# BJCP STUDY COURSE

WRITTEN BY

**STEVE M$^{C}$KENNA**
(Primary and Original Author)

AND

**MIKE SCHWARTZ**
(Additions and Reorganization)

**The purpose of this document is to guide prospective judge candidates through the process of learning the material needed to successfully complete the Beer Judge Certification Exam conducted by the BJCP**

**The course is broken into five study sessions. Each session consists of reading assignments to be completed before the study session, discussion of selected topics related to the readings, and tasting/evaluation of selected beer styles that are associated with the discussion topics. The most common beer styles are not addressed in this course due to time constraints.**

## REQUIRED AND RECOMMENDED READING LIST

**Basic Brewing Information** (must read at least one of these)
The New Complete Joy of Homebrewing - Charlie Papazian
Dave Miller's Homebrewing Guide : Everything You Need to Know to Make Great-Tasting Beer
How to Brew - John Palmer (free at www.howtobrew.com)
The Beer Enthusiast's Guide - Gregg Smith

**Advanced Brewing Information** (should read at least one of these besides Evaluating Beer)
Evaluating Beer - Brewers Publications (absolute must read)
The New Brewing Lager Beers - Greg Noonan
Designing Great Beers : The Ultimate Guide to Brewing Classic Beer Styles - Ray Daniels
Radical Brewing : Recipes, Tales and World-Altering Meditations in a Glass - Randy Mosher
Brewers Publications Classic Beer Style Series

**Extreme Brewing Information** (strictly optional reading)
Principles of Brewing Science - George Fix

**Style Information** (must read one)
Michael Jackson's Beer Companion OR
Michael Jackson's Great Beer Guide
The Essentials of Beer Style: A Catalog of Classic Beer Styles for Brewers and Beer Enthusiasts - Fred Eckhardt (optional)

**BJCP Program and General Beer and Brewing Information**
1998 BJCP Exam Study Guide (Required)
2004 BJCP Style Guidelines **( ignore the 1998 guidelines in the study guide)**, read each style to be covered in the upcoming session.

# BJCP Study Session 1

## BJCP Program, Beer Basics

**BEER STYLES: Doctored Beers, Oddballs from common styles (Munich Helles, Dortmunder Export, Schwarzbier, Kolsch, American wheat, American Brown ale), and Amber Hybrid beers**
**REQUIRED READING: Evaluating Beer, BJCP Study Guide Sections I & II**

---

#### I. ABOUT THE BJCP

The Purpose of the BJCP is always question 1a on the test, worth 5 points. Your answer should mention all of these:

**A.** Purpose: to promote beer literacy and the appreciation of real beer, and to recognize beer tasting and evaluation skills. (Learn this sentence. You need to mention both parts.)

**B.** Recognition is based on judging experience and BJCP exam score. Judges advance in the program by accumulating experience points, and optionally by re-taking the exam to improve their score.

**C.** Judging levels and their requirements:

| **Level** | **Exam Score** | **Experience Points** |
|---|---|---|
| Apprentice | <60 | not required |
| Recognized | 60 | not required |
| Certified | 70 | 5 |
| National | 80 | 20 |
| Master | 90 | 40 |
| Grand Master | 90 | 100 |

In all cases, at least half of the experience points must come from judging. Grand Master level also requires service to the BJCP, such as exam grading. (Important! you must mention both of these.) There are additional levels of Grand Master.

**D.** Experience points are earned by judging competitions; generally 1 point per day of competition, with an extra 0.5 point for Best of Show judges. Points are also given for stewards, staff, and organizers of competitions, and for proctors and organizers of exams.

#### II. THE EXAM

**A.** 3 hours, closed book, no style guidelines. There is a tasting part and an essay part.

**B.** The tasting part is worth 30%. You'll judge 4 beers, being told only the beer style. The beers may be good or bad and may even be misclassified. Proctors will judge the same beers, and your scoresheet is compared to the proctors'. Your numerical scores are not very important; they're only 1/5 of the tasting score and the grading curve is very generous! Much more important is what you taste or smell, how you describe it, and how much feedback you give.

**C.** The essay part is worth 70%. There are 10 questions; question 1 has 2 parts.

**Question 1a** is about the BJCP.

**Question 1b** asks 5 reasons for boiling wort.

**Questions 2, 4, 6, 8, 10**. These five questions are all on styles. They will ask you to name members of a style family, name styles from different parts of the world, compare and contrast between a few styles, etc. Remember these points:

- always describe its important taste/aroma characteristics
- give a rough gravity range, and IBUs if possible
- mention any important ingredients or brewing methods
- place of origin or history if important
- **VERY IMPORTANT!** Always give a commercial example. Graders take a mandatory 0.5 points off for every style that you don't give a commercial example for. (Memorize an example along with every style; it actually helps you remember the style characteristics.)

**Question 3** asks you to give a complete all-grain recipe for a beer style. Only a few mainstream styles are used: Oktoberfest, Bavarian weizen, North German pilsner, Czech pilsner, doppelbock, etc. You must:

- list ingredients and quantities
- describe the brewing process
- give gravities and IBUs
- mention important flavor/aroma characteristics and why your ingredients and process contribute to them.

**Questions 5, 7, 9**. These are technical questions. One will be on troubleshooting; it will name a few defects and ask what causes them, how to avoid them, and what beer styles they're allowed in, if any. One will usually be very general (describe hops and their uses), (describe the malting process). The third is usually either another troubleshooting question or a more specific question on process or sensory characteristics.

## III. LAGERS VS. ALES

Until mid-1800's, all beers were ales. Ale yeasts (Saccharomyces cerevisiae) ferment at temps above about 60°F. Often, but not always, float to top while active ("top fermenting") but eventually sink.

Lager yeasts (Saccharomyces uvarum) isolated in the 1840's at Carlsberg. Ferment at temps as low as 40°F. Tend to remain on the bottom ("bottom fermenting").

Lager styles swept the world and by the mid-1900's had wiped out ales everywhere except Britain, Ireland, Belgium, and (counting wheat beers) Germany.

The characteristic of ales is the wide range of fermentation flavors they contain, especially esters. But ales can also be very clean, with only faint esters. In judging ales, must compare to the ester level expected for the particular style.

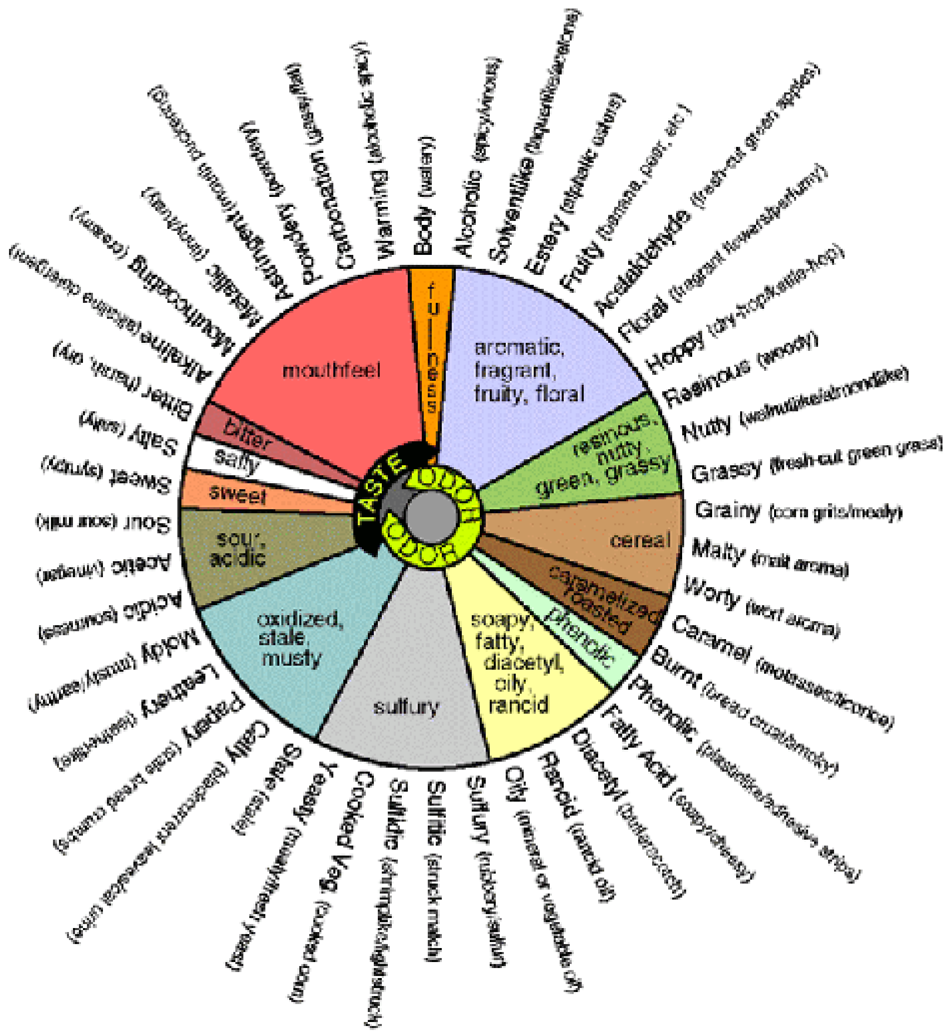
Characteristic of lagers is their lack of fermentation flavors: no esters. Lager flavors come mainly from malt and hops, not yeast. In judging, any detectable level of esters is a fault in a lager.

**IV. FLAVORS**

Most flavors consist of two components, and aroma and a taste.  The study sessions on flavor will address the aroma and taste components individually as well as the flavors that they create.

**The Beer Flavor Wheel**

The Beer Flavor Wheel was developed in the 1970s by Morten Meilgaard. It was subsequently jointly adopted as the flavor analysis standard by the European Brewery Convention, the American Society of Brewing Chemists, and the Master Brewers Association of the Americas.




**A. Tasting Techniques**

What seems to be the most common tasting technique among beer judges as the following:

- Inspect the bottle for signs of contamination such as a ring at the liquid level.
- When pouring, note the amount of foam.
- Immediately smell the aroma.  Many compounds are too volatile and will disappear quickly.
- Look at the appearance
- Taste a small amount making sure it touches the entire inside of your mouth.
- After the beer is stabilized, smell the aroma again to see what's changed.

- Taste the beer again after it has warmed somewhat.

