Yeast

- Discovered as a biological process around 1860 by Louis Pasteur, rather than a chemical reaction (like enzymes)
- Single Celled Fungi
- Metabolize sugars into CO2 and Alcohol (as well as by products, esters, keytones, phenols, fatty acids)
- Brewer's Yeast
  - Saccharomyces Cerevisiae: Ale Yeast (fruit, spice and alcohol)
    - Top Fermenting, Warmer temps (>55)
  - Saccharomyces Pastorianus: Lager Yeast (sulfur)
    - Bottom Fermenting, cooler temps (44-50)
  - Brettanomyces
    - B.anomalous; B. Bruxellensis; B. Lambicus; B. Claussenii
    - More robust and able to break down more complex sugars
    - Funky, earthy, horse blanket, pineapple, barnyard, acidic
- Terms
  - Viability: % of living yeast in within a population
    - < 90% has noticeable impact on beer
  - Vitality: condition of living yeast in culture
  - Attenuation: % of sugars in wort converted
  - Flocculation: Tendency for yeast to clump together and drop out of solution
- By Products
  - Esters: (fruity, banana). Promoted by warmer temps.
  - Acetaldehyde (green apple). By product associated with young beer, will condition out with time.
  - Keytones: (Diacetyl). Will condition out of beer with time.
  - Phenols: (spice, clove, pepper, smoke). Yeast selection and stress (low pitch, extreme hi/lo temps).
  - Fusel Alcohol: (solvent). Heavier weight alcohols caused by yeast stress and high activity (high gravity, high temps, under pitch).
    - Generally will not condition out of beer
  - Fatty Acids: Can increase instability and oxidize beer
- Phases
  - Lag (0-24 hours after pitching)
    - Yeast takes stock of resources (FAN, O2, sugars, nutrients)
    - Begins building cell membranes and budding
    - Aerobic conditions are important at this stage
  - Exponential (Primary)
    - 4-hours to 6-days (longer for lagers)
    - 2/3-3/4 of total attenuation occurs during this stage
    - Krauesen forms
    - Anaerobic
  - Stationary (conditioning)

        - Begins in 3-10 days
        - Environment becomes alcoholic and lacking in nutrients
        - Much of yeast goes dormant, or dies.
        - Remaining yeast are scavengers
            - More complex sugars
            - Bi-products produced in primary phase
- Pitch Rates
    - 1 million cells per ml of wort per degree plato (roughly sg/4)
- Pitch temps
    - Ale – approx. 60-65 degrees
    - Lager – approx. 50-60 degrees
    - Raise temps 6-8 at end of ferm schedule to foster final attenuation and condition
        - Except Belgians that are already at high temps
- Nutrients
    - Most necessary nutrients are inherent in brewing water and mash
    - Add
        - Calcium (Cal Chloride is most neutral)
        - Zinc
        - O2
            - Need about 10ppm
            - Shaking, splashing – 4ppm
            - Aquarium pump – 8ppm
            - Pure O2, 60-90 seconds at 1L/Min – 10-14ppm
- Best Practices
    - Do a starter – increase yeast count, health and cell strength
        - Also stores reserves for lag phase
    - Hydrate dried yeast
        - Add dry yeast to sterile H2O at 95 degrees. Let cool to pitching temp. Pitch.
    - Pitch 3-5 degrees below desired ferm temp and let temp rise.
    - Harvest yeast for future batches.
        - Cultures improve each generation, however, difficult to keep cultures pure in homebrew environment, so limit harvest to 2-3 times per pure pitch.
        - Blended cultures will have different balance than original blend.
        - Harvesting tends to select for less flocculent yeast.
    - Maintain head space in fermentation vessel to allow room for krauesen
        - OR use blow off tube/hose
- Troubleshooting
    - No/slow start
        - Yeast viability – re-pitch new yeast
        - Temps too cold – raise temps
        - Give it an O2 Boost
    - Stuck fermentation
        - Rouse yeast by swirling vessel
        - Increase temps

    - Add fresh yeast
- Isn't finishing
    - Consult brew notes (high mash temp, higher than expected OG?)
    - Increase temps
    - Add yeast
    - Give it a sugar boost
    - Add enzymes (amylase)

