being a bit too cool and the yeast are working slower than normal.
Cure: This condition is not a problem.
Cause 2: Gusher Infection However, the sustained bubbling is often due to "gusher type" infection. These infections can occur at any time and are due to wild yeasts or bacteria that eat the higher order sugars, like dextrins. The result in the fermentor is a beer that keeps bubbling until all of the carbohydrates are fermented, leaving a beer that has no body and very little taste. If it occurs at bottling time, the beer will overcarbonate and will fizz like soda pop, fountaining out of the bottle.
Cure: Improve your sanitation next time.
If the beer seems to be bubbling too long, check the gravity with a hydrometer. Use a siphon or turkey baster to withdraw a sample from the fermentor and check the gravity. If the gravity is still high, in the teens or twenties, then it is probably due to lower than optimum temperature or sluggish yeast. If it is below 10 and still bubbling at several per minute, then a bug has gotten hold. The beer will not be worth drinking due to the lack of flavor.

Symptom: The fermentation seems to have stopped but the hydrometer says 1.025.
Cause 1: Too Cool This situation is commonly referred to as a "stuck fermentation" and can have a couple causes. The simplest cause and probably the most common is temperature. As previously discussed, a significant drop in temperature can cause the yeast to go dormant and settle to the bottom.
Cure: Moving the fermentor to a warmer room and swirling the fermentor to stir up the yeast and get them back into suspension will often fix the problem.
Cause 2: Yeast The other most common cause is weak yeast. Referring back to previous discussions of yeast preparation, weak yeast or low volumes of healthy yeast will often not be up to the task of fermenting a high gravity wort. This problem is most common with higher gravity beers, OGs greater than 1.048.
Cure: Add more yeast.
Cause 3: Low Attenuating Extracts Another common cause for extract kit brewers is the use of extracts high in dextrins. Two brands are known to be high in unfermentables, Laaglanders Dry Malt Extract (Netherlands) and John Bull Liquid Malt Extract (UK). These are not bad extracts, in fact they are high quality, but their use is better suited to heavier bodied beers like strong ales, porters and stouts, where a high finishing gravity is desired.

YEAST / FERMENTATION REVIEW: - Review

- Saccharomyces = Yeast
- Saccharomyces Cerevisiae = Ale Yeast (top fermenting, up to 12% ABV)
    - 55 - 75 F (low end = German, middle range = English, high end = Belgian)
- Saccharomyces Carlsbergensis = Lager Yeast (bottom fermenting, up to 8% ABV)
    - Less than 55 F
    - Also called Saccharomyces Uvarum

- Yeasts normally reproduce asexually, creating exact copies
    - In low nutrient environments, yeasts reproduce sexually, creating mutations of the yeast (a bad situation)

- Neither yeasts (ale or lager) can ferment lactose sugar
    - Other sugars are fermented to differing degrees depending on the yeast strain
    - In general, lager yeasts ferment more types of sugars, creating dryer, thinner, more alcoholic beers (all generally speaking)

- Saccharomyces Delbruckii = German wheat beer yeast that produces clove and banana
- Brettanomyces Bruxellensis = Wild yeast used to produce Belgian farmhouse sweaty horse hair character
- Brettanomyces Lambicus = Wild yeast used with other (regular) yeasts to create Lambic, sour, tart character
- Lactobacillus Delbruckii = Lactic acid bacteria used with various yeasts, etc. to create lactic sourness (Guinness, Berliner Weisse, Sour Belgians)
- Pediococcus Cerevisiae = Acetic bacteria used with various yeasts, etc. to create acetic sourness

- "Belgian Blend Yeasts" are certain combinations of the above yeasts and bacterias used to create different styles of Belgian and sour beers

- Yeast strains vary by:
    - Optimum fermentation temps
    - Ability to ferment complex sugars
    - Tendency to flocculate / settle out
    - Tolerance level to alcohol
    - Production of fermentation by-products
    - Ability to metabolize (break down) fermentation by-products

