BJCP STUDY GROUP - SESSION 2

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

- Mashing
- Hops

- Astringent (mouth drying - a mouthfeel, not a flavor)
- Bitterness
- Husky / Grainy
- Earthy
- Floral / Rose-like
- Grassy
- Diacetyl (butter, butterscotch)
- Metallic (tinny, coiny, blood-like)

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

3. European Amber Lager
    - 3A. Vienna Lager
    - 3B. Oktoberfest / Marzen
4. Dark Lager
    - 4A. Dark American Lager
    - 4B. Munich Dunkel
    - 4C. Schwarzbier (Black Beer)
5. Bock
    - 5A. Maibock / Helles Bock
    - 5B. Traditional Bock
    - 5C. Doppelbock
    - 5D. Eisbock
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

SESSION 2

> Technical Topic 1

- Mashing, lautering, sparging, including types used for different beer styles, mash schedules and enzymes, etc.

Mashing (and Lautering and Sparging)
Compiled by Ron Smith

- The primary goal of mashing is to complete the breakdown of proteins and starches that was started during the malting process.

- This is accomplished by several groups of enzymes that breakdown different proteins and starches during a series of rests at different temperatures.

- Under-modified malts, like some pale lager malts require an **Acid Rest** to acidify the mash by promoting the growth of lactic-acid producing bacteria at this temperature range. An Acid Rest is especially needed when the brewing water has a low Ca content (Ca helps lower pH if present in sufficient quantities). If roasted grains are being used, they will also help acidify the mash.

- Cellulose and gums in the under-modified malts are also broken down during this rest by certain enzymes that are active during this period. Wheat, rye and some adjuncts (corn, rice, etc.) that have a high level of cellulose and gums, really need these materials broken down to avert stuck mashes and other problems.

- The **Acid Rest** takes place in the 95-120 degree F range (or 95-105 F) for 15-30 minutes (up to 2 hrs). Don't let infusion water exceed 140 F (see enzymes info below).
    - Note: An extended Acid Rest can create too much bacteria and too much lactic acid, lowering the pH too much and souring the beer.

    - Note: Ferulic acid, which is the precursor to 4-vinyl-guaiacol (the clove phenol) is also produced during the Acid Rest, so along with the use of wheat malt, which itself would benefit from a mutli-rest (step mash), it is a good idea to do this when making traditional German Weizen beers.

- The **Protein Rest** is the next stage for under-modified malts and takes place in the 113-127 degree F range for 15-45 minutes. Don't let infusion water exceed 158 F (see enzymes info below).
    - Note: An "extended" or "inadequate" / "skipped" Protein Rest can lead to a whole host of potential problems, including thin body, cloudiness / reduced clarity, poor head retention, and making the beer more prone to Diacetyl, DMS, Vegetal, Sourness, Bacterial Contamination, Solventy flavors, etc.
        - Basically, all of these problems are due to either converting too much protein to amino acids (extended) and not leaving enough nutrients for the yeast / fermentation - OR - not converting enough proteins, leaving them in the wort to reduce clarity, increase the hot and cold break, which strips out bitterness when it coagulates, and provides too much food for the growth of bacteria and wild yeasts.

    - Note: For all the above reasons, many great brewers believe that this Protein Rest is still very important even with fully modified malts.

- The Protein Rest breaks down complex mash proteins to create peptides and amino acids, which are essential for proper yeast growth. This rest also improves the body, head retention, clarity and hop bitterness of the finished beer. It also reduces the finished beer's susceptibility to chill haze and bacterial infections. This rest also increases the FAN level in the wort (see FAN below).

- Note: **FAN**, **Free Amino Nitrogen** is the product of enzymatic breakdown of proteins and is a key nutrient for healthy yeast growth.

- The **Saccharification Rest** is the **Starch Conversion** period, and is where most fully-modified malts "start" their mash process. This occurs in the 130-160 degree F range (145-158 F) for 45 - 120 minutes. **Don't let infusion water exceed 167 F (see enzymes info below).**

  - Note: A sub-rest of this major rest is the Maltose Rest (or Beta Rest), which takes places in the 145-149 F range. During this temp range, maltose formation is encouraged from the Beta-Amylase enzyme. This is important to increase wort fermentability and maximize the utilization of available enzymes.

  - Note: **Under-Conversion** of the mash will leave excessive levels of starches in the beer, which will lead to cloudiness and beer that is more prone to bacterial contamination. Under conversion could be from too short of time in this rest, excessive use of adjunct grains, or mash enzyme destruction, or a watered down mash.

  - Note: **Over-Conversion** of the mash will leave the beer thin, lacking residual sweetness, alcoholic and/or out of balance. This can be the result of too long of time in this rest, and temps too low.

  - Note: **Fully Converted, But At Temps Too High** will result in too many unfermentable sugars, which leads to too much residual sugar in the beer, a beer that is too sweet and out of balance, as well as having too much body.

- In the Saccharification Rest, starches are broken down into dextrins (non-fermentable sugars) and fermentable sugars. The starches must first be gelatinized (**Gelatinization**) for this to take place, and this occurs around this temperature range (130-150 degrees F for barley malt).

  - **Gelatinization** is the process in which hard starch granules and globules become water soluble and are broken down into a thick, viscous paste.

  - **Liquefication** follows gelatinization, and is where the thick gelatinized starch paste is further broken down into a thin liquid. This is primarily done by the **Alpha-Amylase** enzyme.

  - **Saccharification** follows liquefication, and is where the starches are broken down a final time (converted) into dextrins and maltose (sugars) by both Alpha-Amylase and **Beta-Amylase**.

- During this period, two types of sugars are produced based on the temp and time:
  - Below 150 degrees F = Favors beta-amylase, producing a more fermentable wort.
  - Above 155 degrees F = Favors alpha-amylase, producing a more dextrinous (non-ferm) wort.

  Remember Ronism: **Hot Body needs AA** !!!

- Various types of sugars are produced varying from very simple to very complex (monosaccharides, disaccharides, trisaccharides, and oilosaccharides).

- **Lauter Rest** or **Mash-Out** is an optional period just before **Lautering** (the removal of the sweet wort from the mash), where the mash temp is raised to 165 - 170 degrees F (typically 168 F - about the same as sparge water during lautering) and held for several minutes. This deactivates the amylase enzymes, halting the conversion process and reducing the viscosity of the wort making it easier for lautering.

- Note: Temps above 170 F will leach tannins from the malt husks, imparting a husky or grainy flavor and/or an astringent mouth feel. Excessive tannins can also cause cloudiness.

- Note: **Grist** is the ground malts and adjunct grains. A good quality grind will leave the malted barley husk intact, yet crush the starchy endosperm into fine granules, like grits or corn meal. A poor quality grind will contain shredded husks, a significant amount of fine powdery "flour" like particles and/or large uncrushed pieces of grain.

- Note: **Mash-In** is the process of mixing and hydrating the dry grist with hot water, typically associated with infusion and step mashing.

- Note: **Dough-In** is the process of mixing and hydrating the dry grist with "cold" water, typically associated with decoction mashing. The purpose of doughing-in is to fully hydrate the grist prior to reaching the higher temps that will activate any mash enzymes. Thus, dough-in at or below the Acid Rest temp.

- Note: **Mash** is the mixed water and grist (compared to a porridge or oatmeal).