Malt

- Germinated cereal grains: barley, wheat, oats, sorghum, rye …
- Barley is primary brewing malt
  - Best at converting sugars (high enzyme content – diastatic power)
  - Best beer characteristics (flavor, color, clarity, aroma, mouthfeel)
- What's inside
  - 80% of grain is endosperm: complex poly-saccharides (starches). Stable food source
  - Enzymes, which break down starches when activated by heat
  - Amino acids: molecular building blocks (peptides, polypeptides, proteins)
    - Bonded by nitrogen, which breaks up during germination and creates FAN
  - Lipids (waxes, fats, fatty acids)
- Mashing: Soaking crushed malt in hot water to activate enzymes which break down sugars
  - 113F – B-glucanase: Breaks down proteins, not necessary with modified malts and may thin out beer.
  - 126F – Protease: Solubilize proteins and produces FAN
  - 140F – B-amylase: Breaks starches down to sucrose/maltose (more fermentable/dry)
  - 162F – A-amylase: Breaks starches down to maltose, malto-triose, dextrines (more flavor and body)
  - 167F – Mash out: Denatures enzymes and sets mash. Also makes mash more viscous to promote sparge/lauter.
- Base malts have greater diastatic power (ability to break down starches) and should be >=80% of grist.
  - 2-row (Pale malt, pilsner malt)
  - 6-row (more proteins)
  - Wheat (huskless, can promote stuck sparge)
  - Rye (even stickier than wheat)
  - … Vienna, Munich (generally used with other base malts)
- Caramel Malts
  - AKA Crystal Malt: Sugars are caramelized in malt by increased temps.
  - Adds color and flavor (honey, caramel, toffee, raisin)
  - Add body, head and mouthfeel to beer
  - Do not exceed 15% of grist with "cara" malts
- Roasted Malts
  - Highly roasted to impart chocolate, coffee, roast and burnt flavors/dark colors
  - Can impart acidic, burnt, or astringent characters – adding at end of mash reduces harsh characteristics
    - Should be <5% of grist
- Maillard Reaction
  - Carmelization is thermal decomposition of sugars …
  - Maillard is thermal decomposition of amino acids (proteins)
    - Toasting bread, steak
  - Can achieve by decocting mash or by long boil times
  - Melanoidins are browning aspect of maillard reaction

- Dimethyl Sulfide (DMS)
    - S-methylmethionine (SMM) is precursor to DMS and is inherent in malt
    - Tastes like corn, cabbage, shrimp in finished beer
    - Usually driven away by kilning, however, lightly kilned malts (pilsner) haven't been heated enough to mitigate all SMM.
        - Increase boil time (90-min)
        - Don't cover boil so DMS can precipitate
- Troubleshooting
    - Poor conversion
        - Be sure you are using adequate base malt (diastatic Power)
        - Be sure that you have good crush on malt
        - Be sure pH is in 5.2-5.5 range
        - Be sure you haven't denatured enzymes by increasing mash temp >167 degree
    - Stuck sparge/lauter
        - Malt crushed too fine
        - If using huskless malt (wheat), be sure to add rice hulls
        - Raise mash temp to make more viscuous.
    - Hazy beer
        - Check recipe to determine if you are using high protein malts
        - Be sure you are using modified malts, or performing a protein rest otherwise
        - Be sure you are getting good hot/cold break
        - Use finings: Whirlfloc, Isinglass, Irish Moss, Gelatin
    - Under attenuation
        - Check mash temps (>150 results in less fermentable wort)
        - Check recipe for percentage of base malt (diastatic power) – should be 80% +

Hops

- Historically, beer was sweet and spoiled easily
- As with food, brewers began adding spices and herbs to flavor beer and to provide balance
  - Gruit: dandelion, burdock root, marigold, horehound, ground ivy, heather … and hops
  - Discovered that beer brewed with hops did not spoil as quickly (and tasted better)
- First record of hop cultivation in 750, but not a widely adopted brewing ingredient until 13th century
  - Preferences tilted due to taxation
  - 1500's hops still considered a "wicked and pernicious weed"
  - "Beer" is name given to ale brewed with hops.
- Production
  - Most hops production occurs near 48th parallel
    - Germany and US top producers
    - Ethiopia is third!
- Fundamentals
  - Humulus Lupulus (Cousin to cannibus lupulus)
  - Aggressively growing climbing vine
    - Single plant can grow up to 25 feet and produce 2-3 pounds dry weight of cones
    - Only female plants produce cones
  - Alpha acids (Humulones/Co-humulones)
    - Isomerize into bitter compounds (iso-humulones)
    - Many contend that iso-co-humulones are more harsh bitter
  - Beta Acids (Lupulones)
    - Are sensitive to oxidative decomposition (bad)
  - Essential oils
    - Myrcene
    - Humulene
    - Caryophyllene
  - Flavonoids
- Application
  - First Wort Hopping
    - Add low alpha finishing hops during lauter
      - Volatile oils which are normally insoluble, have chance to oxidize to more soluble compounds before boiling off
    - Results in less harsh bittering that is more uniform and compliments aroma/taste
      - IBU equivalent of 20-minute boil addition
  - Bittering hops
    - Alpha acids isomerize into bittering compounds
    - Flavor/aroma boiled away
    - Really about adding IBUs
    - 95% isomerization at 60min, 99% at 90 min
  - Flavoring hops (<30 min)

