Overview of Wort Production

*Post-malting, Pre-fermentation*

- Crush Grain
- Mashing (Leif)
  - water chemistry (Jacque)
  - single/step infusion
  - decoction
- Lautering
  - continuous
  - parti-gyle
  - batch
  - no-sparge
- Boiling & HSA
- Cooling & Beer Clarity
- Aeration/Oxygenation (Jim)
Grain Crush

* Crush the starchy endosperm while leaving the husk intact *

- Large commercial mill: 6 roll mill 75% grits, rest hulls & flour
- >10% flour bad =>
  - mash balls & cakes readily =>
  - unconverted starch =>
  - starch in wort =>
  - irreversible haze in finished beer
- Too coarse => poor efficiency & sweet spent grains
  & iodine test shows intense blue/black
- Too fine => stuck sparge, impossible to lauter
- Good crush has mix/range of particle sizes
- Palmer: coarser crush is better: stuck sparges suck,
  long lautering costs more than using more malt
Grain Bed Filter

- Husks allow water to flow thru bed w/o compacting
- Grain bed *is* the filter
- Hulls are approximately 5% by weight of malted barley (though this is somewhat conflicted by previous slide)
- When adding wheat, rye, or other adjuncts, add rice hulls at 5% by weight of these grains
- Palmer: corn & rice don't have beta-glucan, so should be easy to sparge, but rice hulls help nonetheless

Mashing & Water Chemistry

Next time Jacque will discuss water chemistry
Later, Leif will discuss mashing
- Mashing is the process of converting starches in the malt into sugar
  - Single Infusion / step mash
  - Decoction mash
- This is done by enzymes that naturally occur with the malt
- These enzymes are active in certain temperature and pH ranges, hence the water chemistry and mash procedures
- Mashing is basically steeping the crushed malted grains in hot water for a time.
- Mashing produces wort which we need to separate from the steeped grains.
Lautering

Method of separating the sweet wort from the mash

- Mash-out (optional if grist ratio 1.5-2 qts/lb & all barley)
  - Raise mash to 170F
  - Stops enzyme action
  - Makes grain bed more fluid
- Vorlauf (recirculate)
  - Clarify wort
  - Remove starches & tannins from wort
- Draw first runnings
  - Remove excess water from above grain bed
  - Reduce pressure on grain bed
- Sparge
  - Rinse the sweet wort from the grains

Sparging (common notes)

- Adjust sparge water pH similarly to mash
- Take it slow, 45-60min typical
- Stop when S.G. < 1.008 [Palmer] or 1.012 [Noonan]
- Sparge water temperature:
  - 165F - 170F [Palmer] or 170F - 176F [Noonan]
- Runoff temperature:
  - < 170F to avoid husk tannin extraction (astringency)
- pH < 6 to avoid astringency (<=5.8 better [Noonan]) avoid:
  - Malt tannins: astringent & don't flocculate in boil
  - Lipids: poor head retention, more ester formation,
    precursors to cardboard & stale flavors
- Poor filtering leads to: cloudy, astringent, unstable beer
Sparging: Specifics

- Continuous:
  - Balance inflow & outflow to maintain water level
  - Best yield: 80%
- Parti-gyle
  - First runnings: drain completely (beer #1)
  - Second runnings: re-fill, vorlauf, drain again (beer #2)
- Batch:
  - Parti-gyle to produce one beer
  - "entire" porter [Palmer]
  - Yield: 75%
- No-Sparge
  - Fastest: Just drain the first running
  - No tannin extraction
  - Smooth, richer-tasting wort
  - Poor yield: 65%

Reasons to Boil Your Wort

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________
8. ____________________________
Reasons to Boil Your Wort

1. Extract, isomerize and dissolve hop α-acids
2. Stop enzymatic activity from the mash
3. Sanitize the wort (kill bacteria, fungi, and wild yeast)
4. Clarify the wort by coagulating undesired proteins and polyphenols (incl tannins) in the hot break
5. Evaporate undesirable harsh hop oils, sulfur compounds (e. g. DMS), ketones, and esters.
6. Promote the formation of melanoidins and caramelize some of the wort sugars (although this is not desirable in all styles)
7. Evaporate water vapor, condensing the wort to the proper volume and gravity (this is not a primary reason, it's a side effect of the process)

Isomerize hop acids in boil

- Boiling causes hop resins to isomerize (they are changed into different forms of the same chemicals)
- Isomerized hop resins are more water soluble
- Long vigorous boil agitates and breaks up hop resins
- Some hop resins end up in hot-break and cold-break
- Some hop resins are adsorbed onto yeast cells during fermentation
- Hop utilization is often between 10% and 40%
- Too long a boil (>2 hours) can cause reduced bitterness and harsh bitter compounds to be formed
- Higher wort pH increases hop isomerization, but best flavor is achieved when pH is 5.0 to 5.4
- High gravity wort sugars block isomerization
Coagulate Proteins