- Note: **Infusion** is adding water to the mash.

- Note: **Lauter Tun** is the vessel with a false bottom which acts as a filter or strainer for the mashed grains. Often the same vessel as the **Mash Tun**, which is where the mash is held. Sometimes these are separate vessels and the mash must be transferred to the Lauter Tun for lautering.

- **Mash Enzymes** include:

  - **Phosphatase Enzymes** - Group of enzymes including phytase, which breaks down insoluble phytin into phytic acid. Phytase is active in the 86-128 F range (i.e. mostly the Acid Rest range, but also works a little in the Protein Rest range) and is destroyed at temps at or above 140 F (watch infusion water temp - don't exceed this).

  - **Non-Proteolytic Enzymes** - Groups of cytoclastic and cytolytic enzymes, which hydrolyze hemicelluloses, pectin and gums to sugars. If not broken down, these substances can create lautering or stuck mash problems, especially if unmalted grains, such as barley, rye, wheat or oats are part of the grist. Cytase and B-Glucanase are the prominent enzymes of interest in this group. They are active in the 95-113 F range (i.e. mostly the Acid Rest range) and are destroyed at temps at or above 140 F.

  - **Proteolytic Enzymes** - KNOW THIS - Group of enzymes which includes Protease, Peptase, Peptidase amd Proteinase. These enzymes reduce complex proteins into simpler amino acids. They are active in the 113-128 F range (i.e. mostly the Protein Rest range) and are destroyed at temps at or above 158 F.

  - **Beta-Amylase** (B-Amylase) - The enzyme responsible for chopping maltose molecules off the ends of long starch and dextrin chains. The optimal temp is in the 140-149 F range and it is destroyed at or above 167 F. This is often described as a wood-chipper chipping long branches into small wood chips.

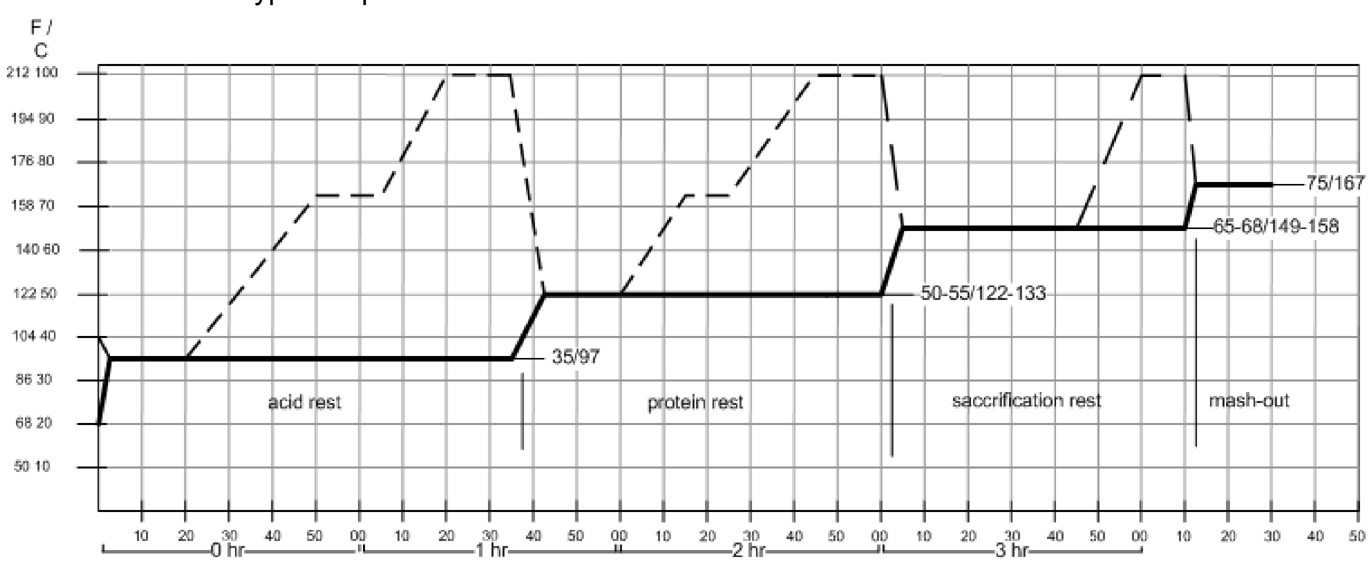
  - **Alpha-Amylase** (A-Amylase) - The enzyme responsible for breaking long starch molecular chains into shorter chains such as dextrin and maltose. The optimal temp is 158 F and it is destroyed at or above 176 F. This is often described as a chain saw cutting up large tree branches into shorter straight pieces of wood.

- 3 types of mashing procedures include:

- **<u>Single-Step Infusion (Infusion)</u>** - The mash temp is held constant at 145-158 F (usually 150-155 F) for 30-90 minutes.
    - Typically 1.0 - 1.5 quarts of water per pound of grain.
    - Need fully modified malts.
    - Less efficient, so uses more grain.
    - No Protein Rest results in various problems stated above.

- **<u>Multi-Step-Infusion (Step)</u>** - The mash temp is moved through the different phases / rests described above. <u>This is necessary if using under-modified malts as is used in traditional pilsners, and/or adjuncts and other starch sources that convert at different temps (such as corn, rice, potatos, wheat, etc.).</u> In addition to traditional Pilsners, this method is also appropriate for American Light and Standard Lagers that use adjuncts.
    - Different rest temps are achieved by either direct heating or by adding hotter Water.
    - Typically 1.0 or less quarts of water per pound of grain to start for water addition method (need to add more water for additional rests).
    - Typically 1.1 - 1.9 quarts of water per pound of grain for direct heated method.
    - Typically uses a Protein Rest at 113-128 F for 15-45 minutes, then an optional Maltose Rest at 140-149 F for 20-45 minutes, then a Saccharification Rest at 155-158 F.
    - Use of a Protein Rest results in many favorable conditions for the beer.
    - This process enhances the yield from the grain, but it requires a lot more time and energy.

- **<u>Decoction</u>** - This type of mashing involves the removal of about 1/3 of the mash and running it through a brief saccharification rest at a relatively high temp. It is then boiled for 10 - 30 minutes, and then mixed back in to the main mash. This process can be repeated as many as 3 times (i.e. Triple Decoction) depending on the modification of the malt, the grains and adjuncts being used, and the beer style being made. Each time the "Decoction" is added back to the mash, it raises the temp of the mash to next rest. See a typical triple decoction mash schedule below.



FORMULA:
decoction volume =

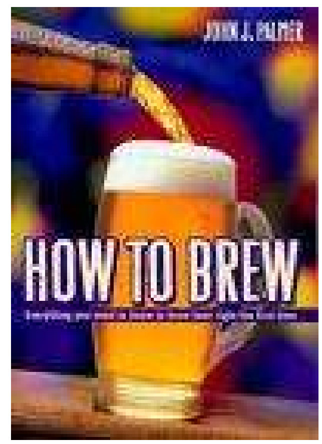
= total mash volume * (target temp - start temp) / (boil temp - start temp),
Then add another 15% - 20%.

Learn more at…
http://www.homebrewtalk.com/wiki/index.php/Decoction_mash

If doing only a single or a double decoction, would just do the last one or two rests.