        - Moderate bitterness and characteristic flavor
    - Aroma/Finishing hops
        - Light bittering, fewer oils are evaporated
        - Steeping (flame out additions) may have tannins or grassy flavors that normally get boiled off
    - Dry hops
        - Added during fermentation
        - Improves hop aroma (may add vegetal flavors as well)
    - Wet hops
        - Adding fresh hops off bine to wort
- Growing hops
    - Obtain Rhizome (root clipping) of desired strain
    - Bury rhizome horizontally approx. 4” deep, where plant will receive full sun. Buds pointed up.
    - Place rhizomes 2-feet apart
    - Drip irrigate, don’t saturate as this will promote mold and fungus
    - Once they’ve grown 8-12” begin training them around a string or lattice.
    - Place 2 strings per rhizome and trim 2-3 bines per string (6 bines per rhizome)
    - After about 2-months of growth, trim bottom 3-4 feet of plant to prevent soil born disease and fungus
    - Harvest in late summer/fall when cones begin feeling dry/papery
        - Note: cones usually appear after about the 2-3rd growing season, after roots are established
    - OK to clip bines/string and lay out to pick cones.
    - Air dry the cones for 48-72 hours (better not to heat)
    - Vacuum seal and freeze – keep out of light
- Sensory and Characteristics
    - Cascade (grapefruit, floral, citrus)
    - Centennial (bright, fruity)
    - Amarillo (apricots, peaches)
    - Simcoe (grapefruit, pineapple, pine)
    - Citra (grapefruit, pineapple, mango, pine)
    - East Kent Goldings (floral, lemony)
    - Fuggles (earthy)
    - Sorachi Ace (lemony, dill)
    - Summit (orange, tangerine, grapefruit)
    - Styrian Goldings (orange marmalade)
    - Noble hops
        - Old world, central Europe, relatively low alpha
        - Floral, spicy, herbal
        - Hallertau, Tettnang, Saaz
- Popular Hops
    - Bittering Hops: Magnum, Chinook, Nugget, Challenger, Centennial
        - Generally select for high alpha, low co-humulone

        - Accentuate bitterness by increasing sulfates
    - Flavoring hops: Cascade, Amarillo, Styrian Goldings, Saaz, Fuggles, Hallertau, East Kent Goldings, Noble hops
    - Aroma hops
        - Galazy, Mosaic
- Best Practices
    - Categorize hops by character to foster interchangeability
        - Noble hops: Hallertau, Tettnang, Saaz
        - Citrusy American: Cascade, Amarillo, Citra
        - Tropical: Galaxy, New Zealand strains
        - English/European: Fuggles, East Kent Goldings, Styrian Goldings
        - Clean bittering hops: Magnum, Chinook, Challenger
    - Storing hops
        - Fresh is important
        - Hops can oxidize and become stale
            - Lose color, intensity and character
            - Taste/smell like sweaty socks, cheese
        - Store in freezer away from light (think skunky beer)
        - Seal in painted jar and bathed in CO_2
    - Don't bitter with lo alpha hops –
        - Uses a ton of hops
        - Might add vegetal notes (see above)
        - Might jam up system (see above)
        - No apparent relationship between measured bitterness and hop flavor/aroma
        - Spicy hops are perceived as more bitter than floral/fruity hops
- The problem with IBUs
    - A good absolute measure, a poor relative measure
        - "Hoppyness" is about balance with malt
    - Human taste threshold of hops is about 100 IBUs