Beer flavors can generally be classified by the aspect of brewing that they are most closely associated with, in these sessions we'll address the following areas:

- Brewhouse
- Fermentation
- Storage and
- Contamination

**B. Flavors Associated with Contamination**

The flavors in this group are generally off flavors and can be associate with microbial or not microbial sources.

**Microbial**

- cloves (eugenol, 4-vinylguaicol)
- acidic (lactic, acetic acid)
- diacetyl
- DMS
- sulfur
- musty/moldy
- acetaldehyde

**Non-microbial**

- medicinal (ortho-chloro-phenol)
- musty/earthy

**V. BEERS**

# BJCP Study Session 2

## Water Chemistry

**BEER STYLES: Porters and Stouts**
**REQUIRED READING: Evaluating Beer, BJCP Study Guide Sections III & IV. A.**

---

### I. COMPONENTS

**A. Positive ions (cations)**

| Cation | Sources | Effects |
|---|---|---|
| Calcium<br>$Ca^{2+}$ | calcium sulfate (gypsum),<br>calcium carbonate (chalk),<br>calcium chloride | • Most important ion in brewing.<br>• Acidifies mash and wort (lowers pH: 5.2-5.6). Acidity is needed by enzymes in mashing and also prevents extraction of tannins (astringency) from the hulks.<br>• A yeast nutrient.<br>• Optimum 50-100 ppm. |
| Magnesium<br>$Mg^{2+}$ | magnesium sulfate<br>(Epsom salt) | • A yeast nutrient.<br>• Helps in enzymatic reactions during ferment.<br>• Most brewing water has sufficient amounts.<br>• Optimum 10-15 ppm. |
| Sodium<br>$Na^{+}$ | sodium chloride (salt) | • Can accentuate flavors.<br>• Large amounts are unpleasant (salty).<br>• Optimum 75-100 ppm. |
| Iron<br>$Fe^{3+}$ | rust | • Unpleasant metallic flavorùserious defect!<br>• Detectable at 0.05 ppm. |

**B. Negative ions (anions)**

| Anion | Sources | Effects |
|---|---|---|
| Carbonate and bicarbonate<br>$CO_3^{2-}$ and<br>$HCO_3^{-}$ | calcium carbonate (chalk) | • Makes mash/wort more alkaline (increases pH).<br>• High pH extracts tannins from grain husks causes astringency and chill haze.<br>• Increases hop utilization.<br>• Removes calcium from water.<br>• Roasted malts (acidic) can counteract effects.<br>• Carbonate and bicarbonate are in equilibrium with each other (pH-dependent) and adding one is much like adding the other.<br>• Optimum <50 ppm in pale beers; if >200 ppm, should only brew dark beers. |
| Chloride<br>$Cl^{-}$ | sodium chloride (table salt),<br>calcium chloride | • Increases malt sweetness.<br>• Usually <150 ppm; can be 300 ppm in British ales. |

| | | |
|---|---|---|
| Sulfate<br>$SO_4^{2-}$ | calcium sulfate (gypsum)<br>magnesium sulfate (Epsom salt) | • Increases hop bitterness.<br>• Gives beer a dry finish.<br>• <20 ppm in pilsners, much more in British ales. |

**C. Hardness**

This term is an attempt to wrap up all the different cation and anion levels in one simple number. We pretend that all the cations are calcium and all the anions are carbonate, then measure the hardness as ppm as calcium carbonate (or just ppm), or an obsolete English unit grains. It is larger than just the sum of calcium plus carbonate levels, because it includes all the other ions too (most importantly magnesium and sulfate).

**Temporary hardness:** boiling the water makes calcium combine with carbonate and precipitate out as solid calcium carbonate. The part that precipitates out is called temporary hardness.

**Permanent hardness:** this is the part that doesn't go away after boiling; basically everything that's left after calcium and carbonate combine and drop out. This may include some excess calcium or excess carbonate (but not both), depending on which started out in the higher amount.

**D. Units**

Ion levels and hardness may be expressed in either ppm (parts per million) or mg/l (milligrams per liter). They are exactly the same thing.

**E. pH and Alkalinity**

pH measures the amount of the cation $H^+$ (hydrogen) in water. The practical limits are 0 to 14 (values outside this range are possible but not important here). Neutral water is pH 7. Below 7 is acidic; above 7 is alkaline (basic).

- optimum pH of mash: 5.0-5.6
- pH of beer during/after fermentation: 3.9-4.6
- pH of sour beer styles: as low as 3.0

Alkalinity is a water chemist's term that expresses the same concept as high pH. It takes into account only carbonate, bicarbonate, hydroxide ($OH^-$), and $H^+$; expressed (confusingly) as ppm calcium carbonate. This is NOT the same thing as hardness.

## II. FAMOUS BREWING WATERS AND THEIR EFFECT ON STYLES

**Pilsen**: very soft water. Can brew beers that display balanced hoppiness and maltiness together. Home of Pilsner Urquell.

**Dortmund**: very hard water (calcium, chloride, sulfate, and carbonate all high). Increases malt sweetness and hoppiness even in pale beers. Home of DAB.

**Munich**: high carbonate. Good for dark lagers (roasted malt acidifies mash). Home of Munich dunkels like Paulaner, Hacker-Pschorr.

**Burton**: high calcium, very high sulfate. Hoppy, dry styles best here: British pale ales and bitters. Home of Bass.

**London**: salty (high sodium, chloride). Less hoppy bitters and pale ales, allowing Na and Cl to accentuate malt sweetness. Home of Fullers and Young's.

**Dublin**: very high carbonate. Need roasted malts to acidify this water. Brew stouts here. Home of Guinness.

**Lake Michigan**: medium hardness, moderate levels of all ions. Can brew nearly anything with this water, either as-is or by increasing selected ions. (Not Bohemian pilsners. To brew them here, start with distilled water and add back a small amount of minerals.)

**Water Profiles From Notable Brewing Cities**

| City | Calcium (Ca+2) | Magnesium (Mg+2) | Bicarbonate (HCO3-1) | Sulfate (SO4-2) | Sodium (Na+1) | Chloride (Cl-1) | Beer Style |
|---|---|---|---|---|---|---|---|
| Pilsen | 10 | 3 | 3 | 4 | 3 | 4 | Pilsner |
| Dortmund | 225 | 40 | 220 | 120 | 60 | 60 | Export Lager |
| Vienna | 163 | 68 | 243 | 216 | 8 | 39 | Vienna Lager |
| Munich | 109 | 21 | 171 | 79 | 2 | 36 | Munich Helles, Munich Dark, Oktoberfest |
| London | 52 | 32 | 104 | 32 | 86 | 34 | Bitter |
| Edinburgh | 100 | 18 | 160 | 105 | 20 | 45 | Scottish ale |
| Burton | 352 | 24 | 320 | 820 | 44 | 16 | India Pale Ale |
| Dublin | 118 | 4 | 319 | 54 | 12 | 19 | Dry Stout |

Sources
Burton: "The Practical Brewer", p. 10,
Dortmund Noonen, G., "New Brewing Lager Beer"
Dublin "The Practical Brewer", p. 10,
Edinburgh
London "Fermentation Technology", p. 13, Westermann and Huige
Munich
Pilsen "American Handy Book", 2:790, Wahl-Henius, 1902
Vienna
Table excerpted from How to Brew by John Palmer (www.howtobrew.com)

**III. MINERALS TO ADD IN BREWING**

To increase carbonate (for brewing stouts or dark lagers): calcium carbonate (chalk).

To increase calcium (for any style in calcium-deficient water): calcium sulfate (gypsum) for hoppy beers; calcium chloride for sweet malty beers; calcium carbonate for stouts and dark lagers.

To increase sulfate (for hoppy beers): calcium sulfate (gypsum) unless calcium is already too high; otherwise use magnesium sulfate (Epsom salts).

To increase chloride (for malty beers): sodium chloride (table salt) or calcium chloride, depending on whether you want more calcium or not.

To counteract high carbonate (for brewing pale beers in high carbonate/alkaline water): add lactic acid to acidify mash.

**IV. FLAVORS**

Water chemistry tends to have a more indirect effect on flavors, enhancing specific aspects of the beer flavor. Waters with high hardness or a high sulfate tend to enhance hop bitterness, while soft water enhances malt flavor. The main way in which water chemistry directly affects beer flavor is that very hard or high sulfate water tends to give beer a dry minerally taste.

When tasting English pale ales, this is evident in the flavor profile. Pale ales from Burton tend to have a drier and more minerally finish than those from London or from Scottish ales. This is almost solely due to the sulfate content of the water. This effect is also noted in the difference between porters and stouts , which have very similar ingredients. Stouts originated when Dublin brewers tried to create porter, but the hard water (very high and bicarbonate) caused a much sharper roasted flavor in the beer. It's almost impossible to brew light beers with the traditional Dublin water because they have a harsh taste to them.

**V. BEERS - PORTERS AND STOUTS**

**Porter:** dark brown-black, roasted malt (mainly chocolate, sometimes with some black patent; but never roasted barley). A British invention, but now virtually impossible to find there; Fuller's London Porter is made for the US, and is not sold in Britain.

1. Robust: lots of roastiness, chocolate-like. Bitter, often with hop flavor and aroma too. Sometimes higher gravities, up to 1.065.
Examples: Anchor Porter, Sierra Nevada Porter.

2. Brown: still roasty, but lower gravity, lower bitterness, little hop flavor/aroma. Same relationship to robust porter as northern English brown ale is to American brown ale.
Examples: Samuel Smith's Taddy Porter, Fuller's London Porter.

**Stout:** black, sharp roasted flavor (requires roasted unmalted barley, not chocolate malt). Sharp, dry roastiness distinguishes from the softer, chocolatey roastiness of porters. Usually very bitter to counter the acidity of the roasted malt. Generally no hop flavor/aroma.

1. Dry stout: dry, roasty, coffee-like. Bitter. Usually low gravity, low 1.040's.
Examples: draught Guinness (US and Ireland; also widget cans), Murphy's, Beamish.

2. Sweet stouts: have residual unfermentable sugars and low bitterness. Often purposely sweetened by adding lactose, an unfermentable sugar.

Examples: Mackeson Triple XXX.

3. Oatmeal stout: unmalted oatmeal adds silky, oily texture and sweetness from unfermentable sugars. Supposedly first commercialized by Samuel Smith’s after a suggestion by Michael Jackson.
Example: Samuel Smith’s Oatmeal Stout.

4. Foreign extra stout: like dry stout but higher gravity. Guinness makes versions up to 1.080. Very popular in the Caribbean.
Example: Guinness Extra Stout (US bottles 6.0%), Dragon Stout (Jamaica, 7.5%).