- Typically 1.1 - 1.9 quarts of water per pound of grain for initial mash.
- Typically uses an Acid Rest at 95-105 F, then a Protein Rest at 122-127 F, then a Saccharification Rest at 155-158 F, and finally a Lauter Rest at 167 F.
- Many positive effects on the beer, in addition to the rich melanoidins produced.
- A downside to this method is the possible extraction of higher levels of tannins due to the extended mash schedule and handling of the grain, as well as pulling out some DMS precursors from the grain.
- This process requires the most time and energy.

- Lautering (from How To Brew)**:**



- Lautering is the method most brewers use to separate the sweet wort from the mash. A lauter tun consists of a large vessel to hold the mash and a false bottom or manifold to allow the wort to drain out and leave the grain behind. Lautering can be conducted several ways, but it usually consists of 3 steps. These are: mashout, recirculation, and sparging.

- Mashout:

Before the sweet wort is drained from the mash and the grain is rinsed (sparged) of the residual sugars, many brewers perform a mashout. Mashout is the term for raising the temperature of the mash to 170°F prior to lautering. This step stops all of the enzyme action (preserving your fermentable sugar profile) and makes the grainbed and wort more fluid. For most mashes with a ratio of 1.5-2 quarts of water per pound of grain, the mashout is not needed. The grainbed will be loose enough to flow well. For a thicker mash, or a mash composed of more than 25% of wheat or oats, a mashout may be needed to prevent a Set Mash/Stuck Sparge. This is when the grain bed plugs up and no liquid will flow through it. A mashout helps prevent this by making the sugars more fluid; like the difference between warm and cold honey. The mashout step can be done using external heat or by adding hot water according to the multi-rest infusion calculations. (See chapter 16.) A lot of homebrewers tend to skip the mashout step for most mashes with no consequences.

- Recirculation:

After the grain bed has settled and is ready to be lautered, the first few quarts of wort are drawn out through the drain of the lauter tun and poured back in on top of the grainbed. The first few quarts are almost always cloudy with proteins and grain debris and this step filters out the undesired material from getting in your boiling pot. The wort should clear fairly quickly. After the worts starts running clear (it will be dark and a little bit cloudy), you are ready to collect the wort and sparge the grainbed. Re-circulation may be necessary anytime the grain bed is disturbed and bits of grain and husk appear in the runoff.

- Sparging:

Sparging is the rinsing of the grain bed to extract as much of the sugars from the grain as possible without extracting mouth-puckering tannins from the grain husks. Typically, 1.5 times as much water is used for sparging as for mashing (e.g., 8 lbs. malt at 2 qt./lb. = 4 gallon mash, so 6 gallons of sparge water). The temperature of the sparge water is important. The water should be no more than 170°F, as husk tannins become more soluble above this temperature, depending on wort pH. This could lead to astringency in the beer.

The wort should be drained slowly to obtain the best extraction. Sparge time varies depending on the amount of grain and the lautering system, .5 - 2.5 hours. Sparging means "to sprinkle" and this explains why you may have seen or heard discussion of "sparge arms" or sprinklers over the grain bed for lautering. There is no reason to fool with such things. There are three main methods of sparging: **English**, **Batch** and **Continuous**.

In the **English** method of sparging, the wort is completely drained from the grain bed before more water is added for a second mash and drained again. These worts are then combined. Alternatively, the first and second runnings are often used to make separate beers. The second running is lighter in gravity and was traditionally used for making a Small Beer, a lighter bodied, low alcohol beer suitable for high volume quaffing at mealtimes.

Batch Sparging is a U.S. homebrewing practice where the full volume of sparge water is mixed into the mash. The grain bed is allowed to settle, and then the wort is drained off. The re-circulation step in this process takes place in the first minutes of the sparge. You can use more than one batch of water if you need to. This method differs from the English method in that the mash is not held for any significant time at the saccharification temperature before draining.

Continuous Sparging usually results in better extractions. The wort is re-circulated and drained until about an inch of wort remains above the grain bed. The sparge water is gently added, as necessary, to keep the fluid at least at that level. The goal is to gradually replace the wort with the water, stopping the sparge when the gravity is 1.008 or when enough wort has been collected, whichever comes first. This method demands more attention by the brewer, but can produce a higher yield.

MASHING REVIEW: - Review

- Mashing completes the breakdown of proteins and starches started during the malting process and creates sugars

- Single-Step Infusion Mashing:
    - The most common and easiest type
    - Basically hold the crushed grain in water at about 150 degrees F for 90 min or so
        - Below 150 = more fermentable wort (thinner beer)
        - Above 150 = less fermentable wort (maltier beer)

- Step Infusion Mashing:
    - For undermodified malts or in certain situations when using adjuncts that convert at different temperatures (corn, rice, potatoes, wheat, etc.)
    - Traditional Pilsners use an undermodified malt, so this mashing technique is approp.
    - Traditional American Lagers use adjuncts (corn and rice), so this is approp.
    - Wheat malt's excessive proteins require a protein rest, which is part of this technique
    - Water low in Ca, especially if using dark malts, needs help acidifying the mash, which is accomplished during the acid rest, which is part of this technique
    - Steps Involved:
        - Acid Rest = 95 - 120 degrees F - To acidify the mash (prevents stuck mashes and affects the beer's final flavor)
        - Protein Rest = 113 - 127 degrees F - To breakdown proteins (increases / allows for better yeast growth and better head formation)

- Saccharification Rest / Starch Conversion - This is the usual Single Step
    - Sugars are formed

- Decoction Mashing:
    - Involves removing about a third of the mash and increasing the temp (doing a high saccharification rest), boiling it for 15 - 30 min, then returning it to the main mash. This can be done multiples times (i.e. double decoction, triple decoction, etc.)
    - This technique promotes the creation of melanoidins for Bocks, other German Lagers, Pilsners, etc.

- Mash Out:
    - After mashing is complete, it is heated to about 168 degrees F and held for a few minutes before lautering / sparging
    - This is a debatable step, but it apparently increases extraction rates and makes lautering / sparging easier and better

- Lautering:
    - The process of draining the wort from the mash (in homebrewing, this is usually done in the same vessel, so it doesn't have to be transferred)
    - Sparging is the process of rinsing the grain with approx 168 degree F water
    - Intial runoff is returned (Vorlauf) to prevent astringency and chill haze
    - This process of draining the wort must be done slowly to not flush starches and proteins into the wort / brew kettle, and to increase extraction rates
    - Temps too high during this process will release tannins and starches which have negative results (astringency, chill haze, flavor, etc.)
    - May need rice hulls with wheat or rye, which have no husks of their own, to eliminate stuck mashes
    - pH of sparge water above 6 also promotes tannins extraction (astringency)

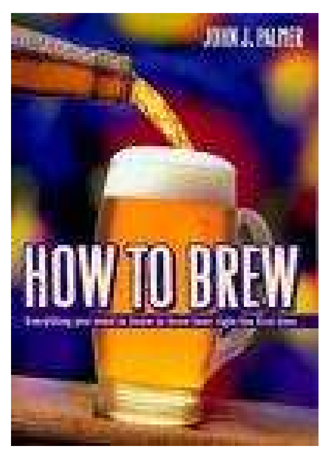
- Rule of Thumb: 10 lbs of grain = 1.054 gravity (specialty grains add a bit less)

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

> Technical Topic 2

- Hops, including varieties, IBUs, hopping scheduled and the association with different beer styles.