Dirty Dozen: Tips for improving homebrew

- Use Fresh Ingredients
  - Garbage in – garbage out.
  - Stored grains can become stale (whole grains are more resilient than crushed grains)
  - Hops can oxidize (think skunky beer), lose aromatics, and take on vegetal qualities
  - Yeast loses viability
  - Embrace good storage techniques
    - No light
    - No Oxygen (CO2 baths)
    - Cold temps
- Sanitation
  - Cold side: Hoses, gaskets, carboys, buckets, airlocks …
  - Bottles (caps), kegs (gaskets)
  - Use Star-san – don't fear the foam!!
    - < 2.5 pH (Acidic)
    - Not as effective at killing lacto-bacteria (which produces acid)
  - Use heat
    - +175 degrees, 10-15 minutes
    - Boil (wet), oven (dry), steam (dishwasher)
  - Iodine (iodopher)
    - Will stain equipment after awhile
    - Doesn't affect flavor or function of equipment
  - Alcohol
    - Produced by beer
    - Great for adjuncts (soak in vodka – tincture!)
  - Bleach: Must rinse … don't use it.
- De-Chlorinate the water
  - Chloramine (ammonia treated chlorine)
  - Leaves a residual taste in beer
  - Remove it!
    - Aerate (Chlorine)
    - Boil (Chlorine)
    - Camden tablets – potassium metabisulfate (Chorine/Chloramine)
    - Carbon filters/RV filters
    - Reverse Osmosis
    - Store purchased water
      - Low in ions/buffers
- Manage pH
  - Measure of how acidic/alkaline a solution is
  - 7 is neutral … 5 is 100 times more acidic than 7 (algorithmic)
  - Should target 5.2 in mash
    - Malts tend to drive mash pH to target
    - Ions in water serve as buffers that inhibit pH reduction

        - Filtered water is often stripped of ions and will drop in acidity much quicker than tap water.
    - Why it matters
        - Better enzyme activity and starch conversion
        - Lower pH in the finished wort which improves yeast health during fermentation
        - Lower pH in wort inhibits bacteria growth (infection)
        - Improved hop extraction rates in the boil
        - Better protein and polyphenol precipitation both during the cold break and post fermentation
        - Improved clarity in the finished beer with reduced chill haze
        - Improved flavor and clarity stability as the beer ages
- Don't over sparge
    - Sparging is adding brewing liquor to the mash in order to rinse the sugars from the mash
        - Lautering is the process of separating the wort from the mash
    - Sparging tends to increase wort pH (adding higher pH water to acidic wort)
    - Lautering compacts the grain bed and reduces the sugars in the mash solution
    - The effect is to increase the amount of tannins we draw off the grain husks
        - The result being perceived as astringency
    - Best practices
        - Don't use sparge water over 170 degrees
        - Acidify your brewing liquor (sparge water) to reduce pH < 6.0
        - Cease lautering when run-off reaches 1.010
        - Maintain pressure of lauter flow to prevent compacting grain bed, which can inhibit lauter (stuck sparge), extract tannins, and promote channeling (which reduces efficiency significantly)
- Boil it good
    - A good boil pasteurizes the wort
    - Enzymes are de-natured, setting the malt profile and sugar complex
    - Proteins "break" from solution, fostering clarity and less heavy mouthfeel
        - Tannins floc with protein break and drop from solution
    - Hop alpha acids are isomerized and made soluble
    - DMS is volatilized and boiled off
    - Caramelization of sugars takes place
    - Maillard reaction occurs (protein reaction to heat)
        - Adds flavor and complexity to beer
    - Hot solution is conducive to adding sugars and adjuncts (dissolves into solution)
    - Wort is concentrated due to evaporation
    - pH levels are reduced
    - O2 is boiled off, which makes beer more stable.
    - Boiling best practices
        - Leave headroom in kettle to give room for breaks and hop foam
        - Don't cover kettle to let DMS precipitate
        - Use kettle with clad bottom to promote better heat distribution and prevent scorching