5. Imperial stout: maltier, high alcohol, high bitterness, often with intense barleywine-like esters:
Examples: Samuel Smith's Imperial Stout, North Coast Old Rasputin, Bell’s Expedition Stout.

# BJCP Study Session 3

## Grains, Adjuncts, and Mashing

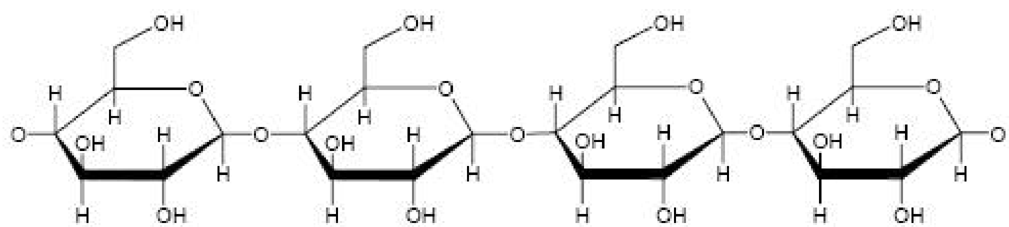
**BEER STYLES: Scottish and Strong Ales**
**REQUIRED READING: Evaluating Beer, BJCP Study Guide Sections IV. B. & C.**

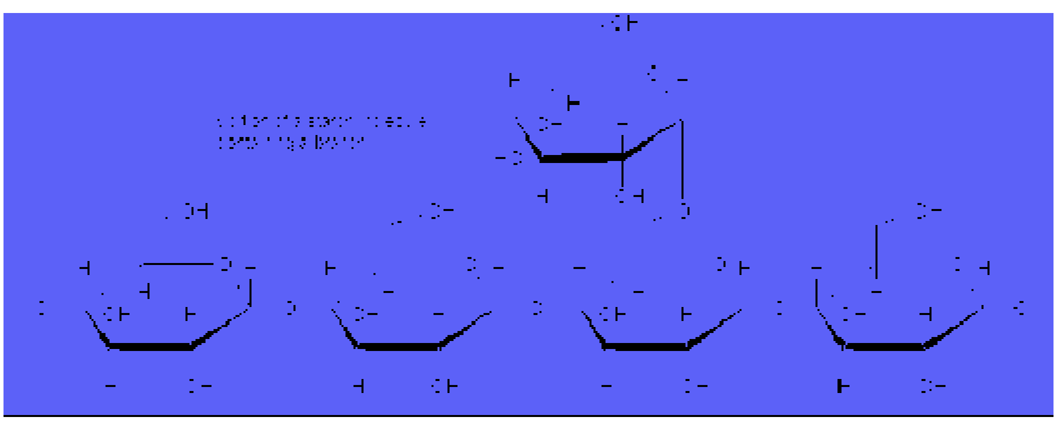
---

### I. BARLEY CONSTITUENTS

**A. Husk:** Made of cellulose (a sugar polymer: sugar molecules linked together) and tannins (phenol polymers). Both are insoluble under normal brewing conditions. But if mash water becomes too alkaline (pH greater than 6.0), tannins can dissolve, causing astringency (drying, puckering flavors; like black tea or red wine). pH tends to rise
during sparging, so oversparging is a common cause of astringency. Husk is needed as filter bed for mash, so must be not be over-crushed.

**Glucose (one of many kinds of sugars)**





**Portion of a cellulose molecule**

**Portion of a starch molecule containing a branch**

**B. Starch:** The seed's food supply. Also a polymer of sugar, but different from cellulose. Occurs in granules inside the seed. Granules swell and partially dissolve in water at about 149F (called gelatinization). This lets enzymes attack the starch, converting it to sugars. Starch which dissolves but is not converted into sugars cannot be fermented, and causes haze in beer ("permanent" haze since beer is hazy even at room temp). This is mainly a problem if mash temperature gets above 171F: then the remaining unconverted starch granules burst open and dissolve, but there are no active enzymes left to convert starch. (This is done intentionally in Belgian white and lambic styles.)

**C. Proteins:** Any of thousands of different kinds of polymers of amino acids. They make up part of the internal structure of cells. Small proteins are necessary for head retention in beer. Larger proteins cause "chill haze" in beer: they combine with tannins to form an insoluble complex at low temps, but redissolve at room temp. Large proteins can gel in the mash and cause stuck runoff (especially in wheat, oats, and rye beers; protein at fault is gluten).

**Enzymes:** All enzymes are proteins. Enzymes are catalysts that allow chemical reactions to happen. Some critical enzymes in brewing:

- **phytases**: release calcium and phytic acid from the malt, making it more acidic (lower pH). Generally only useful for extremely soft water (like Plzen’s) which lacks calcium. Can also be helpful when brewing with only light colored malts if mash pH is too high. Optimum temp around 95F.
- **proteases**: enzymes that break down other proteins into smaller proteins, and eventually into amino acids. Some breakdown of proteins is needed to prevent chill haze and stuck runoffs; also to produce free amino acids in the wort, since they are essential nutrients (FAN) for yeast. This breakdown happens during germination in highly modified malts (English); poorly modified malts (traditional German but not modern German!) need a "protein rest" around 122F during mashing to allow this to happen. All modern barley malts are highly modified and need little or no protein rest; however it is needed with wheat malt to break down gluten. Too much protease activity will destroy small proteins, causing poor head retention. Proteases work fastest around 122F, but are destroyed at higher temps.
- **alpha-amylase**: breaks down starch molecules into smaller starches by cutting chains in the middle. End result is very small starches (4-10 sugar units) called dextrins; they are nonfermentable and are needed for body (they increase viscosity of beer). Optimum temp is high, around 158F. For bigger body and less fermentable wort = sweeter or maltier beer, mash at higher temp (158F) where beta-amylase is destroyed quickly but alpha-amylase still works. German bock styles use this technique.
- **beta-amylase**: breaks down starch molecules starting from the ends, cutting off fermentable two-sugar units (maltose). Cannot work past branch points, so alpha-amylase is needed to cut up the branched starches before beta-amylase can finish the job. Works best around 140F, and decomposes at higher temps--but starch is not gelatinized until temp reaches 149F! So for best beta-amylase activity, need to bring temp to just above gelatinization (150-153F) to let beta-amylase do its work while it can, until it's destroyed. This gives lighter body and more fermentable wort = driest beer.

## II. SOURCES OF STARCH

**A. Six-row barley** malt: mostly American variety. Thick husks, very high protein (enzyme) content. This is needed when making beer from adjuncts like rice and corn, since they have low enzyme contents and can't convert themselves. Used in American standard lagers.

**B. Two-row barley malt:** traditional European varieties; also American Klages. Some (not all) are lower in enzymes and protein than six-row. Thin husk, so lower tannin content but also poorer filter bed. Used in most European beers.

**C. Wheat malt:** has no husk, no contribution to filter bed. Very high in protein, but not all of the protein is enzymes. There is plenty of enzyme to convert the starch. Much of the protein is gluten, a gum-like protein (think of bread dough)--causes stuck runoffs unless you're careful about protein rest. Small amounts add head retention to any beer (many homebrewers add a little wheat malt for this reason). Large amounts make beers cloudy.

**D. Adjuncts (Rice, corn, oats, unmalted wheat, sugar, etc.):** adjuncts, used as a cheap source of starch. Most are boiled, then converted by enzymes from barley malt.

1. Rice and corn - rice and corn are the two most common adjuncts used by most major breweries. They are used because they are a cheap source of starch, will dilute the total amount of protein in the wort (important for American high protein six-row malt), and are relatively neutral in flavor. The use of rice or corn will result in a lighter bodied and lighter flavored beer. Rice and corn must be boiled to gelatinize the starches, making them available to the malt's saccharification enzymes.

2. Sugar - used mainly in English and Belgian style beers. Inexpensive source of fermentable carbohydrates, "dries" stronger beers providing a lighter body and less flavor, candied varieties can add specific flavors. Sugars are directly fermentable and need no modification.

3. Oats - historically used in beers from many countries, particularly rural or farm beers. Currently , their main use is in stouts and several Belgian style ales. The betaglucans present in oats can provide an increased mouthfeel and perception of increased body. Oats can be included with the mash as you would include adjunct malts. The main problem issue with oats is that they are very high in betaglucans (gummy substances) that can result in a stuck mash. For that reason, it's important to do a betaglucan rest if using more than a minor percent oats in the mash.

4. Unmalted wheat - historically used mainly in Belgian ales. Provides additional starches and a lot of protein. Makes beers very cloudy. Used in Belgian Wit Beer, Saisson, and sometimes others. Can cause problems with stuck mash due to protein gums. Used the same as wheat malt would be.

## III. MALTING

Germinating the grain, then killing it by roasting. This releases the enzymes in the grain and starts breaking down the starches, making them more accessible to water in mashing. In caramel (crystal) malts, the starch breakdown is taken almost to completion, generating sugars. The temperature and duration of roasting determines the darkness of the malt.

- Steep in aerated water 2 days, drain and germinate 4-6 days at 60F.
- To make pale and lager malts: dry with hot air.
- To make dark malts: dry with hot air, then roast in kiln at high temps to desired darkness: Vienna < Munich < chocolate < black patent. Vienna and Munich are considered toasted, chocolate and black patent are considered roasted.
- To make caramel (crystal) malts: steam malt by heating in closed kiln while still wet. This mashes malt in the husk. Temp is kept in alpha-amylase range so result is largely small, unfermentable dextrins rather than sugars. When done, roast to desired darkness.
- To make roasted barley (for stouts), skip the steeping and germination steps and simply roast.

Darkening of malt is not just burning. There are two main types reactions. Both are very important in cooking as well as brewing.

1. Caramelization: breakdown of sugars and dextrins alone to form sweet, brown caramel. You can do this yourself with pure sugar on the stove. Important in caramel (crystal) malts.

2. Maillard or browning reaction: sugars combine with amino acids to make melanoidins, brown compounds with a toasty flavor. Important in high-kilned malts like Vienna, Munich, and aromatic. Think

of a range of flavors: first toasty, then roasty, then burnt. Melanoidins are the beginning of this range; they are characteristic of Oktoberfests and Viennas.

Real burning (pyrolysis) does occur in dark roasted malts like black patent and roasted barley.

Some browning and caramelization occurs during the boil, but most happens during malting.

## IV. TYPES OF MALT

The following malt types are from Dingemans Belgian malting facility but are typical of most maltsters.