Hops
Compiled by Ron Smith



Hops Are Used To:
- Increase head retention
- Inhibit the growth of lactobacillus and other bacteria
- Make the beer more stable and give it a longer shelf life (preserve it)
- Aid in kettle coagulation

PLUS, Of Course, Bitterness, Hop Aroma, and Hop Flavor.

- 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.

Hops - What are They ?

Hops are the cone-like flowers of a climbing vine that is native to the temperate regions of North America, Europe and Asia. The species has separate male and female plants and only the female vines produce the cones. The vines will climb 20 ft or more up any available support and are commonly trained onto strings or wires when grown commercially. The leaves resemble grape leaves and the cones vaguely resemble pine cones in shape but are light green, thin and papery. At the base of the petals are the yellow lupulin glands which contain the essential oils and resins that are so prized by brewers

Hops have been cultivated for use in brewing for over 1000 years. The earliest known cultivation was in Central Europe, and by the early 1500s, cultivation had spread to Western Europe and Great Britain. At the turn of the century, about one dozen varieties of hop were being used for brewing; today, there are over one hundred. The focus of breeding programs has been to maintain desirable characteristics, while improving yield and disease resistance.

Hops - How Are They Used ?

Hops are a natural preservative and part of the early use of hops in beer was to preserve it. Hops were added directly to the cask after fermentation to keep it fresh while it was transported. This is how one particular style of beer, India Pale Ale, was developed. At the turn of the 18th century, British brewers began shipping strong ale with lots of hops added to the barrels to preserve it over the several month voyage to India. By journey's end, the beer had acquired a depth of hop aroma and flavor. Perfect for quenching the thirst of British personnel in the tropics.

Beer wouldn't be beer without hops - hops provide the balance, and are the signature in many styles. The bitterness contributed by hops balances the sweetness of the malt sugars and provides a refreshing finish. The main bittering agent is the alpha acid resin which is insoluble in water until **isomerized** by boiling. The longer the boil, the greater the percentage of isomerization and the more bitter the beer gets. However, the oils that contribute characteristic flavors and aromas are volatile and are lost to a large degree during the long boil.

Note: The degree of Isomerization is "Utilization".

Utilization is Affected by:
- Gravity of the wort
- Boil time

- Wort volume
- Vigor of the boil

There are many varieties of hops, but they are usually divided into two general categories: **Bittering** and **Aroma**. Bittering hops are high in alpha acids, at about 10 percent by weight. Aroma hops are usually lower, around 5 percent and contribute a more desirable aroma and flavor to the beer. Several hop varieties are in-between and are used for both purposes. Bittering hops, also known as kettle hops, are added at the start of the boil and boiled for about an hour. Aroma hops are added towards the end of the boil and are typically boiled for 15 minutes or less. Aroma hops are also referred to as finishing hops. By adding different varieties of hops at different times during the boil, a more complex hop profile can be established that gives the beer a balance of hop bitterness, taste and aroma. Descriptions of the five main types of hop additions and their attributes follow.

Hop Additions #1 of 5 - First Wort Hopping
An old yet recently rediscovered process (at least among homebrewers), first wort hopping (FWH) consists of adding a large portion of the finishing hops to the boil kettle as the wort is received from the lauter tun. As the boil tun fills with wort (which may take a half hour or longer), the hops steep in the hot wort and release their volatile oils and resins. The aromatic oils are normally insoluble and tend to evaporate to a large degree during the boil. By letting the hops steep in the wort prior to the boil, the oils have more time to oxidize to more soluble compounds and a greater percentage are retained during the boil. Only low alpha finishing hops should be used for FWH, and the amount should be no less than 30% of the total amount of hops used in the boil. This FWH addition therefore should be taken from the hops intended for finishing additions. Because more hops are in the wort longer during the boil, the total bitterness of the beer in increased but not by a substantial amount due to being low in alpha acid. In fact, one study among professional brewers determined that the use of FWH resulted in a more refined hop aroma, a more uniform bitterness (i.e. no harsh tones), and a more harmonious beer overall compared to an identical beer produced without FWH.

Hop Additions #2 of 5 - Bittering
The primary use of hops is for bittering. Bittering hops additions are boiled for 45-90 minutes to isomerize the alpha acids; the most common interval being one hour. There is some improvement in the isomerization between 45 and 90 minutes (about 5%), but only a small improvement at longer times (<1%). The aromatic oils of the hops used in the bittering addition(s) tend to boil away, leaving little hop flavor and no aroma. Because of this, high alpha varieties (which commonly have poor aroma characteristics) can be used to provide the bulk of the bitterness without hurting the taste of the beer. If you consider the cost of bittering a beer in terms of the amount of alpha acid per unit weight of hop used, it is more economical to use a half ounce of a high alpha hop rather than 1 or 2 ounces of a low alpha hop. You can save your more expensive (or scarce) aroma hops for flavoring and finishing.

Hop Additions #3 of 5 - Flavoring
By adding the hops midway through the boil, a compromise between isomerization of the alpha acids and evaporation of the aromatics is achieved yielding characteristic flavors. These flavoring hop additions are added 40-20 minutes before the end of the boil, with the most common time being 30 minutes. Any hop variety may be used. Usually the lower alpha varieties are chosen, although some high alpha varieties such as Columbus and Challenger have pleasant flavors and are commonly used. Often small amounts (1/4-1/2 oz) of several varieties will be combined at this stage to create a more complex character.

Hop Additions #4 of 5 - Finishing
When hops are added during the final minutes of the boil, less of the aromatic oils are lost to evaporation and more hop aroma is retained. One or more varieties of hop may be used, in amounts varying from 1/4 - 4 oz, depending on the character desired. A total of 1-2 oz. is typical. Finishing hop additions are typically 15 minutes or less before the end of the boil, or are added "at knockout" (when the heat is turned off) and allowed to steep ten minutes before the wort is cooled. In some setups, a

"hopback" is used - the hot wort is run through a small chamber full of fresh hops before the wort enters a heat exchanger or chiller. A word of caution when adding hops at knockout or using a hopback - depending on several factors, e.g. amount, variety, freshness, etc., the beer may take on a grassy taste due to tannins and other compounds which are usually neutralized by the boil. If short boil times are not yielding the desired hop aroma or a grassy flavor is evident, then I would suggest using FWH or Dry Hopping.

Hop Additions #5 of 5 - Dry Hopping

Hops can also be added to the fermenter for increased hop aroma in the final beer. This is called "dry hopping" and is best done late in the fermentation cycle. If the hops are added to the fermenter while it is still actively bubbling, then a lot of the hop aroma will be carried away by the carbon dioxide. It is better to add the hops (usually about a half ounce per 5 gallons) after bubbling has slowed or stopped and the beer is going through the conditioning phase prior to bottling. The best way to utilize dry hopping is to put the hops in a secondary fermenter, after the beer has been racked away from the trub and can sit a couple of weeks before bottling, allowing the volatile oils to diffuse into the beer. Many homebrewers put the hops in a nylon mesh bag - a Hop Bag, to facilitate removing the hops before bottling. Dry hopping is appropriate for many pale ale and lager styles. When you are dry hopping there is no reason to worry about adding unboiled hops to the fermenter. Infection from the hops just doesn't happen.