        - Wait until initial hot break before adding bittering hops to boil
        - Reduce heat when adding hops
        - Keep spray water bottle near boil, a squirt will break surface tension from foam breaks, which is cause of boil overs
        - Post boil pH should be around 5.2
            - Add gypsum if necessary
        - Add aromatics at flame out so not to boil off volatile aromas
        - Don't scorch sugars/grains/adjuncts at bottom of kettle
- Chill it good
    - Facilitates cold break, which precipitates proteins and solids from solution
    - Reduces exposure to potential contaminants by reducing time to yeast pitch
    - Chilling methods
        - Create concentrated wort then top off with cold, sterilized water
            - Pro: enables brewing volumes that exceed kettle size
            - Con: More work; water ended late in conveys watery character to finished beer
        - Soak kettle in ice bath (or snow in winter)
            - Pro: Cheap
            - Cons: Takes longer to chill; requires life of heavy kettle full of boiling wort
        - Immersion chiller
            - Pro: Can easily sanitize chiller in boil; leaves break in kettle
            - Cons: Takes longer than some alternatives; need to run off water
        - Plate chillers
            - Pro: Quick and effective chilling
            - Cons: More difficult to clean; break material ends up in fermentation vessel; need to run off water
        - Counterflow chiller
            - Pro: Easier to clean/rinse than plate chiller
            - Cons: Break material ends up in fermentation vessel; need to run off water.
- Oxygenate the wort
    - Yeast need O2 to synthesize sterols and unsaturated fatty acids for cell membrane biosynthesis.
    - Without aeration, fermentations tend to be under-attenuated because O2 availability is a limiting factor for yeast growth
        - The yeast stops budding when sterol levels become depleted
    - O2 is essential during the lag phase
        - Need about 10ppm of O2
        - Shaking, stirring, splashing = 4ppm
        - Aquarium pump = 8 ppm
        - Pure O2, 60-90 seconds at 1L per minute = 10-14ppm
- Don't Oxygenate the Beer

    - Oxidation is the loss of electrons during a reaction by a molecule, atom or ion. While the term implies O2 as a catalyst (which it is), it is a legacy term as various compounds can serve as catalysts
    - In laymans terms, Oxidation is the decomposition of compounds in beer
    - In brewing, Oxidation is associated with aging and staling of beer (stability)
        - Papery, lipstick, rotting vegetables, sherry-like, vinous, toffee, butter
        - Other oxidizing compounds in beer include yeast enzymes, hops, and melanoidens
    - Tips for reducing oxidation
        - Limit agitation of mash (hard stirring)
        - Don't splash hot work
        - Reduce headspace in fermentation vessels, kegs and bottles
            - Cap with CO2
            - In primary, yeast will provide CO2 and pressure that inhibits O2 presence
        - Don't splash during transfers
        - Store cool, and limit movement of beer
        - Don't keep opening carboys for samples
        - Use O2 absorbing bottle caps
        - Consider the permeability of fermentation vessels
        - Drink hoppy beer fresh, as they will break down with age.
- Pitch enough healthy yeast
    - 2 billion cells per gallon per degree plato
        - 5 gallons 15 plato wort (1.060) = 15 x 5 x 2B = 150B cells
        - Smack Pack, vial or dry yeast pak contains about 100B cells
        - WAG (Wild Ass Guess) method: about 1.5B cells per 1ml of thick slurry
        - Double for Lagers
    - Use a yeast starter
        - Increase cell count, strengthen cell walls, get them warmed up
        - Pitch starter about 18-24 hours after krausen has settled
    - Hydrate dried yeast
- Manage Fermentation Temps
    - Hold temps at steady temps
        - 62-64 degrees for ales
        - 48-52 degrees for lagers
        - Raise temps into 80s for Belgian styles
    - Recommended schedule
        - Pitch yeast when wort is 3-5 degrees below target and let it warm to stable temps
        - Hold temps steady for 2/3 of ferm schedule
        - For final 1/3 of schedule raise temps 2 degrees per day to reach 6-8 degrees above primary temp.
            - This fosters conditioning and finish
            - Exception is with Belgians that are already at high temp.