- Good fermentation is based on many factors:
    - Temperature (pitching temp and temp of fermentation)
    - pH (5.0 - 5.5 at pitching)
    - Oxygen (need a lot, but can't add after fermentation has begun or will create oxidation) (aeration is good, oxidation is bad)
    - Nutrients (including Calcium / Ca and Magnesium / Mg)
    - Food / Sugars (good sugars, i.e. maltose)
    - Yeast Vitality (age and health of the yeast)

- Fermentation Phases:
    - Respiration Phase or Lag Phase or Adaptation Phase
        - Need lots of oxygen
        - Yeast building up and preparing for fermentation
    - Fermentation (primary or attenuative phase)
        - Temp is very important
        - Yeast consuming sugars, producing alcohol and CO_2
        - High Krausen is the peak of the foamy head
    - Sedimentation (secondary or conditioning phase)
        - Wort sugars depleted
        - Flocculation and settling
        - Diacetyl produced earlier is absorbed by the yeast
            - Can increase temp a little for a diacetyl rest to make sure this happens

- Attenuation - The percent of malt sugar that is converted by the yeast strain
    - Ex: 1.040 OG to 1.010 FG = 75% attenuation
        - Low = 65-70%
        - Med = 71-75%
        - High = 76-80%

Also, review the section on Yeast in the BJCP Study Guide.

> **Off Flavors / Problems / Other Flavors** (25 min)
    - Alcoholic (ethanol)
    - Solvent (fusel alcohols, acetone, lacquer thinner)
    - Sherry-Like
    - Acetaldehyde (green apple-like)
        - Also, discuss Cidery (this is different).
    - Esters (fruity)
    - Poor Head Retention
    - Sewer-Like (mercaptan)
    - Sulfur (rotten eggs, burning matches)
    - Soapy / Fatty (goaty)
    - Yeasty

- Alcoholic (ethanol)

HowToBrew: A sharp flavor that can be mild and pleasant or hot and bothersome. When an alcohol taste detracts from a beer's flavor it can usually be traced to one of two causes. The first problem is often too high a fermentation temperature. At temperatures above 80°F, yeast can produce too much of the higher weight fusel alcohols which have lower taste thresholds than ethanol. These alcohols taste harsh to the tongue, not as bad as cheap tequila, but bad nonetheless. Fusel alcohols can be produced by excessive amounts of yeast, or when the yeast sits too long on the trub. This is one reason to move the beer off of the hot and cold break when the beer is going to be spending a lot of time in the fermentor.

BJCP: This flavor may be detected as a spicy, vinous character in the aroma and taste and is often accompanied by a warm or prickly mouthfeel. The simplest and most prevalent alcohol in beer is ethanol, which is produced by the fermentation of glucose and other reducing sugars. Higher, or fusel, alcohols are usually present at sub-threshold concentrations, but elevated levels are associated with underpitching, low levels of dissolved oxygen prior to pitching or low levels of free available nitrogen (FAN). These deficiencies force the yeast to metabolize fatty acids in the trub as a source of oxygen and carbon, producing a greater fraction of long chain alcohols. High gravity worts and high fermentation temperatures also tend to increase the concentration of these higher alcohols through increased yeast activity. Alcoholic characteristics are desired in strong ales and lagers as long as they are not coupled with the solvent notes associated with elevated ester or fusel alcohol levels.

- Solvent (fusel alcohols, acetone, lacquer thinner)

HowToBrew: This group of flavors is very similar to the alcohol and ester flavors, but are harsher to the tongue. These flavors often result from a combination of high fermentation temperatures and oxidation. They can also be leached from cheap plastic brewing equipment or if PVC tubing is used as a lautering manifold material. The solvents in some plastics like PVC can be leached by high temperatures.

BJCP: This describes an aroma and taste similar to turpentine or acetone that is often accompanied by a burning sensation in the back of the mouth. It is due to high concentrations of ethyl acetate and other esters, as well as fusel alcohols. Possible sources include underpitching and fermenting on the trub, especially at elevated temperatures. Contamination by wild yeast may produce elevated levels of both esters and fusel alcohols. Solvent-like notes are generally undesirable, but perceptible levels may be encountered in old ales such as Theakstons Old Peculier.

- Sherry-Like

HowToBrew: Oxidation is probably the most common problem with beer including commercial beers. If the wort is exposed to oxygen at temperatures above 80°F, the beer will sooner or later develop wet cardboard or sherry-like flavors, depending on which compounds were oxidized.