Hop Forms

It's rare for any group of brewers to agree on the best form of hops. Each of the common forms has its own advantages and disadvantages. What form is best for you will depend on where in the brewing process the hops are being used, and will probably change as your brewing methods change.

Table 6 - Hop Forms

Form	**Advantages**	**Disadvantages**
Whole	They float, and are easy to strain from wort. Best aroma character, if fresh. Good form for dry hopping.	They soak up wort, resulting in some wort loss after the boil. Bulk makes them harder to weigh.
Plug	Retain freshness longer than whole form. Convenient half ounce units. Behave like whole hops in the boil. Good form for dry hopping.	Difficult to use in other than half ounce increments. They soak up wort like whole hops.
Pellets	Easy to weigh. Small increase in isomerization due to shredding. Don't soak up wort. Best storability.	Forms hop sludge in boil kettle. Difficult to dry hop with. Aroma content tends to be less than other forms due to amount of processing.

Whichever form of hops you choose to use, freshness is important. Fresh hops smell fresh, herbal, and spicy, like evergreen needles and have a light green color like freshly mown hay. Old hops or hops that have been mishandled are often oxidized and smell like pungent cheese and may have turned brown. It is beneficial if hop suppliers pack hops in oxygen barrier bags and keep them cold to preserve the freshness and potency. Hops that have been stored warm and/or in non-barrier (thin) plastic bags can easily lose 50% of their bitterness potential in a few months. Most plastics are oxygen permeable; so when buying hops at a homebrew supply store, check to see if the hops are stored in a cooler or freezer and if they are stored in oxygen barrier containers. If you can smell the hops when you open the cooler door, then the hop aroma is leaking out through the packaging and they are not well protected from oxygen. If the stock turnover in the brewshop is high, non-optimum storage conditions may not be a problem. Ask the shop owner if you have any concerns.

Hop Types - Bittering Hop Varieties

- Brewer's Gold
- Bullion
- Centennial
- Challenger
- Chinook
- Cluster
- Columbus
- Eroica
- Galena
- Northern Brewer
- Northdown
- Nugget
- Perle
- Pride of Ringwood
- Target

Hop Types - Aroma Hop Varieties
The next group are common examples of Aroma hops. Aroma hops can be used for bittering also, and many homebrewers swear by this, claiming a finer, cleaner overall hop profile. I like to use Galena for bittering and save the good stuff for finishing. But making these decisions for yourself is what homebrewing is all about. There is a category of aroma hops, called the Noble Hops, that is considered to have the best aroma. These hops are principally four varieties grown in central Europe: Czech **Saaz**, **Hallertauer** Mittelfrüh, **Tettnanger** Tettnang, and Spalter **Spalt**.

- Remember Ronism: SHTS (i.e. SHoTS, without the "o").

The location a hop is grown has a definite impact on the variety's character, so only a Tettnanger/Spalter hop grown in Tettnang/Spalt is truly noble. There are other varieties that are considered to be Noble-Type, such as Perle, Crystal, Mt. Hood, Liberty, and Ultra. These hops were bred from the noble types and have very similar aroma profiles. Noble hops are considered to be most appropriate for lager styles because the beer and the hops grew up together. This is purely tradition and as a homebrewer you can use whichever hop you like for whatever beer style you want. We are doing this for the fun of it, after all.

- British Columbia (BC) Goldings
- Cascade
- Crystal (aka CJF-Hallertau)
- East Kent Goldings (EKG)

- Fuggles
- Hallertauer Hersbrucker
- Hallertauer Mittelfrüh
- Liberty
- Mt. Hood
- Progress
- Saaz
- Spalt
- Styrian Goldings
- Tettnang
- Willamette
- Whitbread Goldings Variety (WGV)
- Ultra

Hop Measurement
As noted in the glossary, there are two ways to measure hops for use in brewing. The first way measures the bittering potential of the hops going into the boil. Alpha Acid Units (AAUs) or Homebrew Bittering Units (HBUs), are the weight of hops (in ounces) multiplied by the percentage of Alpha acids. This unit is convenient for describing hop additions in a recipe because it indicates the total bittering potential from a particular hop variety while allowing for year to year variation in the %AAs.

Calculating Alpha Acid Units
AAUs are a good way to state hop additions in your recipes. By specifying the amount of alpha acid for each addition, rather than e.g. 2 oz of Cascade, you don't have to worry about year to year variation in the hop. An AAU is equal to the % AA multiplied by the weight in ounces.

For Example: 1.5 oz of Cascade at 5% alpha acid is 7.5 AAUs. If next year the alpha acid percentage in Cascade is 7.5%, you would only need 1 oz rather than 1.5 oz to arrive at the same bitterness contribution.

The second way estimates how much of the alpha acid is isomerized and actually dissolved into the beer. The equation for International Bittering Units (IBUs) takes the amount of hops in AAUs and applies factors for the boil gravity, volume, and boiling time. IBUs are independent of batch size, and to a large extent, independent of style, unlike the AAU.

Hop resins act like oil in water. It takes the boiling action of the wort to isomerize them, which means that the chemical structure of the alpha acid compounds is altered so that the water molecules can attach and these compounds can dissolve into the wort. The percentage of the total alpha acids that are isomerized and survive into the finished beer, i.e. utilized, is termed the "utilization". Under homebrewing conditions, utilization generally tops out at 30%. Several factors in the wort boil influence the degree to which isomerization occurs. Unfortunately how all these factors affect the utilization is complicated and not well understood. Empirical equations have been developed which give us at least some ability to estimate IBUs for homebrewing.

The utilization is influenced by the:

- Vigor of the boil
- Total gravity of the boil
- Time of the boil, and
- Several other minor factors.

The vigor of the boil can be considered a constant for each individual brewer, but between brewers there probably is some variation. The gravity of the boil is significant because the higher the malt sugar content of a wort, the less room there is for isomerized alpha acids. The strongest bittering factors are the total amount of alpha acids you added to the wort, and the amount of time in the boil for isomerization. Understandably then, most equations for IBUs work with these three variables (gravity, amount, and time) against a nominal utilization. As mentioned earlier, the utilization for alpha acids in homebrewing is generally accepted as topping out at about 30%. A utilization table lists the utilization versus time and gravity of the boil (see www.HowToBrew.com). This allows you to estimate how much each hop addition is contributing to the total bitterness of the beer. By incorporating a factor for gravity adjustment, the IBU equation allows for direct comparisons of total hop bitterness across beer styles. For instance, 10 AAUs in a Pale Ale would taste pretty bitter while 10 AAUs would hardly be noticed in a high gravity Stout. Gravity is not the total difference between styles however, the yeast also yields a particular flavor and sweetness profile which the hop bitterness balances against. As the maltiness of the beer increases, so does the relative balance between hop bitterness and malt sweetness. A very sweet American Brown Ale needs about 40 IBUs to yield the same balance of flavor as a Bavarian Oktoberfest of the same gravity does with 30 IBUs.

This brings up a good question, how bitter is bitter? Well, in terms of IBUs, 20 to 40 is considered to be the typical international range. North American light beers, like Coors, have a bitterness of only 10-15 IBUs. More bitter imported light beers, like Heineken, have a bitterness closer to 20-25. American microbrews like Samuel Adam Boston Lager have a bitterness of about 30 IBUs. Strong bitter ales like Anchor Liberty Ale and Sierra Nevada Celebration Ale have bitterness of 45 or more. While more experimentation and analysis needs to be done to accurately predict hop bittering potential, the IBU equations described on the next page have become the common standard by which most homebrewers calculate the final bitterness in the beer. Everyone who uses these equations is in the same ballpark and that is close enough for comparison.