**Pilsner (1.4-1.8˚ L):**
Light in color and low in protein, Dingemans Pilsner is produced from the finest European two row barley. This malt is well modified and can easily be mashed with a single-temperature infusion.

**Pale Ale (2.7-3.8˚ L):**
Dingemans Pale Ale malt is fully modified and is easily converted by a single-temperature mash. This is the preferred malt for ales of all types. This malt is interchangeable with British pale ale malt.

**Pale Wheat (1.2-2.0˚ L):**
Dingemans Pale Wheat may be used in amounts ranging from 30-70 percent of the total grist in creating many styles of wheat beer and in smaller amounts to aid in head retention.

**Munich (4-7˚ L):**
Dingemans Munich malt undergoes higher kilning than pale malt. The resulting malt will lend a full, malty flavor and aroma, and an orange-amber color. This malt can make up to 100 percent of the grain bill, but low diastatic power makes this malt unsuitable for use with adjuncts.

**Aromatic (17-21˚ L):**
Dingemans Aromatic, aka Amber 50, is a mildly kilned malt that will add a strong malt aroma and deep color when used as a specialty malt. This malt can make up to 100 percent of the grain bill, but it is fairly low in surplus diastatic enzymes.

**Caramel Pils (6-9˚ L):**
Dingemans Caramel Pils, aka Cara 20, is a light crystal malt made by drying barley malt at low temperatures. The result is a malt that will lend body, smoother mouth-feel and foam stability. This malt must be mashed with other kilned malts due to lack of enzymes.

**CaraVienne (19-27˚ L):**
Dingemans CaraVienne, aka Cara 50, is a light crystal malt used by Belgian breweries in producing Abbey or Trappist style ales, and is appropriate for any recipe that calls for crystal malt. Not synonymous with Vienna malt.

**CaraMunich* (40-54˚ L):**
Dingemans CaraMunich, aka Cara 120, is a medium-amber crystal malt that will impart a rich, caramel-sweet aroma and full flavor, as well as intense color. Not synonymous with Munich malt.

**Special B (140-155˚ L):**
The darkest of the Belgian crystal malts Dingemans Special B, aka Cara 400, will impart a heavy caramel taste and is often credited with the raisin-like flavors of some Belgian Abbey ales. Larger percentages (greater than 5 percent) will contribute a dark brown-black color and fuller body.

**Roasted Wheat (10-14˚ L):**

Dingemans Roasted Wheat, aka Tarwe Moutroost 27, is a slightly roasted wheat that will lend nutty, bread-like flavors.

**Biscuit (18-27˚ L):**
This toasted malt will provide a warm bread or biscuit flavor and aroma and will lend a garnet-brown color. Use 5-15 percent maximum. No enzymes. Must be mashed with malts having surplus diastatic power.

**Chocolate (320-350˚ L):**
Dingemans Chocolate malt, aka Mout Roost 900, is a high-nitrogen malt that is roasted at temperatures up to 450˚F and then rapidly cooled when the desired color is achieved. "Chocolate" refers primarily to the malt's color, not its flavor. This malt will lend various levels of aroma, a deep red color and a nutty/roasted taste depending on the amount used.

**De-Bittered Black Malt (500-530˚ L):**
Using an exclusive evaporative process, Dingemans De-Bittered Black Malt, aka Mout Roost 1400, will contribute the same color characteristics as Black malt with a less astringent flavor.

* CaraMunich is a trademark of Mich. Weyermann Malting, Bamberg, Germany.

**V. MASHING**

Using the grain's own enzymes to  break down proteins and convert starch to sugar, then extract the protiens, starch and sugar from the grain. This is done by adding water to mobilize enzymes, starches, and sugars and heat to speed up reactions.

**A. Main Mash Rests:**

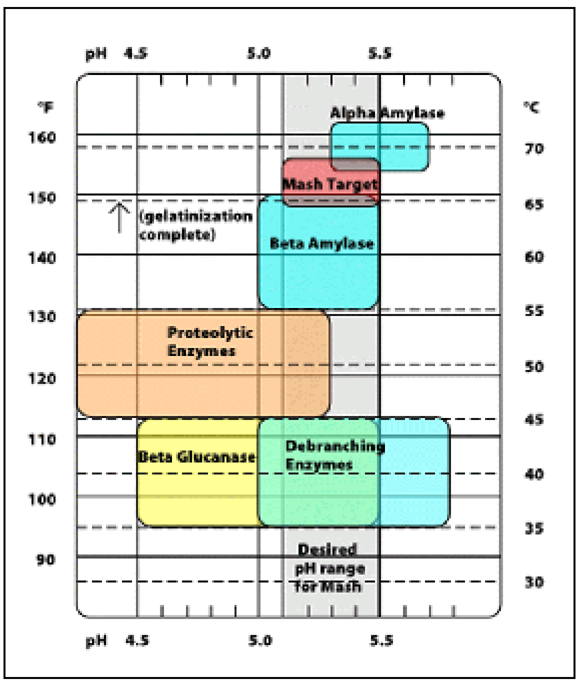
**Acid rest: 95F**. Enzymes (phytases) release calcium and phytic acid from the malt, making it more acidic (lowers pH). Generally only done for extremely soft water (like Pilzen') which lacks calcium. Most brewers skip this step and add calcium directly to the water if needed.

**Protein rest: around 122F**. Usually the lowest-temperature rest, although many brewers skip this also. Breaks down haze and gum proteins, makes amino acids for yeast. Careful not to overdo it though, or you will destroy small proteins needed for head retention. For weizens, brewers often use multiple rests at the low end of the protein rest range, from 105-120F. ***In addition to breaking down proteins, a rest around 111F releases ferulic acid, the precursor of 4-vinyl guiacol responsible for clovey weizen flavor.***

**Saccharification rest**: conversion of starch to sugar and dextrins.

| | |
|---|---|
| **149-153F:** | beta-amylase predominant. Produces highly fermentable wort, dry beer. |
| **154-158F:** | alpha-amylase predominant. Produces less fermentable wort (more dextrins), sweeter/maltier beer. |

**Mash out**: 170F. Very common but not mandatory.  Stops the action of all remaining enzymes to stabilize the wort.




**Enzyme ranges - from How to Brew by John Palmer (www.howtobrew.com)**

**Comprehensive Table of Mash Rest/Conversion Temperatures**

| Rest | Temperature Range/Optimum | Duration (minutes) | Purpose |
|---|---|---|---|
| Lactic acid | 95 - 122 / 110 F<br><br>35 - 50 / 44 C | 24 hours + until pH is <4.0 or degree of sourness is achieved. | Souring/major pH correction of carbonate water. A saccharified portion of the mash (5 - 15% of total) is cooled to <130° F, then mixed with crushed grain.<br>Reference: 1 - p.132 |
| Acid (Phytase) | 86 - 128 / 95 F<br><br>30 - 53 / 35 C | 10 - 20 (infusion)<br><br>60 - 90 (decoction) | pH adjustment of soft or moderately hard water. Used for light colored beer and weissen. Liberates phytase, only works with lightly kilned malts. Affect - increased mineral and yeast nutrient content.<br>Reference: 1 - p.130 |
| Beta Glucanase | 95 - 131 / 104 F | ?? - 30<br>20 seems to work | Beta Glucan (gum) breakdown (wheat and oatmeal only)<br>Reference: 1 - p. 138, 2 - p. 22, 4 |
| Acid/Beta Glucan Weissen | 110 F<br>44 C | 10 | In addition to acid and beta glucan above, it produces ferrulic acid which is later converted to char. phenolics.<br>Reference: 2 - p. 22, 3 - p. 59, 62 |
| Protein | 113-140/122-131 F<br><br>45-60/50-55 C | 15 - 90 | Protein breakdown the lower range (113 - 122) supports peptidase that can decrease body, upper range (122 - 132) favors proteases which is more desirable for more modified malts (nitrogen >37)<br>Reference: 1 - p.136, 138, 2 - p.23 |
| Beta Amylase | 126-154/140-149 F<br><br>52-68/60-65 C | | Saccharification - Fermentable sugars<br>Reference: |
| Alpha Amylase | 130-170/149-158 F<br><br>54.5-77/68-70 C | | Saccharification - Dextrins, longer chain sugars<br>Reference: |
| Saccharification | Temp of:<br>148 - 151 F<br>152 - 155 F<br>155 - 158 F | | Produces:<br>Light beer<br>Amber, golden lager, pilsener, dortmunder<br>Highly malty beers<br>Reference: 1 - p. 140-42 |

References:
1 - New Brewing Lager Beer; Greg Noonan, 1996
2 - Mashing Basics; Jim Busch, Brewing Techniques Vol. 3, No. 2 1995
3 - German Wheat Beers; Eric Warner, 1992
4 - Oatmeal Stout; Stephan Galante, Brew Your Own - Oct, 1997

**B. Methods of Mashing:**

**Infusion:** add water at first saccharification temp; hold for conversion; mash out; sparge. Traditional British method. Used by many homebrewers and commercial brewers. Simple equipment, fast. Requires well-modified malt because enzymes and starch must be accessible right away. Cannot use wheat or undermodified malts.

**Step Infusion:** add water at protein rest or first saccharification temp; rest; raise to higher temps; mash out; sparge. Used by many homebrewers and commercial brewers. Slower, but enables use of wheat (due to protein rest) and gives better control of starch conversion.

**Decoction:** add water at acid or protein rest temp; remove 1/3 of grain (but not much liquid), raise to conversion temp, then boil it; add this back to mash to raise mash temp; repeat this for total of 2-3 grain boils (decoctions) to raise mash through saccharification range. Traditional method for German and Czech commercial brewers, but becoming uncommon even there. Needed for under-modified malts because their hard starches are only released by boiling. But nearly all modern malts, even German/Czech, are now well modified. Does not cause starch haze because enzymes left behind in the liquid (not boiled) convert the starches released by boiling.

**C. Lautering**

Lautering is the process of draining sweet wort and sparging the grain with hot water to wash out as much sugar as possible.

**Dangers:**

a. Sparge too hot (above 170F): undissolved/unconverted starch granules in grain burst, release starch into solution but there are no enzymes left to convert it! Causes permanent starch haze.

b. Runoff pH too high: tannins from husks dissolve, giving astringent taste. Stop sparge before pH gets above 6.0. Next time add more calcium to the sparge water to keep pH low.

c. Aeration: avoid splashing hot wort or sucking air through grain bed; oxidizes wort, causing stale flavors.

d. Stuck runoff: from poor filter bed or plugging by proteins. Next time use a longer protein rest, or add rice hulls as a filtration aid.