        - Crash beer (drop temp below 40) to drop yeast out
            - This often happens in package (keg or bottle)
    - How to cool
        - Evaporation: Wrap moist towel around carboy
        - Cool ambient: control temps of storage space
        - Place carboy in cool tub of water
        - Create insulated box that is cooled with milk cartons of ice
        - Use a freezer with a temp controller
    - How to heat
        - Wrap in blanket
        - Aquarium heater in bath
        - Insulated space/box (empty fridge) with heat source (lamp, small heater) and controller
        - Ferm wrap
- Let the beer finish!
    - Patience is a virtue
    - Just because you hit terminal gravity does not mean that the beer has finished
        - Many yeast bi-products still reside in beer (diacetyl, acetaldehyde)
        - Flavors have yet to meld into a composed and complimentary state
        - Much of yeast is still suspended in solution
        - This is called a green beer
    - As long as yeast is present, beer will continue to evolve
        - Yeast will consume its own bi-products in absence of sugar
        - Alcohol "esterifies" into smoother, more spicy character
        - As food is reduced, yeast will drop – smoothing flavor and clarifying appearance
    - Give beer 2-3 weeks beyond terminal gravity to condition (Lager)
        - If long conditioning beers, move to secondary to get off trub
        - Secondary in glass carboy to mitigate oxidation
        - Long conditioning on dead yeast can result in autolysis (burnt rubber character)
- No light on beer
    - Lightstruck, or skunky beer occurs with UV light splits apart alpha-acid compounds from hops
    - Hop particles combine with sulfurous molecules from malt to form 3MBT
    - Reaction literally takes seconds.
        - Beware your glass of beer sitting next to BBQ
        - Beware your freshly filled carboy sitting in the sun on your patio after brew day
    - Prevention
        - Use brown bottles, kegs, or cans to store beer
        - Keep carboys out of light
        - Keep hops out of light during storage
        - Don't leave hops sitting in sun on brew day (e.g. weighed in a clear plastic cup)

Funky Beers

- Historically, all beers were funky. As scientists came to understand micro-organisms and developed the ability to isolate cultures (mid 1800s), they learned which cultures produced "clean" beer and began to control accordingly.
  - Many styles that feature sour and funk still persist, and brewers have learned to harness the awesomeness of the funk!
- Main sources of funk in beer:
  - Brettanomyces (British Fungus)
    - A very high attenuating yeast
    - Far more tolerant to extremes than yeast: heat, pH, alcohol, lack of nitrogen
    - Releases enzymes that enable the breakdown of more complex sugars and carbohydrates
    - Most common brett strains for brewers
      - Clausenii: Over-ripe pineapple, funk (British stock ales)
      - Bruxellensis: Sweaty, horseblanket, leathery (Orval)
      - Lambicus: Funk, sour cherry (Lambics)
    - In practice
      - Brett produces more acetic acid (vinegar) in presence of O2 and competition from other organisms
      - 100% brett beers tend to be more fruity/less funky
      - Stressing brett (low pitch, low food source – secondary , higher/lower temps) produces more funk.
      - Give brett time to finish – 4-6 weeks or longer.
  - Lactobacillus
    - Lactic acid producing bacteria (LAB)
    - There are dozens of strains of lacto – most of which are found in our guts
    - Lacto is not very attenuative and will only use about 10% of sugar in wort
    - Common strains used by brewers
      - Delbrueckii, brevis, plantarum, buchneri
      - Brevis and Plantarum produce most lactic acid
      - Work consistently in temps from 86-108(F)
      - Achieves approx. 90% of pH reduction in 24hrs, 100% in 120 hrs.
    - Lacto is intolerant to hops > 10 IBU
      - Increased tolerance can be cultured.
    - Kettle souring with pure culture produces a typically cleaner sour
      - Lacto souring in fermenter, aside from potential inhibition of lactic production due to hops, alters the yeast metabolism process – notably, inhibits ability to clean up diacetyl.
  - Pediococcus
    - A lactic acid producing bacteria (LAB)
    - Native to plant material and fruits
      - Culprit in most spontaneously fermented beers.
      - Capabilities within beer are very strain dependent