Hop Bittering Calculations
We will use the following example:
Joe Ale
6 lbs. of Amber DME
1.5 oz of 6.4% AA Perle hops (60 minutes)
1 oz of 4.6% AA Liberty hops (15 minutes)

For a 5 gallon recipe, we will boil 1.5 oz of Perle hops for 60 minutes for Bittering and 1 oz of Liberty for 15 minutes for Finishing. The recipe calls for 6 lbs. of dry malt extract and it will be boiled in 3 gallons of water because of the pot size. The remaining water will be added in the fermenter. The first step is to calculate the Alpha Acid Units (AAUs).
AAU = Weight (oz) x % Alpha Acids (whole number)
AAU (60) = 1.5 oz x 6.4 = 9.6 AAUs of Perle - AND - AAU (15) = 1 oz x 4.6 = 4.6 AAUs of Liberty

Whenever a brewer is using AAUs in a recipe to describe the quantity of hops, it is important to specify how long each addition is boiled. The boiling time has the largest influence on how bitter a hop addition makes the beer. If no times are specified, then the rule of thumb is that bittering hops are boiled for an hour and finishing hops are boiled for the last 10-15 minutes. Many brewers add hops at 15 or 20 minute intervals and usually in multiples of a half ounce (for ease of measurement).

To calculate how much bitterness the final beer will have from these hop additions, we apply factors for the recipe volume (V), gravity of the boil and the boil time. The time and gravity of the boil are expressed as the utilization (U). The equation for IBUs is:
IBU = AAU x U x 75 / Vrecipe

75 is a constant for the conversion of English units to Metric. The proper units for IBUs are milligrams per liter, so to convert from ounces per gallon a conversion factor of 75 (74.89) is needed. For the metric world, using grams and liters, the factor is 10. (For those of you paying attention to the units, the missing factor of 100 was taken up by the % in the AAU calculation.)

Gravity of the Boil
The recipe volume is 5 gallons. The gravity is figured by examining the amount and concentration of malt being used. As noted in the previous chapter, dry malt extract typically yields about 40 pts/lb./gal. Since this recipe calls for 6 lbs. of extract to be used in 5 gallons, the calculated OG = 6 x 40 / 5 = 48 or 1.048

But, since we are only boiling 3 of the 5 gallons due to of the size of the pot, we need to take into account the higher gravity of the boil. The boil gravity becomes 6 x 40 / 3 = 80 or 1.080
It is the gravity of the boil (1.080) that is used in figuring the Utilization. As you will see in the next section, hop utilization decreases with increasing wort gravity. The higher concentration of sugars makes it more difficult for the isomerized alpha acids to dissolve. I use the initial boil gravity in my utilization calculation; others have suggested that the average boil gravity should be used. (The average being a function of how much volume will be boiled away during the boiling time.) This gets rather complicated with multiple additions, so I just use the initial boil gravity to be conservative. The difference is small, overestimating the total bitterness by 1-3 IBUs.

Utilization
The utilization is the most important factor. This number describes the efficiency of the isomerization of the alpha acids as a function of time. This is where a lot of experimentation is being conducted to get a better idea of how much of the hops are actually being isomerized during the boil. The utilization numbers that Tinseth published are shown in Table 7. To find the utilizations for boil gravities in-between the values given, simply interpolate the value based on the numbers for the bounding gravities at the given time. For example, to calculate the utilization for a boil gravity of 1.057 at 30 minutes, look at the utilization values for 1.050 and 1.060. These are .177 and .162, respectively. There is a difference of 15 between the two, and 7/10ths of the difference is about 11, so the adjusted utilization for 1.057 would be .177 - .011 = 0.166. The Utilizations for 60 minutes and 15 minutes at a Boil Gravity of 1.080 are 0.176 and .087, respectively. Inserting these values into the IBU equations gives:
IBU(60) = 9.6 x .176 x 75 / 5 = 25 (rounded to nearest whole number) and
IBU(15) = 4.6 x .087 x 75 / 5 = 6
Giving a grand total of 31 IBUs.

Table 7 - Utilization as a function of Boil Gravity and Time

Gravity vs. Time	1.030	1.040	1.050	1.060	1.070	1.080	1.090	1.100	1.110	1.120
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.055	0.050	0.046	0.042	0.038	0.035	0.032	0.029	0.027	0.025
10	0.100	0.091	0.084	0.076	0.070	0.064	0.058	0.053	0.049	0.045
15	0.137	0.125	0.114	0.105	0.096	0.087	0.080	0.073	0.067	0.061
20	0.167	0.153	0.140	0.128	0.117	0.107	0.098	0.089	0.081	0.074
25	0.192	0.175	0.160	0.147	0.134	0.122	0.112	0.102	0.094	0.085
30	0.212	0.194	0.177	0.162	0.148	0.135	0.124	0.113	0.103	0.094
35	0.229	0.209	0.191	0.175	0.160	0.146	0.133	0.122	0.111	0.102
40	0.242	0.221	0.202	0.185	0.169	0.155	0.141	0.129	0.118	0.108
45	0.253	0.232	0.212	0.194	0.177	0.162	0.148	0.135	0.123	0.113
50	0.263	0.240	0.219	0.200	0.183	0.168	0.153	0.140	0.128	0.117
55	0.270	0.247	0.226	0.206	0.188	0.172	0.157	0.144	0.132	0.120
60	0.276	0.252	0.231	0.211	0.193	0.176	0.161	0.147	0.135	0.123
70	0.285	0.261	0.238	0.218	0.199	0.182	0.166	0.152	0.139	0.127
80	0.291	0.266	0.243	0.222	0.203	0.186	0.170	0.155	0.142	0.130
90	0.295	0.270	0.247	0.226	0.206	0.188	0.172	0.157	0.144	0.132
100	0.298	0.272	0.249	0.228	0.208	0.190	0.174	0.159	0.145	0.133
110	0.300	0.274	0.251	0.229	0.209	0.191	0.175	0.160	0.146	0.134
120	0.301	0.275	0.252	0.230	0.210	0.192	0.176	0.161	0.147	0.134

Utilization numbers are really an approximation. Each brew is unique; the variables for individual conditions, i.e. vigor of the boil, wort chemistry, or for losses during fermentation, are just too hard to get a handle on from the meager amount of published data available. Then why do we bother, you ask? Because if we are all working from the same model and using roughly the same numbers, then we will all be in the same ballpark and can compare our beers without too much error. Plus, when the actual IBUs are measured in the lab, these models are shown to be pretty close.

Hop Utilization Equation Details

For those of you who are comfortable with the math, the following equations were generated by Tinseth from curve fitting a lot of test data and were used to generate Table 7. The degree of utilization is composed of a Gravity Factor and a Time Factor. The gravity factor accounts for reduced utilization due to higher wort gravities. The boil time factor accounts for the change in utilization due to boil time:

Utilization = f(G) x f(T) where:

$f(G) = 1.65 \times 0.000125^{(Gb - 1)}$

$f(T) = [1 - e^{(-0.04 \times T)}] / 4.15$

The numbers 1.65 and 0.00125 in f(G) were empirically derived to fit the boil gravity (Gb) analysis data. In the f(T) equation, the number -0.04 controls the shape of the utilization vs. time curve. The factor 4.15 controls the maximum utilization value. This number may be adjusted to customize the curves to your own system. If you feel that you are having a very vigorous boil or generally get more utilization out of a given boil time for whatever reason, you can reduce the number a small amount to 4 or 3.9.