**D. Mash Calculations**

Generally speaking, the mash calculations for the exam are very easy. You can use a rough estimate of 0..35 points/pound of malt/gallon times a 75% extraction rate to calculate OG. For FG, multiply the OG Times .75. Make sure to always state your assumptions for any calculations. **Bring a calculator!**

You should expect to have to develop a recipe for one of the following beer styles:

**?????????????????**
**XXXXX**

## V. FLAVORS

### A. Malt Flavors Associated with the Brewhouse

**Standard Malts**

- Cereal
- Grain
- Sweet
- Nutty
- Malty

**Caramel/Color Malts**

- Caramel
- Toffee
- Nutty
- Slightly Burnt

**Roasted Malts**

- Burnt
- Bitter
- Coffee

*Source: Sensory Analysis of Beer-national Home Brewers Conference Seminar Notes*

### B. Off-Flavors Associated with Malt

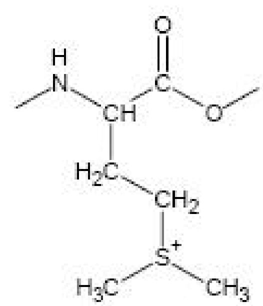
**Astringent**

Drying sensation on sides and/or back of tongue. Unpleasant like a wad of cotton in your mouth. Puckering, lingering harshness and/or dryness in the finish/aftertaste; Harsh graininess.

- Over sparging can cause too high pH can extract tannins from grain.
- Too hot of sparge water (>170°F) can extract tannins from grain.

**DMS (dimethyl sulfide)**

Produced from a natural component of grain protein, SMM (S-methyl methionine, a modified amino acid). SMM is formed in grain during germination and there is lots of it in malt. SMM itself remains attached to insoluble proteins, never makes it into final beer.




**SMM (bound to protien chain through N and O)**

Heat of mashing and boiling slowly decomposes SMM, releasing DMS. DMS is very volatile, and if kettle is uncovered, DMS escapes into air. If kettle is covered, DMS builds up.

During wort chilling, DMS can't escape. If wort chilling is fast, there isn't time to form much DMS. But if chilling is slow, a lot of DMS can build up.

DMS can also be formed by some bacteria, but usually this requires extreme infection which will cause other off-flavors too.

Flavor and aroma are like cooked corn. Also described as "vegetable". Considered a defect in most beers. But some people like this flavor. It accentuates sweetness and maltiness of beer.

Common in some strong European lagers, like Carlsberg Elephant. Also characteristic of Heilemann’s Old Style.

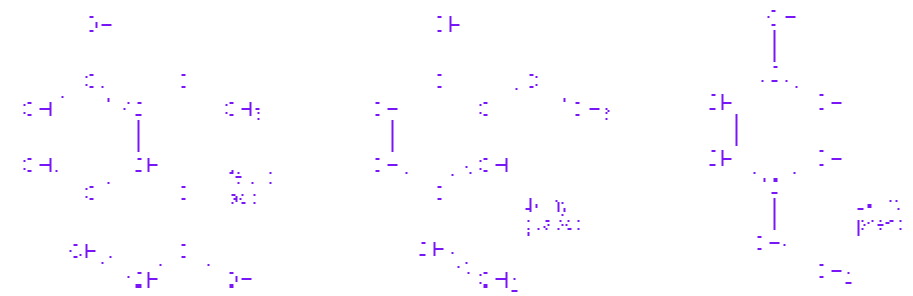
**C. Phenolics and Tannins (part 1)**

Phenol - the parent compound

Phenols are a very large class of aromatic molecules, some with pungent aromas and/or flavors. Many food flavors (those that aren't esters) are phenols: mint, eucalyptus, vanilla, cinnamon, clove.

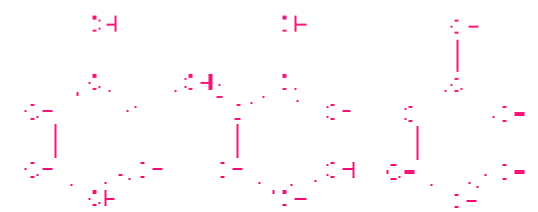
Some phenols are part of the natural signature of yeast or bacteria.

> German weizen yeast produces clove phenolics; required for German weizen (to distinguish from American weiss). Most important of these is 4-vinyl guaiacol; 4-vinyl phenol is also important.



Other phenolics can be produced by wild yeast or bacteria. A sign of infection or just a bad yeast strain. These often smell like band-aids, plastic, smoke, medicine ("Listerine"). More on these in study session #2.

Oversparging (high pH, not necessarily high temperature) can extract tannins from grain husks. Tannins are polyphenols (long chains of phenol molecules). Causes astringency, a mouthfeel rather than a flavor: drying on the roof of the mouth, puckering, like some red wines.



**Example of a typical polyphenol (tannin) molecule**

Tannin and protein together create chill haze. They bind together and become insoluble when cold, then split up and redissolve when warm.

**VI. BEERS - SCOTTISH ALES, STRONG ALES AND BARLEY WINE**

**Scottish ales:** medium to dark brown, very malty, low bitterness. Scottish brewers do not use peated malt (it is used by distillers); but mild peat flavor sometimes comes from the yeast. The three low-gravity styles (60, 70, and 80 shilling, written 80/- are very much like English ordinary, special, and strong bitters, except with more malt flavor and less hops. Recipes are almost identical to bitters except for the lower bittering hops and lack of

flavor and dry hops. Scottish ale yeast strains are very clean, producing few esters. Scottish pubs, unlike the English, do not usually dispense using hand pumps.
Examples: 60, 70, 80/-: MacEwans, Caledonian, Belhaven (these three breweries make all three strengths).

**Old Ales:** brown, estery, malty, complex, moderate alcohol strength, wide range of hop characters. Alcohol strength can overlap with strong bitters and with barleywines; but old ales are less hoppy than both, and are usually darker and more estery than bitters. Can be winey, sherrylike.
Examples: Old Peculier, Old Thumper, Young’s Winter Warmer, Gale’s Prize Old Ale.

**Barleywine:** brown but not roasty, high alcohol, very estery, often very hoppy (especially American variations). BJCP distinguishes American vs. British-style barleywine; American is allowed more hops, and hops should be American rather than British varieties.
Examples: English: Thomas Hardy's, Young's Old Nick, Fuller’s Golden Pride; American: Sierra Nevada, Bigfoot, Anchor Old Foghorn, Rogue Old Crustacean.

**Strong Scotch ales:** distinct from Scottish ales; these are high-gravity ales at barleywine strength but overwhelmingly malty, not hoppy, with only enough hop bitterness to prevent cloying sweetness. Peat-flavored examples are not traditional; normally no peated malt is used. One of the few styles that permits any diacetyl.
Examples: Traquair House, Skullsplitter, bottled McEwan's Scotch Ale.

**Common themes:** pale malt base. Color and flavor highlights from caramel malts. Occasional use of caramel colorants and sugar. Absolutely no roasted malt flavors (rare use of tiny amounts for coloration only). English hops: Fuggles, Goldings, Brewers Gold, Target, Challenger, various other new hybrids. Flavor and aroma hops, except in the Scottish styles and some old ales. Dry hops in the American barleywines. Ale yeasts, with many distinctive ester signatures and fruitiness levels ranging from low in Scottish ales to high in old ales.

# BJCP Study Session 4

## Hops

**BEER STYLES: English Pale Ales and English Brown Ales**
**REQUIRED READING: Evaluating Beer, BJCP Study Guide Sections IV. D**

---

Hops are the cone-shaped female flowers of climbing vine Humulus lupulus.

### I. Components of Hops

#### A. Hop Oils

- Flavor/aroma compounds are 0.5-2.0% of weight of hops.
- Some, not all, are water-soluble.
- Volatile: lost if hops are added early in boil. Late hop additions emphasize the hop oils rather than bittering; dry hopping releases hop oils without any bittering. Hop oils deteriorate in storage due to oxidation.
- Many different compounds; important ones are humulene, myrcene, geraniol, and linalool.
  - Humulene has a refined noble hop aroma.
  - Myrcene gives a pungent, unpleasant flavor and aroma, so hops with high levels of myrcene (50% or more) tend to be poor flavor hops; examples: Cluster, Galena, Bullion.
  - Geraniol and linalool cause the citrus character of Cascades.

#### B. Hop Resins

bittering. Includes alpha acids, beta acids, and other compounds.

**alpha acids:** humulone, cohumulone, and adhumulone. Together they can be 2-15% of the weight of the hops (this is %AA). These are the major bittering components. Look at cohumulone levels to judge harshness of bittering: high levels (30-45% of resin) are common in high-alpha bittering hops; low levels (20-30% of resin) found in noble and flavor/aroma hops.

**beta acids:** lupulone, colupulone, and adlupulone. 2-10% of the weight of the hops. Only 1/10 as bitter as alpha acids. They become more soluble as they oxidize, so old hops will contribute more beta acid bittering (but less alpha acid bittering) than fresh hops.

#### C. Antibacterial Compounds

Hops were first used because of their antibacterial properties.  The antibacterial compounds deteriorate less rapidly than the aroma and bittering compounds.. (ie. Belgian lambic brewers use 3-year-old hops because their oils and resins are gone, only antibacterials remain.)

**II. Varieties** (with place of origin; some now grown elsewhere):

**Germany**

**Flavor/aroma:** Hallertauer (Hersbrucker, Mittelfruh varieties), Tettnanger

**Bittering:** Northern Brewer, Perle, Spalt (for altbier)

**England**

**Multipurpose:** Fuggles, Kent Goldings (highly prized), Challenger, Northdown

**Bittering:** Brewers Gold, Target

**USA**

**Flavor/aroma:** Cascade, Centennial, Willamette (=Fuggles), Mt. Hood (=Hallertauer)

**Bittering:** Cluster, Chinook, Nugget, Galena, Columbus

**Czech Republic**

**Flavor/aroma:** Saaz

**Slovenia (former Yugoslavia)**

**Multipurpose:** Styrian Goldings (=Fuggles)

**Noble hops**
Are the older German/Czech varieties: Saaz, Tettnanger, Spalt, and Hallertauer. These hops are low in myrcene and high in humulene giving a more refined aroma and smoother bitterness than other hops.

**III. Reactions During Boil**

Alpha and beta acids are both insoluble, even in boiling wort.