- Chill haze: protein & tannin molecules come out of solution and flocculate (clump together) to form light-scattering particles.
- During the boil, proteins denature (water separates from the protein). But they don't flocculate on their own, even at boiling temperatures. Agitation is needed (rolling boil).
- Hot-break: flocculation of proteins/polyphenols in the boil.
- Low pH (<5.0) will make a good hot-break nearly impossible.
- Good hot-break reduces chill haze.
- Polyphenols polymerize (link together) and associate with large protein molecules to form hot-break.
- They associate through electrical charges. Tannins are negatively charged and are attracted to positively charged proteins. Proteins change charge sign with pH.
- Hot-break also contains lipids (fatty compounds) and other substances which are harmful to fermentation and flavor.

Carmelization

- Sugars + amino acids + heat = melanoidins (dark color and strong flavor) [carmelization].
- Melanoidins formed in malt during kilning and in wort during boiling.
- Two factors most affect darkening: time and concentration since temperature is "fixed".
- High gravity is most significant: darkens much faster than a low gravity wort.
- Kettle carmelization flavors are less pleasant than those produced in kilning the malt.
- Shorter boil time + full wort boil reduces carmelization (pale beers).
- Stir wort as it enters boil kettle to mix up the first runnings.
How Long to Boil?

>= 60min:
- Better head retention: bind hop compounds to polypeptides forming colloids that survive to finished beer
- Clarity and shelf-life through hot-break
- Better preservative properties of hops

< 60 min:
- Underutilization of hops
- Poor head retention: improper extraction of isohumulones from hops
- Poor clarity due to poor hot-break
- Reduced carmelization
- Too much DMS & other volatile compounds
- Too large a volume at end

Additional Boil Notes

*Whirlpooling at end of boil helps remove hot-break and ultimately reduces off flavors, harmful substances to fermentation, bad flavors, and chill haze*

To get good clarity: need good hot break and good cold-break: rolling boil, pH > 5.0, fast cooling

Misc Notes:
- lighter colored wort => bigger hot-break particles
- decoction mash => less hot-break
- starch carried into kettle => poor hot-break
- avoid drawing hop material into fermenter (carries hot-break with it)
Hot Side Aeration (HSA)

*Hot side aeration can introduce oxidative off flavors in the finished beer that are often perceived as sherry-like, wet paper or cardboard-like*

Temperatures: >80F
Oxidation: chemical interactions with O2 (bad)
Oxygenation: dissolved oxygen in solution (good pre-ferm.)

Can occur in the following processes:
- Mashing
- Lautering
- Transferring
- Cooling

Cool the Wort

Cold-break:
- Same protein/tannin interactions as in hot-break, but they stay in solution at high temperatures and only flocculate when chilled.
- Faster chilling produces more cold break
- pH of 5.2-5.5 at end of boil helps cold-break
- In fermentor: can improve yeast nutrition
- Too much in fermentor: elevated levels of esters, fusel alcohols and chill haze or permanent haze

Slow cooling results in:
- Poor cold break leading to hazy beer
- Wort spoiling bacteria grow best at 80-120F
- increased dimethyl sulfide (DMS) produced when wort is hot, driven off by steam
What is a Hop-back?

A Hop-back:
- Is an additional vessel
- Is used after the boil and whirlpool
- Is like a grant between the boil kettle and the chiller (often closed rather than open)
- Captures or contains whole hops which hold back the hot-break
- Intensifies hop flavor and aroma:
  - Closed system traps volatile hop compounds and they stay in solution due to chiller
- Reduce amount of hops needed in late additions

Beer Clarity

Sources of beer haze:
- Yeast has not settled out yet (wait or chill)
- Wild yeast/bacterial infection (dump)
- Unconverted/insoluble starch (beano)
- Fruit pectin (pectic enzymes)
- Polyphenol/Protein haze (chill haze)

Note:
- Pediococcus damnosus can also make diacetyl
- Non-Lactobacillus lacto strains can also make diacetyl
- Coliforms can make vegetal off-flavors (parsnips/celery)
Polyphenol/Protein Haze

- Large => can come out in hot/cold break
- Small => can create chill haze
- Oxygen can cause chill haze to become permanent

Palmer Theory:
- HSA awareness resulted in less polymerization of smaller polyphenols resulting in more chill haze.
- We've traded clarity for long shelf life

Recipe Remedies for Haze

Reduce Protein / Reduce Polyphenols:
- Increase adjunct percentage (reduce protein)
- Wheat: 5-12% increases haze, 40% reduces haze (?)
- Low AA hops have more hop cone material resulting in more hop polyphenols. Switch to high AA hops
- Last runnings of continuous sparge contain highest proportion of tannin type polyphenols
- Add Irish Moss (next)
Beer Finings

1. 
2. 
3. 
4. 
5. 