Likewise if you think that you are getting less, then you can increase it by 1 or 2 tenths. Doing so will increase or decrease the utilization value for each time and gravity in Table 7.

Calculating the IBUs for each hop addition will help you to design your own beer recipes. You will not be a slave to any recipe book but will be able to take any beer style, any combination of malts, and plan the amount of hops to make it a beer you know you will like.

References

- Garetz, M., *Using Hops: The Complete Guide to Hops for the Craft Brewer* (HopTech, Danville, California, 1994). - Pyle, N., Ed., The Hop FAQ, 1994.
- Tinseth, G., The Hop Page, 1995. - Tinseth, G., personal communication, 1995.

Calculating Hops Needed / IBUs - Example - Oktoberfest:

Step 1) Identify the parameters for this style - AND - Choose those for your recipe:

- OG = ___________ 1.050

- IBUs = ___________ 20

- Hop Aroma Level and Late Hops = ___________ None

- Hop Variety (just use 1 or 2) and Average Alpha Acid %

= ________________________________ Hallertau 4.5%

= ________________________________

Step 2) Calculate Hops Needed:

a) IBU = AAU x Utilization x Volume

IBU = AAU x .2 (avg for bittering) x 15 (for 5 gal batch, comes from 75/5 gal)

THUS:

IBU = AAU x 3

- Flip the equation to get: AAU = IBU / 3 , so knowing the chosen IBUs, calculate the AAUs = ___________ 6.7 or round to 7

b) Determine ounces of hops needed from the AAUs number above with the formula:

AAU = Ounces x % Alpha Acids in Chosen Hop

AAU = Oz x %AA >>> or by flipping the equation >>> Oz = AAU / %AA

- Fill in equation: Oz = AAU ___________ / %AA ___________ = ________ oz

7 / 4.5 = 1.56 or 1.5 oz

<u>- This is the amount of the chosen hop needed to boil for 60 minutes to achieve the desired IBU level in a beer with the chosen OG</u>

HOPS REVIEW: - Review

- Noble Hops: Saaz (spicey), Hallertau (Mittelfruh), Tettnanger, Spalt
    - Not originally common, so noble.   - Ronism: SHoTS

- Aroma Hops:
    - Low alpha acid / bitterness (4 - 5 % AA or so), high aroma
    - EKG, Fuggles, Styrian Goldings, Mt. Hood, Liberty
- Bittering Hops:
    - High alpha acid / bitterness (8 - 10 % AA or so)
    - Magnum, Millenium, Brewers Gold, Newport

- Lupulin Glands - Contain the oils and resins that hold alpha acids

- Isomerization:
    - Alpha acids are not water soluble, but isomerized alpha acids are
    - Takes about 45 - 90 min of boiling time to isomerizes
    - The longer the boil, the more isomerization, the more bitterness created
    - The percent isomerized (used) is the "utilization"
    - Utilization is affected by:
        - Gravity of the wort
        - Boil time
        - Wort volume
        - Vigor of the boil

- AAU's (Alpha Acid Unit) = HBU's (Homebrew Bittering Units) = Oz's x Alpha Acid %
    - Ex: 1.5 oz of a 5 % AA hop = 1.5 x 5 = 7.5 AAUs

- IBU (International Bittering Units) are harder to calculate
    - 1 AAUs = 3.5 IBUs   - Ex: 7.5 AAUs = 7.5 x 3.5 = 26.25 IBUs

- Common IBU range is about 20 - 40
    - 1 - 2 oz of hops for a 5 gal batch is common (0.5 - 4 oz is a broader range)
- Examples:
    - Red, Blond, Brown Ales = Approx 1.5 oz (about 25 - 30 IBUs)
    - American Pale = Approx 2.5 oz (approx 40 IBUs)

- Use hops to:
    - Increase head retention
    - Inhibit growth of lactobacillus and other bacteria
    - Make beer more stable
    - Aid in kettle coagulation

- Other Hopping Methods:
    - First Wort Hopping (FWH) - Adding hops as filling kettle (adds aroma and more bittering)
    - Dry Hopping - Adding hops after the boil (adds aroma and flavor)

- Notes on Types of Hops:
    - American Citrusy Hops - Cascade, Centennial, Chinook, Columbus
    - English Flowery Perfumey Hops - EKG, Fuggles
    - Northern Brewer - Woodsy, Minty, Earthy
    - Saaz - Spicey
    - Simcoe - Piney

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

> Off Flavors / Problems / Other Flavors

- Astringent (mouth drying - a mouthfeel, not a flavor)
- Bitterness
- Husky / Grainy
- Grassy
- Earthy
- Floral / Rose-like
- Diacetyl (butter, butterscotch)
- Metallic (tinny, coiny / like sucking on a coin, blood-like)

- Astringent

Astringency is not an off "flavor", but rather, it is an off "mouthfeel". It is a mouth-puckering sensation that is comparable to chewing or sucking on grape skins or grape seeds, and is often associated with sourness. This off-characteristic is even accounted for in the mouthfeel section of the beer scoresheet. This problem is often caused by the extraction of tannins from the grain husks due to over-crushing, boiling of grains, long mashes, over-sparging, or sparging with alkaline or boiling water. Astringency can also be produced by polyphenols that result from spoilage by acetobacter or wild yeast. Another possible source is oxidation, in which case the responsible compounds are polyphenols and aldehydes. Lastly, spices such as coriander, orange peel and cinnamon also contribute astringent characteristics, but these tend to mellow with age. Over-attenuation and low dextrin levels can increase the perception of astringency.

HowToBrew: Astringency differs from bitterness by having a puckering quality, like sucking on a tea bag. It is dry, kind of powdery and is often the result of steeping grains too long or when the pH of the mash exceeds the range of 5.2 - 5.6. Oversparging the mash or using water that is too hot are common causes for exceeding the mash pH range. It can also be caused by over-hopping during either the bittering or finishing stages. Bacterial infections can also cause astringency, i.e. vinegar tones from aceto bacteria. The brown scum that forms during fermentation and clings to the side of the fermentor is intensely bitter and if it is stirred back into the beer it will cause very astringent tastes. The scum should be removed from the beer, either by letting it cling undisturbed to the sides of an oversize fermentor, or by skimming it off the krausen, or blowing off the krausen itself from a 5 gallon carboy. I have never had any problems by simply letting it cling to the sides of the fermentor.

- Bitterness

Bitterness, or rather excessive bitterness, is perceived as a harsh dry taste on the back of the tongue. It is usually due to over-hopping, especially when high alpha hops are used. Roasted malts and high concentrations of magnesium and sulfate ions also contribute to the overall bitterness. Bitter compounds may also be produced by oxidation or contamination by wild yeast, in which case there are usually other off-flavors. High levels of hop bitterness are appropriate in IPAs and barleywines, while bitterness due to roasted barley/malt is appropriate in robust porters and dry stouts.