BJCP: This is the aroma and taste of dry sherry and is often accompanied by hazelnut or almond notes. The responsible compounds are oxidized members of the melanoidin family. This flavor is one of the few positive flavors attributed to oxidation and adds complexity to barleywines, old ales and Scotch ales. Sherry-like flavors are considered a defect in most other styles, particularly low-gravity ales.

- Acetaldehyde (green apple-like) and Cidery

HowToBrew: A flavor of green apples or freshly cut pumpkin; it is an intermediate compound in the formation of alcohol. Some yeast strains produce more than others, but generally it's presence indicates that the beer is too young and needs more time to condition. Cidery is a different flavor, and can have several causes but are often the result of adding too much cane or corn sugar to a recipe. One component of a cidery flavor is acetaldehyde which has a green-apple character. It is a common fermentation byproduct and different yeasts will produce different levels of it depending on the recipe and temperature. Cidery flavors are encouraged by warmer than normal temperatures and can be decreased by lagering. If it is caused by aceto bacteria, then there is nothing to be done about it. Keep the fruit flies away from the fermentor next time.

BJCP: This compound has the taste and aroma of fresh-cut green apples, and has also been compared to grass, green leaves and latex paint. It is normally reduced to ethanol by yeast during the secondary fermentation, but oxidation of the finished beer may reverse this process, converting ethanol to acetaldehyde. Elevated levels are generally present in green beer or if the beer is prematurely removed from the yeast. It can also be a product of bacterial spoilage by *Zymomonas* or *Acetobacter*. Background levels of acetaldehyde can be tasted in Budweiser due to the use of beechwood chips to drop the yeast before it can be reduced to ethanol.

- Esters (fruity)

HowToBrew: Ales are supposed to be slightly fruity, and Belgian and German wheat beers are expected to have banana flavor components, but sometimes a beer comes along that could flag down a troop of monkeys. Esters are produced by the yeast and different yeast strains will produce different amounts and types. In general, higher fermentation temperatures produce more esters. Next batch, contrive to lower the fermentation temperature by a few degrees.

BJCP: This is an aroma and taste that recalls bananas, strawberries, pears, apples, plums, papaya and/or other fruits. The responsible compounds are esters, which are formed from the combination of an alcohol and an organic acid. High ester levels are a product of the yeast strain, fermentation temperature, high gravity worts and the metabolism of fatty acids in the trub. These flavors are desirable in most ales, particularly Belgian and British styles, and the signature banana notes in Bavarian wheat beers are primary due to the ester isoamyl acetate. Note that esters often have solvent notes at very high concentrations.

- Poor Head Retention

Good head retention is measured in terms of the time required for the head to collapse to half of its initial height. This should be at least a minute in well-brewed and conditioned beers. The beading should also be uniform and tight, leaving lace on the glass as the beer is consumed. Good head retention is promoted by several factors, including isohumulones, high original gravity, alcohol content, dextrins and the levels of high- and medium- molecular weigh proteins. Adequate carbonation is also important. Most of these variables are style-dependent, but the brewer can increase the protein content by adjusting the length and temperature of the protein rest and using adjuncts such as flaked wheat and barley. Fatty acids carried over from the trub and unclean glassware are both detrimental to head stability, since they decrease the surface tension of the foam, causing the bubbles to collapse.

- Sewer-like (mercaptan)
Primarily from yeast breaking down in the fermenter (i.e. beer sitting on the trub too long).
> Ron's Added Note: Autolysized yeast can / may also smell like the air out of an old tire or innertube.

- Sulfur (rotten eggs, burning matches)
HowToBrew: Rotten egg odors (hydrogen sulfide) can have two common causes: the yeast strain and bacteria. Many lager yeast strains produce noticeable amounts of hydrogen sulfide during fermentation. The smell and any sulfur taste will dissipate during lagering. Let the beer condition or lager for a few weeks after primary fermentation. Bacterial infections can also produce sulfury odors and if you are not brewing a lager beer, then this is a good sign that you have an infection. Let the fermentation complete and then taste it before bottling to see if it is infected. Toss it if it is.