Irish Moss

- Red seaweed called carrageen
- Attracts large proteins
- Only clarifier added to boil (last 20 min)
- Enhances hot-break
- Too much can reduce head-retention and hurt yeast nutrition by reducing free amino nitrogen (FAN)
  (not recommended for malt extract/adjunct worts)
- Typically 1tsp/5gal
- Same as whirfloc (from Australia)
Isinglass

- Common in English cask ales
- Protein collagen from cleaning & drying swim bladders of sturgeon, cod, hake, and other fishes
- Excellent clarifier for yeast
- Not very effective on chill haze
- Typically add to fermenter after fermentation (2floz/5gal)
- Do not heat, will denature at 65F
- Keep beer between 50-60F for best results [Miller]

Gelatin

- By-product of collagen extraction from cow hooves and pig skin
- Not as effective as isinglass at removing yeast (need 3x as much to do the job)
- Much less expensive and more shelf stable than isinglass
- Applied the same as isinglass, but 60-90g/L
PVPP/Polyclar

- PolyVinylPolyPyrrolidone (Povidone)
- Micronized white powder (ground up plastic)
- High surface area-to-volume ratio that readily absorbs polyphenols including tannins
- Contact time: few hours
- Most popular commercial clarifier
- Use: 6-10g/5gal after fermentation prior to bottling
  Let it settle a day, then rack off the sediment
- Not approved by FDA for ingestion
- Commercial breweries remove it by filtration
- Can cause excessive foaming [Miller]

Silica Gel

- Silica hydrogels and xerogels
- Used in combination with Polyclar by commercial breweries
- Works synergistically with Polyclar, more effective than either alone
- Binds preferentially to haze-active proteins
  (chemically it reacts w/same sites on the proteins that the polyphenols do)
- Use: 6-10g/5gal, same procedures as Polyclar
- Not FDA approved for ingestion
- Commercial breweries remove it by filtration
Beer Clarity Summary

*If the hazy beer tastes good, then probably protein/polyphenol haze and can be removed by clarifiers as above*

Haze and yeast can also be removed by filtration

Note: Proteins/Polyphenols are responsible for:
- body
- head retention
- some of the flavor
- some color

Removing too many proteins/polyphenols can damage beer

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Head Retention [Noonan]

Causes of poor head retention:
- Excessive protein rest
- Over-modified malt
- Too-high adjunct ratio
- Lipids in ferment (excessive sparging, autolized yeast)
- Overfoaming in ferment
- Overboiling
- Insufficient or deteriorated hops
- Contact with oil
Example Exam Questions (A)


- Give five reasons why a brewer boils his wort, and how boiling achieves these purposes.
- Describe and discuss the following beer characteristics. How are they perceived? What causes them and how are the avoided and controlled? Are they ever appropriate and, if so, where and when? a) Cooked Corn; b) Sherry-like; c) Butterscotch.
- What causes the following off-flavors and how can the brewer avoid them: a) Cidery tastes; b) Cardboardy taste; c) Astringency.
- Explain the principle of mashing. Describe three traditional mashing methods. Give reasons for using each method and the advantages and disadvantages of each.
- What are the functions of the “lauter tun” and “hop back”?
- Name three beer clarifying aids, explaining how, when and why they are used.
- Describe the action of enzymes during brewing, identifying at least two specific enzymes.
- Why is it necessary to chill boiling wort to yeast pitching temperature as quickly as possible? Describe what can happen if the wort is chilled too slowly.
- What are “hot break” and “cold break” and what is happening?
- What is “pH”, what is the proper Ph during the mash, and why is it important in mashing.
- Explain “infusion mashing”, “step-infusion mashing”, and “decoction mashing”, describing the process and giving reasons for the use of each method.
- Discuss the following brewing techniques. How do they affect the beer? A) sparging; b) dry hopping; c) natural conditioning.

Example Exam Questions (B)

http://www.bjcp.org/study.php#exam

- Discuss the following brewing techniques. How do they affect the beer? a) kräusening b) adding gypsum c) fining
- What is meant by the terms hot break and cold break? What is happening and why are they important in brewing and the quality of the finished beer?
- Describe and explain the role of diastatic and proteolytic enzymes in the brewing process and how they affect the characteristics of the finished beer.
- What are five primary purposes for boiling wort? How does a brewer achieve these objectives?
- Explain what happens during the mashing process. Describe three different mashing techniques and the advantages and disadvantages of each.
- Provide a complete ALL-GRAIN recipe for a <STYLE>, listing ingredients and their quantities, procedure, and carbonation. Give volume, as well as original and final gravities. Explain how the recipe fits the style’s characteristics for aroma, flavor, appearance, mouthfeel, and other significant aspects of the style.
- Styles may include:
  - Belgian Tripel Oktoberfest Classic American Pilsner
  - Doppelbock American IPA Bohemian Pilsner
  - Robust Porter Weizen German Pilsner
  - Dry Stout English Pale Ale
Example Exam Answer (mashing)

http://www.thoroughbrews.com/pb/wp_b120e579/wp_b120e579.html (note also: many detailed exam questions provided)

T11. Describe and explain the role of diastatic and proteolytic enzymes in the brewing process and how they affect the characteristics of the finished beer.