During boil, alpha acids slowly change (isomerize) to iso-alpha acids. Iso-alpha acids are water-soluble and bitter. This reaction is one of the reasons for boiling wort.

Percent utilization tells how much of the alpha acids are converted to iso-alpha acids.

Never very high; depends on length of boil. Some disagreement on exact utilization values; competing formulas from Rager, Tinseth, others. These are a few rough values (Rager's):

| boil time | % utilization |
|---|---|
| 0-10 min | 5% |
| 20 min | 10% |
| 40 min | 20% |
| 60 min | 30% |

Utilization is lower in high-gravity worts. High-gravity correction is mainly important for OG higher than 1.050.

IBU's (International Bittering Units) are parts by weight of iso-alpha acids per million parts of beer; that is, ppm of iso-alpha acids. Rough formula:

$$\text{IBU} = \frac{(\text{ounces hops}) \times (\%\ \text{AA}) \times (\%\ \text{utilization}) \times 0.75}{(\text{gallons wort})}$$

example: 2 oz of hops with 7%AA boiled for 40 min (=20% utilization) in 5 gallons of wort:

$$IBU = \frac{2 \times 7 \times 20 \times 0.75}{5} = 42 \text{ IBU}$$

This formula is simplified (no correction for high-gravity boils) and rounded off, but good enough for the recipe question on the exam. Suggest you memorize formula and the rough utilization percentages. You will need to use it at least once on the exam. Bring a calculator!

## V. FLAVORS

### A. Hop Flavors

**Hoppy (aroma)**

- Floral Compounds
- Citrus Compounds
- Noble Aroma - Herbal, Spicy, Oxidation Products

**Bitter**

### B. Kettle Induced Flavors

- Caramel
- Roasted, Rich (Maillard Reaction Flavors)
- Burnt (off flavor)

### C. Off-Flavors Associated with Hops

Cheesy, sweat socks, old sneaker

Isovaleric acid - formed in old or poorly stored hops. (Smell your hops before you use them)

Astringency

Can occur at high hopping levels.

*Sources:*
*Sensory Analysis of Beer-national Home Brewers Conference Seminar Notes*

## VI. BEERS - ENGLISH BITTER AND BROWN ALES

**Bitters:** by far the most popular ales in England. Light to brown, low alcohol, usually estery, moderately hoppy (bitterness, hop flavor, and aroma). Highly commercialized examples in England tend to have low esters, low hops. Traditional ones can be extremely fruity and hoppy. Dry-hopping is common. Mainly pale malt; color is mainly from caramel malts but may be darkened by brewer’s caramel (a coloring) or tiny amounts of black malt. Sugar is often used to lighten the body while adding alcohol.

Many brewers make two strengths: “ordinary” and “special” or “best”. Traditional real ale has made a comeback in England and most pubs receive their bitter still fermenting in the casks; they allow it to carbonate naturally in their cellar and then dispense it using hand pumps (beer engines).
Examples: Boddington's, Ruddles, Adnam's, Marston’s Pedigree, Fuller’s Chiswick Bitter (ordinary) and London Pride (special). (Fuller’s is a good one to memorize for the exam because they make ordinary, special, and strong bitters, plus an IPA, a porter, and a barleywine.)

**Strong Bitter/English Pale Ale:** The British consider bitter and pale ale to be the same style; bitter is the draft version, pale ale is the bottled version. But the bottled versions are usually made about 0.5-1% stronger. In addition to pale ales, some unusually high-gravity draft bitters will fit in this style. "Extra Special Bitter" is a trade name used on only one beer, Fuller's ESB; it is darker, maltier, higher alcohol than Fuller’s other bitters. English pale ales include Bass (only bottled and U.S. draft versions; the British cask version is a special bitter), Young's Ramrod, Whitbread, Double Diamond, Sam Smith's Old Brewery Pale Ale.

**Brown Ale**

Brown, caramel-accented maltiness. Contrast to brown-colored German and Belgian styles: brown ales get their color from caramel malt, Germans get it from Munich malt, Belgians use either Munich malt or dark candy sugar.

1. Mild: low gravity (1.030Æs), low bitterness session beer. Nearly extinct in the UK.
Examples: Brain's Dark, Bank's Mild, Moorhouse Black Cat Mild.

2. Southern English: similar to mild but higher gravity (1.040Æs). Nearly extinct in UK.
Examples: Mann's Brown Ale, Oregon Nut Brown.

3. Northern English: like Southern, with more bittering hops but still not very high.
Examples: Newcastle Brown Ale, Samuel Smith's Brown Ale.

4. American: a homebrewer's invention, much hoppier than English tradition, with flavor/aroma hops too. Like a cross between brown ale and American pale ale.
Examples: Brooklyn Brown Ale. (Pete's Wicked Ale first commercialized the style but modern Pete's is much less hoppy and no longer represents the style)

# BJCP Study Session 5

## Yeast

**BEER STYLES: Belgian and French Ales, Sour Ale, Belgian Strong Ale**
**REQUIRED READING: Evaluating Beer, BJCP Study Guide Sections IV. E. & F.**

---

### I. FOUR STAGES OF YEAST LIFE CYCLE

| Phase | Consumes | Produces |
|---|---|---|
| Initial (Lag) | • oxygen from aerating wort<br>• glycogen from the cell reserves,<br>• nitrogen amino acids originally from malt protein | • sterols, needed for good cell walls in later stages<br>• no CO2 |
| Respiration | • more oxygen<br>• sugars from wort<br>• more nitrogen | • reproduction<br>• CO2<br>• diacetyl, esters, fatty acids, acetaldehyde<br>• slight acid pH drop to ~ 4.5 |
| Fermentation | • no oxygen<br>• more sugars<br>• acetaldehyde if present<br>• diacetyl at higher temperatures | • ethanol<br>• CO2<br>• diacetyl, esters, fatty acids |
| Dormancy | • no oxygen<br>• no sugars | • nothing unless yeast feet on each other (autolysis) |

- Yeast switch from initial phase to respiration when cell walls become strong and permeable enough to let in nutrients and sustain growth.
- They reproduce only during respiration.
- They switch from respiration to fermentation when oxygen runs out.
- They switch from fermentation to dormancy when fermentable sugars run out, or when alcohol content gets too high. Then they build an internal supply of glycogen (a polymerized form of sugar, related to starch) and drop to the bottom of the fermenter.

**Equations:**

Respiration: sugar ($C_6H_{10}O_5$) + 6 $O_2$ $\longrightarrow$ 6 $CO_2$ + 5 $H_2O$

Fermentation: sugar ($C_6H_{10}O_5$) + $H_2O$ $\longrightarrow$ 2 $CO_2$ + 2 ethanol ($C_2H_5OH$)

### II. FERMENTATION PROBLEMS

- **Crabtree effect:** if there is too much simple sugar (glucose = corn sugar, fructose = honey; sucrose = table sugar) in the wort, yeast will skip respiration, so they never reproduce.

  - Result: too few yeast cells, weak or "stuck" fermentation.

- **Pasteur effect:** opposite of Crabtree effect. Re-introducing oxygen during fermentation causes yeast to resume respiration.

- **Too little oxygen:** initial and respiration phases suffer. Not enough yeast cells, and the ones present are weak.

  - Result: stuck fermentation, high final gravity ("under-attenuation"), or high byproducts such as fusels and diacetyl.

- **Too little nitrogen:** results similar to too little oxygen. Nitrogen comes from "FAN" (free amino nitrogen) = amino acids formed by breakdown of malt proteins by grain enzymes during malting and mashing. Not usually a problem with all-grain brews, but FAN can be low in malt extracts.

- **Diacetyl:** produced during both respiration and fermentation, but later re-absorbed by yeast during fermentation at temps above 68F. This is automatic in most ales but not in lager fermentations; most lagers are raised to 68F ("diacetyl rest") between main fermentation and lagering period.

## III. YEAST AND BACTERIA SPECIES

### A. Saccharomyces cerevisiae

Ale yeast. Ferments mainly above 60F, best 68-72F; Belgian strains sometimes a few degrees higher. Often (not always) floats to surface while active (top-fermenting); later sinks. Produces esters and other byproducts. Until mid-1800's, all beers were ales. Sanitation, aeration, and yeast life cycles were not understood and sourness, haziness, diacetyl, and high ester levels were common in beer.

### B. Saccharomyces uvarum

Lager yeast. Discovered in 1840's at Carlsberg (Copenhagen, Denmark). Ferments well around 50F; slowly down to about 40F. Usually sinks to bottom while fermenting (bottom-fermenting). Produces almost no esters when fermenting at low temperature. Can ferment one complex sugar (maltotriose) that Saccharomyces cerevisiae cannot. Lager yeasts were introduced at the same time as modern sanitation and lager styles became associated with better beer, even though sanitation helped ales as much as lagers. Lager styles swept the world and by the mid-1900's had wiped out ales everywhere except Britain, Ireland, Belgium, and (counting wheat beers) Germany.

### C. Brettanomyces (several kinds)

Lactic acid-producing yeast found mainly in Belgian ales. Major producer of esters and fatty acids in lambic styles; characteristic "sweaty/horse-blanket" aroma. Very slow fermenter (months/years); can ferment some complex sugars which Saccharomyces cannot.

### D. Lactobacillus (several kinds)

A type of bacteria, not yeast. Anaerobic: does not need oxygen. Produces mainly lactic acid. A common wort-spoilage organism. Required in one beer style (Berliner weisse; species here is Lactobacillus delbruckii); major participant in Flanders red/oud bruin styles; and, to lesser extent, in Belgian lambic styles.

### E. Pediococcus (several kinds)

Another type of anaerobic bacteria. Producer of lactic acid and diacetyl. Mainly important in Belgian lambics. A wort-spoilage organism, much-feared in non-lambic breweries since it's hard to remove from equipment.

**F. Acetobacter (several kinds)**

Another bacterium, but this one is aerobic: grows only if oxygen is present. Produces acetic acid; this is the organism used to make vinegar. Only severe contamination and presence of oxygen during fermentation will lead to acetobacter in beer.

**G. "Wild yeast" (many other species of yeast and bacteria)**
Can cause "superattenuation" (greater than expected degree of fermentation); production of phenolics and fusels.