            - Able to synthesize/metabolize more complex carbs
                - Secretes exopolysaccharide (sugar residue)
                - Appear “ropy” or “sick”
                - But, in time, will consume and metabolize this as well
            - Pedio is mostly homofermentative
                - While not fully anerobic, O2 does inhibit growth
            - In practice
                - The “ropiness” and subsequent metabolizing contributes fuller, more silky mouth and more complex sour character – not just tart
                - This requires more time (6 months to 5 years!)
                - Pedio needs to be paired with primary yeast for fermentation
                    - It plays well with Brett
                    - Brewing strains are much more hop tolerant
                - Pedio fermentation produces significant amounts of diacetyl, which needs long aging to clean up.
                - It is a hyper-attenuating bacteria (especially when paired with brett)
                    - Be careful in bottling
- Wort Production
    - Although sour beers can be made with standard grist/wort recipes, these additional considerations can improve results:
        - Use malts and mash techniques that result in higher protein content
        - Use malts and mash techniques that result in more residual and complex sugars (dextrines)
        - Goals are to produce a more starchy and dextrinous wort
    - These techniques account for both the capability of brett and pedio to break down more complex compounds and the fact that they need a longer stock of nutrition to get them through extended fermentation/conditioning.
- WTF!
    - Pellicles: In presence of O2, pedio and brett (and other bugs) will produce polymers, cells and proteins that coagulate into a surface cap as a way to mitigate O2 exposure.
        - This is not harmful (unless mold begins to form)
    - Butyric acid: A product of the clostridium bacteria generally introduced by malt in sour mashing. Smells like vomit, or baby diaper (yuk!).
    - Acetobactor: is an acetic acid producing bacteria that resides on plants, gets carried around by bugs, and drifts in the air.
        - It turns ethanol into vinegar in presence of O2.

Parti-Gyle: Multiple beers from a single mash

- Types of Parti-gyle
    - Splitting wort after boil
        - Different fermentation/adjunct treatments
    - Second runnings of wort off mash
        - Big beer/small beer
    - Split multiple runnings of wort to achieve targeted gravities
        - Partitioning the wort (Parti)
- Background
    - Historically, making multiple beers from a single mash was a standard practice and usually involved pulling the first runnings as the premium beer, second runnings as a standard beer, third runnings as a table beer, and even fourth runnings for the peasants and children.
        - Mention of the practice shows up in the literature dating back to the 1700s
        - It is more cost effective, and it maximizes production time, and uses all the extract in the mash
        - It saved brewers on taxes
        - Expands menu of offerings
        - Is the source of many styles we enjoy today (Trappist Single for example)
    - Benefits
        - Essentially, a 2 for 1 brew day
        - Make more styles of beers (won't have to consume umpteen gallons of same beer)
        - Helps to gain knowledge and understanding of distinctions between styles.
        - Provides opportunity to use different treatments: yeast, adjuncts, temps, etc to see differences in outcomes.
    - Equipment: working back from the glass
        - Two beer glasses ☺
        - Two 5-gallon kegs (corneys)
        - Two 6.5 gallon Ale Pales (or carboys)
        - Two 10 gallon boil kettles
        - Two burners
        - Mash Tun
            - Hold approx. 30# of grist and up to 10-12 gallons of water
        - Hot Liquor Tank for sparge
            - Approx 15 gallons
        - Two yeast starters (Erlenmeyer flasks – 5L)
        - *Feel free to make adjustments to fit your system/process – basically, you need an extra boil kettle and burner if you plan to brew each "gyle" concurrently.
    - What to Brew
        - A single style with different tweaks
            - Gravity, hops, ferm temps, yeast, adjuncts
        - Closely aligned styles

            - Best Bitter, Strong Bitter; Pilsner, Kolsch; Scottish Heavy, Scottish Export
        - Different styles, but with similar grists
            - Am Porter, Irish Stout; Belgian Tripel, Helles Bock
        - Big Beer … Little Beer
            - RIS, Porter; Golden Strong, Trappist Single; Helles Bock, Helles
        - Get outside the box
            - Marzen, Cal Commons; NEIPA, Sour NEIPA; Pale Ale, Starter wort
    - The key – estimating gravity of the runnings
        - There are charts for estimating the potential extract of 1# of malt in 1-gallon of water. Basically, the SG at 100% conversion: 1.040 = 40 gravity units of potential extract
        - Many charts are available to help determine mash extract potential
        - Multiply GUs of all malts in recipe x their weight then add them up
            - Pale Malt 10# * 37 GUs = 370
            - Crystal 2# * 33 GUs = 66
            - Total extract potential for recipe = 436 gravity units
        - Mash efficiency is ratio of how many GUs end up in boil kettle
            - 10 gallons of 1.040 wort = 400 GUs = 91.7% mash efficiency (400/436)
            - This calculation is helpful in determining strategies for hitting target gravity at end of boil
                - If I start with 10 gallons of 1.040, but need to hit OG of 1.050, I need to boil down to 8 gallons. 400/50 = 8.
                - Likewise, if my boil evaporated down to 6 gallons, I know from the above calculation that I need to add back 2-gallons of water to hit the volume needed to result in a finishing OG of 1.050 (50 gravity units)
        - Rules of thumb for determining gravity for two boils
            - 2/3 of potential gravity will run off in first ½ of runnings
            - Half of potential gravity will run off in first 1/3 of running.
            - Example: Mash with potential extract of 1200 gravity units
            - 90% mash efficiency (system/process dependent) = 1080 GU
                - If I ran this off into a single kettle and got 18 gallons of wort, I would anticipate my gravity to be 1.060 (1080/18).
                - But when splitting between two kettles:
                    - 2/3 of potential gravity is in first ½ of running
                    - 9 gallons wort at 1.080
                        - 1080 * .67 / 9 = 80.4 (1.080)
                        - 356 gravity units remain
                        - If I run off balance to second kettle, I will anticipate getting 9 gallons of 1.040 wort (356/9 = 39.56)
                        - Note that in a 50/50 run off where I fill one kettle then the other, I anticipate that the big beer will be twice the gravity of the small beer