BJCP: These flavors, not to be confused with DMS, have the aroma and taste of rotten eggs, shrimp or rubber. The compounds responsible for these flavors originate from sulfur-containing amino acids such as cysteine and methionine. Possible sources include yeast autolysis, bacterial spoilage and water contamination. These flavors can be quite putrid and are not desirable in any style. In the same family are sulfitic flavors, which recall the aroma of a struck match. They are usually due to the overuse of antioxidants, and while rare in beer, are quite common in wine and cider.

- Soapy / Fatty (goaty)
HowToBrew: Soapy flavors can caused by not washing your glass very well, but they can also be produced by the fermentation conditions. If you leave the beer in the primary fermentor for a relatively long period of time after primary fermentation is over ("long" depends on the style and other fermentation factors), soapy flavors can result from the breakdown of fatty acids in the trub. Soap is, by definition, the salt of a fatty acid; so you are literally tasting soap.

- Yeasty
HowToBrew: The cause of this flavor is pretty easy to understand. If the yeast is unhealthy and begins autolyzing it will release compounds that can only be described as yeasty. Also if the beer is green, too young, and the yeast has not had time to settle out, it will have a yeasty taste. Watch your pouring method too, keep the yeast layer on the bottom of the bottle.

>**Beer Styles 1** (65 min)

9. Scottish and Irish Ale

9A. Scottish Light 60/-
9B. Scottish Heavy 70/-
9C. Scottish Export 80/-
- Behaven Scottish Ale (cans or bottles)

9D. Irish Red Ale
- Smithwick's Irish Ale
- AND -
- Murphys Irish Red

(a lager version)

9E. Strong Scotch Ale
- Founders Dirty Bastard - AND -
- Belhaven Wee Heavy

11. English Brown Ale

11A. Mild

11B. Southern English Brown Ale

11C. Northern English Brown Ale
- Wynchwood Hobgoblin - AND-
- Newcastle Brown Ale

8. English Pale Ale

8A. Standard / Ordinary Bitter
- Boddington’s Pub Draught - OR -
- Tetley’s Original Bitter

8B. Special / Best / Premium Bitter
- Fuller’s London Pride

8C. Extra Special / Strong Bitter (English Pale Ale)
- Fuller’s ESB

10. American Ale

10A. American Pale Ale
- Sierra Nevada Pale Ale

10B. American Amber Ale
- North Coast Red Seal Ale

10C. American Brown Ale
- Bell’s Best Brown

> **HOMEWORK - Old Sample Exam Questions** (complete on your own) - Review

S2. Identify, describe and differentiate all the members of the Stout family. Give commercial examples of each style.

S14. Briefly describe the characteristics of Robust Porters, Baltic Porters, Dry Stouts and British Pale Ales. Identify the malt type which characterizes each style. Give commercial examples of each style.

S15. Describe and differentiate the taste and aroma characteristics of following beer styles. Give commercial examples of each:
a) American Brown b) Munich Dunkel c) Robust Porter

T16. What is meant by the terms hot break and cold break? Why are they important in brewing?

T18. What are all the primary purposes for boiling wort? How does boiling achieve the brewers objectives.
- THIS QUESTION USED TO ALWAYS BE ON THE EXAM, AND IT ASKED FOR "5" PRIMARY PURPOSES !!!

S6. Describe and differentiate English Old/Strong Ales and Barley Wines. Give commercial examples of each style.

S19. Describe and differentiate the taste and aroma characteristics of Guinness Foreign Extra Stout, Sierra Nevada Porter and Watney's Cream Stout.

T15. Discuss the following brewing techniques. How do they affect the beer?
a) step infusion mashing b) krausening c) sparging
d) adding gypsum e) fining

T9. Discuss the considerations in selecting a particular strain of yeast when brewing the following beer styles: a) English Bitter b) Doppelbock c) California Common

T10. Describe the role of yeast in beer production and the positive and negative effects on the finished product of oxygen introduction during the various stages of fermentation.

S18. Describe, differentiate and compare the characteristics of the following beer styles. Give commercial examples of each style:
a) Dusseldorf Alt b) Northern German Altbier
c) California Common d) Special Bitter

END OF SESSION 3