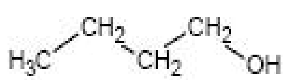
**IV. FLAVORS RELATED TO YEAST**

**A. Alcohols.**

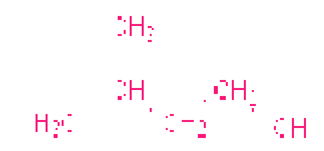
The main alcohol in beer is "ethyl alcohol" or "ethanol" (CH3CH2OH). It may be the only alcohol present. Tastes "warming". Don't worry about any of the chemical structure drawings, they will not be on the test.

**Ethanol**

The minor alcohols are the "fusel alcohols", with longer carbon chains than ethanol. Example fusel alcohols: butanol, isoamyl alcohol.




**Butanol**



**Isoamyl Alcohol**

Fusels are fermentation byproducts from ordinary yeasts. Factors leading to fusel formation: high fermentation temperatures, stressed yeast (due to too little yeast, low aeration at pitching). They can also be caused by bacterial infections.

Some fusels taste pleasant and alcohol-like, others taste solvent-like or burning. They may cause hangovers (some debate about this). Fusels are undesirable in nearly all beers, though they're allowed at low levels in many strong ales, like barleywines and Belgians.

**B. Esters**

Natural fermentation by-product produced by many yeasts. Some yeasts (like lagers, but also some ales) produce almost no esters.

Characteristic of esters is their fruity aroma and flavor. This is desirable in some styles (mostly Belgian, British) but undesirable in others (all lagers, some American ales).

Tends to be a result of high-temperature fermentations: fermenting the same yeast at lower temp produces less esters, higher temp produces more.

Chemically: esters are the product of a reaction between an alcohol and an acid.

- Important alcohols: ethanol and fusel alcohols.
- Important acids: acetic acid and fatty acids.

Esters fall into different flavor categories. Two important ones:

> **banana esters:** these are products of fusel alcohols plus acetic acid. Example: isoamyl acetate, which is real banana flavor. This is an extremely common ester produced by many yeasts, especially Belgians. OK in Belgian styles in moderation but not at high levels. In homebrews, banana esters are usually found in strong ales fermented at too high a temperature.

COOCH2CH2CH3CHCH3CH3

> **apple esters:** these are products of ethanol plus fatty acids. Example: ethyl caproate, which is apple flavor (but unlike acetaldehyde, it's persistent). Many other fruit flavors fall in this category. These esters often occur in British styles. In homebrews, an excess of apple esters is usually a defect, caused by weak fermentation or infection.

COOCH2CH2CH2CH2CH3CH2CH3

COOCH2CH3CH3

> **ethyl acetate:** a unique ester, it's the product of ethanol plus acetic acid. Flavor is solvent-like, similar to nail polish remover. Undesirable in all styles.

**C. Acetaldehyde** (pronounced asset-AL-duh-hyde)
An intermediate which yeast makes on the way to ethanol. Given time to complete the fermentation, yeast will convert all the acetaldehyde to ethanol.

Usually means beer was removed from the yeast too soon.

Flavor and aroma are like "cut green apples".

Acetaldehyde is very volatile - it disappears quickly after the beer is poured. This is one reason why it is important to get a first impression sniff of the beer as soon as possible. If the apple aroma lasts for a long time, it is probably an ester, not acetaldehyde.

Undesirable in all styles except American lagers, where Budweiser has made it acceptable. Anheuser-Busch deliberately makes acetaldehyde at a high level by adding beechwood chips which cause the yeast to drop out prematurely. Try a fresh Bud!

Similarities and differences from diacetyl: both are fermentation intermediates produced by healthy yeast. Both will be reabsorbed and converted to alcohol after sugars are consumed. Both will be left behind if yeast is crashed out too soon. Difference: diacetyl is produced in several other ways, all of which are problems: weak fermentation, infection, etc. Diacetyl is more pungent and does not evaporate quickly.

**D. Solvent -** Aromas and flavors of higher alcohols (fusel alcohols). Similar to acetone or lacquer thinner aromas.

**F. Diacetyl** (pronounced die-ASS-et-eal)
Simplest and most important member of a family of beer flavor components called vicinal diketones (VDK's).

A natural fermentation byproduct of yeasts. Yeast release diacetyl during fermentation, but later reabsorb it and convert it to ethanol. But reabsorption requires healthy yeast and temps around 68F or higher.

Reasons for excess diacetyl in beer:

- Cold fermentation with no diacetyl rest.
- Weak fermentation; yeast die before they can reduce diacetyl.
- Fermentation stopped prematurely by cooling or filtration (Red Hook ESB does this).
- Defective yeast; some strains produce more diacetyl than they can later reduce.
- Bacterial infection.

Diacetyl rest: in lagers and other cold-fermented styles, the temperature is raised to 68 F for a day or two between the primary and the secondary. This allows yeast to digest the diacetyl.

Buttery or butterscotch flavor and aroma. Also described as vanilla-like. Causes a slick sensation on the palate. Many people cannot taste diacetyl at all, though they might be able to feel it. Some people enjoy this flavor.

Permissible at low levels in a few styles, mostly English and Scottish ales, and dry stouts; check the style guidelines. A serious defect everywhere else. Historically, brewers associated it with bad fermentation practice and infection, without knowing the reasons behind it. Even in styles where it's permitted, brewers today never make diacetyl on purpose.

**G. Lactic Acid**

Simple organic acid, used internally by all organisms but usually not released.

Produced in beer by infections of lactic acid bacteria (Lactobacillus, Pediococcus, others) or some yeasts (Brettanomyces). Oxygen is not required. Only way to prevent it is to avoid these organisms by practicing good sanitation.

Clean sour flavor with no aroma (important - this distinguishes it from acetic acid).

Undesirable in most beer styles. But required in four styles:

- Belgian lambics (from Pediococcus, Brettanomyces, and wild yeasts living in air and wooden casks).
- Flanders red and oud bruin (from Lactobacillus living in casks).
- Berliner weisse (from Lactobacillus added intentionally).

**H. Acetic Acid**

An even simpler organic acid, also used internally in all organisms.

Produced in beer by bacterial infections (such as Acetobacter). Requires oxygen. Prevent by improving sanitation and not aerating after fermentation starts.

Strong sour flavor and vinegar aroma. (Vinegar is 5% acetic acid in water).

Undesirable in nearly every beer style. Allowable in very small amounts in "hard" lambics, but only if well-balanced with lactic acid and other flavors.

**I. Fatty Acids**

A family of organic acids with long chains of carbon atoms. Each has a different flavor and aroma. Examples:

- caproic acid (6 carbons): goat-like, sweaty, fatty
- caprylic acid (8 carbons): goat-like, fatty
- capric acid (10 carbons): soapy

Released by yeast as byproducts of fermentation. Some yeast strains produce almost none; others (like Brettanomyces) produce a lot. The particular fatty acids produced are part of the yeast's "signature".

Can react with ethanol to produce the "apple" family of esters. The yeast may do this during fermentation, or it may happen very slowly on its own as the finished beer ages.

Control is similar to esters: keep fermentation temperature low, or use a cleaner yeast strain.

Part of the desired flavor profile for some styles (especially lambics) but not allowed in cleaner styles like lagers and American ales.

## V. FLAVORS DEVELOPED DURING STORAGE

### A. Oxidized

Reaction of oxygen (from air) with many components of beer:

- iso-alpha acids from hops
- fatty acids
- polyphenols
- fusel alcohols (oxidation produces trans-2-nonenal, an aldehyde with a cardboard-like flavor, detectable at 0.1 ppb)

Can occur:

- in hot wort, if splashed during mashing, lautering, or after boil (hot-side aeration)
- in fermenter, if air enters after $CO_2$ production subsides (infection and acetic/lactic acid production also possible here)
- in bottle, due to air in headspace

Symptoms:

- wet cardboard, papery
- gravel-like
- wine-like, sherry-like (mainly in strong ales after bottle aging)

Sherry-like flavor develops mainly from oxygen leakage during long aging.
Cardboard flavor develops early, from oxygen introduced during brewing and bottling.

Small amounts of sherry-like flavor are acceptable to add complexity to some strong ale styles, like old ales, barleywines, and strong Belgians; but undesirable in other styles. Cardboard flavor is never desirable.

**B. Autolysis** (auto = self, lysis = break down)
After sugar is gone, yeast should go dormant and consume little stored glycogen. Instead, some yeast may use up their glycogen and then look for more food by eating their neighbors. They secrete enzymes that break down the cell walls of other yeasts.

Destruction of yeast cells releases protein breakdown products which include sulfur compounds.

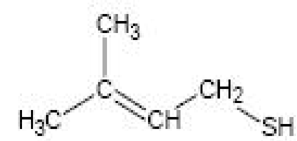
Flavor is described as rubbery, sulfury, yeasty, or beef-like. Never desirable.

Prevention:

- Most beers should not be aged in contact with excessive amounts of yeast (just enough for priming is OK).
- In strong beers which do benefit from aging on the yeast, it should be done at cool temperatures.
- Yeast from weak fermentations (under-oxygenated or under-pitched) is more susceptible to autolysis.

**B. Skunky (Light-struck)**

Reaction of light with iso-alpha acids splits off a piece of the iso-alpha acid molecule. This piece reacts with proteins to form a small sulfur-containing compound (3-methyl-2-butene-1-thiol), the same one produced by skunks.




*(Miller Brewing uses reduced-iso-alpha acids: extracted from hops, then chemically modified so they are still bitter but do not react with light. This allows them to use clear*
*bottles without causing skunkiness.)*

A problem in:

- highly hopped beers
- clear bottles
- less of a problem in green bottles
- even less so in brown bottles

Strong aroma and flavor of skunk. In England (where there are no skunks), aroma is called "catty".

## VI. BEERS - BELGIAN AND FRENCH STYLE ALES

**A. Lambics**

Belgian wheat beers, made with 40% unmalted wheat. “Spontaneously fermented” using wild yeast/bacteria which come from air in the Zenne or Senne Valley near Brussels (Zenne is the Flemish spelling; Senne is French; the region is mainly Flemish-speaking but Brussels city dwellers speak mainly French). Fermentation is done in old wooden barrels, which may contribute microorganisms too. Very high hop levels are used, but hops are aged 2-3 years and contribute no flavor, aroma, or bitterness. Strong lactic acid sourness required; low acetic acid OK only if in balance. Traditional examples have goaty/sweaty flavor and aroma from Brettanomyces. Commercialized examples are sweetened with sugar and/or diluted with fruit juice.

Straight (unblended) lambic: 1-3 year old lambic blended and bottled from the original casks; it spends the entire time in primary fermentation. Generally uncarbonated. Example: Cantillon Bruocsella. Cantillon may be the only brewer selling aged, single-fermentation lambic.