T11. Answer:
The two main categories of enzymes in malted grains are proteases and amylases. The protease enzymes are most active between mash temperatures of 123°F and 128°F and they breakdown proteins and protein byproducts. Amylase enzymes are active between mash temperatures of 140°F and 162°F. Amylase enzymes degrade starch into fermentable byproducts (sugars) and unfermentable byproducts (dextrins). The two diastatic enzymes used in mashing are alpha-amylase and beta-amylase enzymes. Beta-amylase enzymes are active between 140°F-149°F, acts only at the ends of the “sugar chains”. It snips off two sugars at a time to produce highly fermentable sugars (maltose) in the wort. Alpha-amylase enzymes act non-specifically, breaking big sugar chains into smaller chains. The Alpha-amylase produces some fermentable sugars but produces many dextrins.

In the brewing process, there are four critical parameters for saccharification. The parameters are: time, temperature, pH, and mash thickness. Manipulation of each of these parameters means having total control of the wort you produce. For example, mashing with short time periods in the protease temperature range can help the clarity of the beer, while longer times can negatively affect head retention. Long time periods in the Beta-amylase temperature range will result in highly fermentable and highly attenuated wort. Mashing in the Alpha-amylase temperature range produces more dextrins that will contribute to the mouth feel and body of the beer. A pH, between 5.2 and 5.6, is required for enzymes to promote rapid starch to sugar conversion. A thick mash, with “water to grist ratio” (quarts of water/per pound grain) between 0.8 and 1.25, will keep the enzymes active for longer times at long time and temperature combinations. A thinner mash facilitates overall enzyme activity at the expense of a short activation time.

By controlling the relative balance between sugars and dextrins in your wort, the brewer can control the alcohol level and the body of the finished beer. Finding the perfect balances of the mash properties gives the brewer control over what your beer will be.

Example Exam Answer (water/wort/carb)

http://www.bjcp.org/docs/mastering.pdf (Gordon Strong - tips on mastering the exam)

Q: Discuss the following brewing techniques. How do they affect the beer? (a) adding gypsum, (b) fining, (c) krausening.

A1: a. Adding gypsum (popular brewing salt addition). Serves to adjust the pH of the water used to brew with. Proper pH should be between 5.2 - 5.7. Brewing salts can be used to mimic traditional brewing waters with gypsum - one can "burtonize" the water to simulate that of Burton-on-Trent good for English Pale Ales, as it accentuates the hops, bitterness and flavor. b. Fining - using additives (fish guts) one can clear their beer. Finings are most well known with English Bitters. Cask conditioned ales are fined i.e. cleared during stillage prior to serving. The result is a beautiful (clear) beer upon dispense. c. Krausening - the act of adding young beer to mature beer to carbonate the finished product. When your beer has finished fermenting one can add krausen of young not fully fermented beer to the main beer. The result is a renewed fermentation that can serve to carbonate the beer and/or bottle condition it. 158 words, Score: 7/10

A2: a. adding gypsum accomplishes 2 things: increasing Ca++ and SO4--; Calcium will help yeast metabolism in proper levels, and also allows the wort to acidify. It is also critical to proper enzyme function. Sulfate lends a soft edge to hop bitterness by affecting alpha-acid extraction and creating a synergistic perception effect. b. Fining is the addition of kettle finings (Irish moss) to coagulate proteins to clarify beer. It may also be carried out post-fermentation (Isinglass, Bentonite, Polyclar) to help precipitate tannins and/or proteins that may cause haze, or even flavor instability. c. Krausening is the addition of a portion of actively fermenting wort to a wort that has finished fermenting. It is used chiefly as a means of providing "natural" carbonation. It also reduces residual diacetyl and may contribute acetaldehyde ("green" beer character) in the finished beer. 138 words, Score: 10/10
My References

General Resources to Study

Nice list of example exam questions (esp for style Q):
http://www.thoroughbrews.com/pb/wp_b120e579/wp_b120e579.html

Alternative style guide format for studying for the exam:
http://www.bjcp.org/docs/StylePresentation.pdf

Off-flavor flash cards with lots of detailed information:
http://www.bjcp.org/docs/OffFlavorFlash.pdf