- Husky / Grainy

Husky or grainy is sometimes used to describe astringency (and vice versa), and this is due to the primary cause of astringency being something related to the grain, mashing, sparging, etc. Although Husky and grainy may sometimes be associated with astringency, a husky or grainy character could be evident independent of a strong astringency. It appears in both the aroma and taste, and is reminiscent of the flavor of spent grains, raw grain, cereal, etc. The probably causes are similar to that of astringency (i.e. over-crushing, long mashes, over-sparging, or sparging with alkaline or hot water. Some low levels are acceptable in some lagers, but are not appropriate in any ale.

HowToBrew: These flavors are akin to the astringent flavors produced from the grain husks. These flavors are more evident in all-grain beers due to poor grain crushing or sparging practices. If the grain husks are shredded during crushing by the use of a Corona grain mill for instance, these husk flavors are more likely to be extracted during the sparge. Follow the same procedures recommended to prevent astringency to correct the problem. Grainy flavors can also be contributed by highly toasted malts. If you are making your own toasted malts, allow them to age at least two weeks after crushing so the harsher aromatic compounds can dissipate. Cold conditioning the beer for a month or two will often cause these harsh compounds to settle out with the yeast.

- Grassy

Grassy is an off-flavor that is reminiscent of freshly cut grass or grass leaves. The responsible compounds include some aldehydes produced by the oxidation of alcohols in the finished beer or the deterioration of improperly stored malt or hops. However, some English and American hops, when used in large quantities, can also produce grassy notes, but even in this case, this flavor should never be a significant part of the beer's profile.

HowToBrew: Flavors reminiscent of chlorophyll and fresh cut grass occasionally occur and are most often linked to poorly stored ingredients. Poorly stored malt can pick up moisture and develop musty smells. Aldehydes can form in old malt and can contribute green grass flavors. Hops are another source of these green flavors. If the hops are poorly stored or not properly dried prior to storage, the chlorophyll compounds will become evident in the beer.

- Earthy

Like smelling dirt or a basement. Typically from certain varieties of hops, but aged corked beers can also have this character.

- Floral / Rose-like

Typically from certain varieties of hops.

- Diacetyl (butter, butterscotch)

This compound is responsible for an artificial butter, butterscotch or toffee-like aroma and taste. At low levels, it may also produce a slickness on the palate. A significant number of tasters cannot perceive diacetyl at any concentration, so every judge should be aware of his or her limitations. Diacetyl is a fermentation by-product which is normally absorbed by the yeast and reduced to more innocuous diols. High levels can result from prematurely separating the beer from the yeast or by exposure to oxygen during the fermentation. Low FAN levels or mutation may also inhibit the ability of yeast to reduce diacetyl. Note that high fermentation temperatures promote both the formation and elimination of diacetyl, but the latter is more effective. For that reason, lager breweries often employ a diacetyl rest, which involves holding the beer in the 50-55 F range for a few days after racking to the conditioning tank. Diacetyl is also produced by lactic acid bacteria, notably *Pediococcus damnosus*. Low levels of diacetyl are permissible in nearly all ales, particularly those brewed in Scotland, and even some lagers, including Czech pilsners and Vienna-style beers.

HowToBrew: Diacetyl is most often described as a butter or butterscotch flavor. Smell an unpopped bag of butter flavor microwave popcorn for a good example. It is desired to a degree in many ales, but in some styles (mainly lagers) and circumstances it is unwanted and may even take on rancid overtones. Diacetyl can be the result of the normal fermentation process or the result of a bacterial infection. Diacetyl is produced early in the fermentation cycle by the yeast and is gradually reassimilated towards the end of the fermentation. A brew that experiences a long lag time due to weak yeast or insufficient aeration will produce a lot of diacetyl before the main fermentation begins. In this case there is often more diacetyl than the yeast can consume at the end of fermentation and it can dominate the flavor of the beer.

- Metallic (tinny, coiny, blood-like)

HowToBrew: Metallic flavors are usually caused by unprotected metals dissolving into the wort but can also be caused by the hydrolysis of lipids in poorly stored malts. Iron and aluminum can cause metallic flavors leaching into the wort during the boil. The small amount could be considered to be nutritional if it weren't for the bad taste. Nicks and cracks in ceramic coated steel pots are a common cause as are high iron levels in well water. Stainless steel pots will not contribute any metallic flavors. Aluminum pots usually won't cause metallic flavors unless the brewing water is alkaline with a pH level greater than 9. Shiny new aluminum pots will sometimes turn black when boiling water due to chlorine and carbonates in the water. The protective (grayish) oxides of aluminum can be enhanced by heating the clean pot in a dry oven at 250°F for about 6 hours.

>Beer Styles 2

3. European Amber Lager

   3A. Vienna Lager
   - Negra Modelo

   3B. Oktoberfest / Marzen
   - Paulaner Oktoberfest

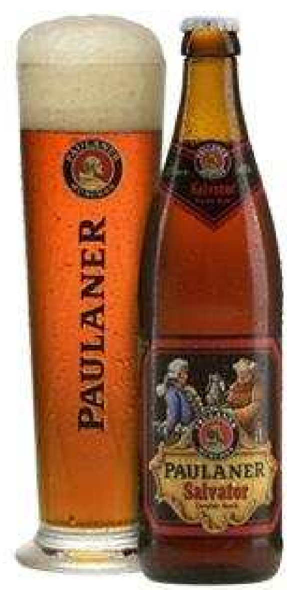
4. Dark Lager

   4A. Dark American Lager
   - Shiner Bock

   4B. Munich Dunkel
   - Ayinger Altbairisch Dunkel

   4C. Schwarzbier (Black Beer)
   - Kostritzer

5. Bock



   5A. Maibock / Helles Bock
   - Einbecker Mai-Bock - AND -
   - Steiglbock (Austrian Helles Bock)

   5B. Traditional Bock
   - Einbecker Urbock Dunkel

   5C. Doppelbock
   - Salvator

   5D. Eisbock
   - Kulmbacher

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

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

S23 (new). Describe and differentiate the American Pale Ale, American Amber Ale, and American Brown Ale beer styles. Give commercial examples of each style.
S24 (new). Describe and differentiate the English IPA, American IPA, and Imperial IPA beer styles. Give commercial examples of each style.
T3. What are body and mouthfeel? Explain how the brewer controls these characteristics.
T4. Describe the hopping schedule for an American Pale Ale and a Munich Dunkel, explaining why you have selected specific amounts and varieties of hops and how your schedule fits the style.
T19. Explain what happens during the mashing process. Discuss three different mashing techniques and the recommended usage and the advantages and disadvantages of each.
S12. Describe and compare the subcategories of British Bitters, Scottish Ales and Irish Red Ales. Give commercial examples of each.
S13. Identify, describe and compare English Milds, English Brown Ales, American Brown Ales, and Brown Porters. Give commercial examples of each style.

T5. Describe the hopping schedule for an English Brown Ale and a Bohemian Pilsner explaining why you have selected specific amounts and varieties of hops and how your schedule fits the style.

T6. Describe the hopping schedule for a British Mild and a Bohemian Pilsner explaining why you have selected specific amounts and varieties of hops and how your schedule fits the style.

T7. What are hops and how are their active ingredients extracted by the brewer? Discuss the differences between the various varieties and the styles with which they are normally associated.

END OF SESSION 2