**Gueuze**: 2-3 year old lambic, blended with young partially fermented <1 year old lambic, and bottled immediately. It undergoes secondary fermentation and carbonation in the bottle, like a homebrew. The young lambic serves as the “priming sugar”. Blonde, highly carbonated, sour. Examples: Cantillon Gueuze, Hanssens Gueuze, Oud Beersel Gueuze, Frank Boon Gueuze, Lindemans Cuvee Rene. Sweetened, non-traditional examples: Belle Vue, Chapeau, and regular Lindemans Gueuze.

**Fruit lambics:** kriek (cherry), framboise/frambozen (raspberry), others less common. Fruit added to 1 year old lambic, then fermented in the original casks 1-2 more years. Should have color and flavor of fruit, plus lambic sourness and sweaty flavor. Mass-market examples add sugar or fruit juice at bottling time. Examples: Cantillon Kriek, Cantillon Rosé de Gambrinus (framboise), and Hanssens Kriek are unsweetened; Frank Boon Kriek and Framboise are unsweetened or slightly sweetened; varieties from Lindemans, Belle Vue, and Chapeau (De Troch) are all sweetened.

**B. Other Sour Belgian Ales**

**Oud Bruin/Flanders brown:** dark colored, malty but not sweet, slight lactic sourness, estery and often vinous/winelike. Brown color is due to a combination of Munich malt and caramelization from a very long boil. Example: Liefmans Goudenband (which has recently been increased in alcohol so it's stronger than BJCP style allows). Liefmans and a few others also make cherry and raspberry flavored Flanders browns, which they call kriek and framboise; do not confuse with lambics.

**Flanders red:** dark colored, medium-dry, lactic-sour. Flanders red is drier, lighter, more aromatic, cherry/winelike than Flanders brown. Often aged for years in wooden barrels and may have some tannic oak character. Examples: Rodenbach, Rodenbach Grand Cru, Duchesse des Flandres. Rodenbach Grand Cru is aged for several years; Michael Jackson has called it "the best beer in the world". Regular Rodenbach is a blend of a small amount of Grand Cru with young beer that is only aged for a few months. Grand Cru may now have been discontinued as a separate product.

**C. Strong Belgian Ales**

General characteristics: not hoppy; malt character is balanced by estery flavors and sometimes by spices. Highly carbonated. Strong Belgian beers are drier and less full-bodied than German and British strong beers because Belgians often use up to 20% sugar ("candy sugar", highly fermentable) in place of malt. Light candy sugar is sucrose, chemically the same as table sugar. Sometimes it's caramelized to make darker versions.

"Trappist" beers come from the 6 Trappist monasteries: Chimay, Westmalle, Rochefort, Orval, and Westvleteren (all in Belgium), and La Trappe (in the Netherlands). Many non-brewing monasteries have licensed their names to commercial brewers; by Belgian law their beers must be called "abbey", not "Trappist".

**Dubbel:** dark, malty, but relatively dry compared to other strong dark ales; sometimes hints of chocolate flavor or nuttiness but not roasty like a porter. Color comes mainly from dark candy sugar or caramelization during the boil. Estery; but high levels of banana ester are only common in homebrew versions. Clovey spiciness is optional, uncommon. Can be raisiny, vinous from long aging. Examples: Chimay (regular or red label), Westmalle Dubbel, La Trappe Dubbel; abbeys: Affligem Dubbel, Ommegang (USA), Unibroue Maudite (Canada), New Belgium Abbey (USA).

**Tripel:** blonde, medium-dry, neutral malt character; moderate hoppiness in some examples like Westmalle. Estery. Some versions have clove-spicy flavors, produced by the yeast; but spicy flavor is not required, and spices are not intentionally added to this style. Examples: Westmalle Tripel (inventor of the style), La Trappe Tripel, Affligem Tripel, New Belgium Tripel (USA).

**Belgian strong golden ale:** high-alcohol blonde ales in styles other than tripel. They divide very roughly into two groups. The "Duvel" group are very dry, highly carbonated, delicately estery, and often very hoppy; examples: Duvel, Lucifer, Delirium Tremens. The "Grand Cru" group are sweeter and, unlike the Duvel group, are usually spiced with coriander, orange peel, or other spices. Some spiced tripels can be placed in either this category or in the tripel style. This is the only strong Belgian style that is frequently spiced. Examples: La Chouffe, Hoegaarden Grand Cru, Karmeliet Tripel, Unibroue Fin du Monde (Canada).

**Belgian strong dark ale:** dark, sweet, malty (from dark candy sugar or Munich malt) but not roasty. Estery, sometimes but not always spiced. Medium to very high alcohol. Examples: Bush (sold as Scaldis in USA), Kwak, Kasteelbier, Chimay Grand Reserve (blue label), Rochefort 10, Westvleteren 12. (Note the last 3 are Trappist, similar to dubbels but stronger.)

**D. Belgian and French Ales**

**Belgian pale ale:** very misused style, often used as a catch-all for "singels", which are low-gravity versions of dubbels and tripels (e.g. La Trappe Enkel). Authentic examples are more like British ales, but with less hops than bitters and less maltiness than Scottish ales. Light brown, mildly malty, low-medium hop character, low-medium alcohol; a "session beer". Examples: De Koninck, Palm.

**Witbier:** "white beer": cloudy yellow-white beer made with 40-50% unmalted wheat and often 5% oats. Spiced with coriander (source of orange flavor) and bitter orange peel (source of bitterness). Mildly hoppy, often with a bit of lactic tartness. Examples: Hoegaarden Wit, Blanche de Bruges.

**Bière de Garde:** amber to copper-colored, malty, low hop flavor and bitterness, sweet finish. Aroma is estery and musty/earthy—important for style. Moderately strong. Generally not spiced. Style is from northern France, not Belgium. Examples: Jenlain, Trois Monts, Sans Culottes.

**Saison:** Belgian counterpart to biere de garde. Blonde-amber to orangeish, mildly malty, medium hop flavor and bitterness. Unlike biere de garde, this style is often spiced. Compared to biere de garde, saison is lighter colored, more hoppy, less malty, and spicy instead of earthy. Examples: Saison DuPont, Saison Silly, Fantôme.

**Belgian Specialty Beer:** a BJCP non-style which encompasses all of the unique Belgian beers which do not fit the other established styles. These tend to be judged very subjectively in competitions. Examples: Orval (between Belgian pale and strong golden, but very hoppy, dry-hopped); Oerbier (like strong dark, but sour); Arabier (like strong golden, but sour); etc.

**1. LIGHT LAGER**
- A. Lite American Lager
- B. Standard American Lager
- C. Premium American Lager
- D. Munich Helles
- E. Dortmunder Export

**2. PILSNER**
- A. German Pilsner (Pils)
- B. Bohemian Pilsener
- C. Classic American Pilsner

**3. EUROPEAN AMBER LAGER**
- A. Vienna Lager
- B. Oktoberfest/Märzen

**4. DARK LAGER**
- A. Dark American Lager
- B. Munich Dunkel
- C. Schwarzbier

**5. BOCK**
- A. Maibock/Helles Bock
- B. Traditional Bock
- C. Doppelbock
- D. Eisbock

**6. LIGHT HYBRID BEER**
- A. Cream Ale
- B. Blonde Ale
- C. Kölsch
- D. American Wheat or Rye Beer

**7. AMBER HYBRID BEER**
- A. North German Altbier
- B. California Common Beer
- C. Düsseldorf Altbier

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

**9. SCOTTISH AND IRISH ALE**
- A. Scottish Light 60/-
- B. Scottish Heavy 70/-
- C. Scottish Export 80/-
- D. Irish Red Ale
- E. Strong Scotch Ale

**10. AMERICAN ALE**
- A. American Pale Ale
- B. American Amber Ale
- C. American Brown Ale

**11. ENGLISH BROWN ALE**
- A. Mild
- B. Southern English Brown Ale
- C. Northern English Brown Ale

**12. PORTER**
- A. Brown Porter
- B. Robust Porter
- C. Baltic Porter

**13. STOUT**
- A. Dry Stout
- B. Sweet Stout
- C. Oatmeal Stout
- D. Foreign Extra Stout
- E. American Stout
- F. Imperial Stout

**14. INDIA PALE ALE (IPA)**
- A. English IPA
- B. American IPA
- C. Imperial IPA

**15. GERMAN WHEAT AND RYE BEER**
- A. Weizen/Weissbier
- B. Dunkelweizen
- C. Weizenbock
- D. Roggenbier (German Rye Beer)

**16. BELGIAN AND FRENCH ALE**
- A. Witbier
- B. Belgian Pale Ale
- C. Saison
- D. Bière de Garde
- E. Belgian Specialty Ale

**17. SOUR ALE**
- A. Berliner Weisse
- B. Flanders Red Ale
- C. Flanders Brown Ale/Oud Bruin
- D. Straight (Unblended) Lambic
- E. Gueuze
- F. Fruit Lambic

**18. BELGIAN STRONG ALE**
- A. Belgian Blond Ale
- B. Belgian Dubbel
- C. Belgian Tripel
- D. Belgian Golden Strong Ale
- E. Belgian Dark Strong Ale

**19. STRONG ALE**
- A. Old Ale
- B. English Barleywine
- C. American Barleywine

**20. FRUIT BEER**

**21. SPICE/HERB/VEGETABLE BEER**
- A. Spice, Herb, or Vegetable Beer
- B. Christmas/Winter Specialty Spiced Beer

**22. SMOKE-FLAVORED & WOOD-AGED BEER**
- A. Classic Rauchbier
- B. Other Smoked Beer
- C. Wood-Aged Beer

**23. SPECIALTY BEER**

**24. TRADITIONAL MEAD**
- A. Dry Mead
- B. Semi-Sweet Mead
- C. Sweet Mead

**25. MELOMEL (FRUIT MEAD)**
- A. Cyser (Apple Melomel)
- B. Pyment (Grape Melomel)
- C. Other Fruit Melomel

**26. OTHER MEAD**
- A. Metheglin
- B. Braggot
- C. Open Category Mead

**27. STANDARD CIDER AND PERRY**
- A. Common Cider
- B. English Cider
- C. French Cider
- D. Common Perry
- E. Traditional Perry

**28. SPECIALTY CIDER AND PERRY**
- A. New England Cider
- B. Fruit Cider
- C. Apple Wine
- D. Other Specialty Cider or Perry

**Session 1**

**Session 2**

**Session 3**

**Session 4**

**Session 5**