            - Second estimating tool:
                - Half of gravity units will run off in first 1/3 of wort
                - From example above, if I only pull 6 gallons of my estimated 18 gallons of wort from mash, I can anticipate that I will get 6 gallons of 1.090 wort
                - Leaving 12 gallons and 540 gravity points in mash (potentially 1.045 wort if I run it all into second kettle)
                - Now, if I use the first formula and pull 1/2 of the remaining volume of 12 gallons, I should get 6 gallons and 360 gravity points = 1.060 (with 180 gravity points and 6 gallons – 1.030 – remaining in mash).
                - If I add half the remaining mash wort to the second kettle, I will add 3 gallons and 120 gravity points, bringing the total in kettle 2 to 9 gallons and 480 gravity points = 1.053.
                - And, if I add the remaining mash wort to the first kettle, I will get 9 gallons and 600 gravity points (adding final 60 GUs and 30gallons, to 540 GUs and 6 gallons). Pre-boil gravity will be 1.067
                - Finally if I boil both kettles down to 7 gallons, my OG for each will be:
                    - Kettle 1 600/7 = 1.085
                    - Kettle 2 480/7 = 1.069
            - Not as confusing as it seems.
        - If gravity in boil kettle is low, and you cannot adjust by boiling off, you can add sugar (corn sugar, honey, brown sugar, table sugar, etc) at a rate of 46 gravity units per pound.
            - Example, if at end of boil, I am at 1.036 and 7 gallons (252 GUs) and my target is 7 gallons of 1.040 (280 GUs), I know that I need to add 28 GUs to my boil. This is equivalent to .6# of sugar (.6*46 = 28).
        - I also know that If I have 8 gallons of 1.060 (480 GUs) wort in kettle 1 and 6 gallons of 1.040 (240 GUs) of wort in kettle 2, and that I want 7 gallons in each kettle – I can pull 1 gallon from kettle 1 to event my volume. By doing this, I will be adding 60 GUs to kettle 2 for a total of 300, or a gravity of 1.043 (300/7).
- These methods not only help you calculate Parti Gyles, they can help you make game time audibles as you try to make adjustments to hit desired gravities.

Fun Techniques

- Decoction Mash
  - A technique for raising mash temp by removing a portion of the mash, boiling it, then returning it to the mash
    - Adds color and melenoidens (improved malt character)
    - Breaks down starches, enables improved mash efficiency
    - Improves “crispness” of beer
    - Improves clarity by breaking down proteins
  - Typically done with German lagers and ales
  - How to do it
    - Use brewing softward/calculator to determine amount to decoct
    - Draw thick mash, not liquid (that’s where most of the enzymes are)
    - Rest the decoction at 150-ish to convert sugars before raising to boil
    - Be sure not to burn the mash (stir!)
    - Be careful when handling hot mash (wear gloves)
- Recirculating Mash
  - A process of cycling the wort through the mash
    - Sets grain bed for sparging
    - Improves clarity of beer by filtering solids and proteins
    - Can help control mash temperature
    - Can help improve mash efficiency
  - Vorlauf: Simply drawing wort into a pitcher and pouring it back into mash
  - Pump recirc: running wort through a pump and back to mash
  - RIMS: Run wort through pump/heater and back into the mash.
  - HERMS: Run wort through pump, through wort chiller immersed in HLT, and back into wort
    - Can use RIMS and HERMS to control mash temp
  - In all cases, be careful to control flow, as you may over compact the grain bed, causing tunneling or stuck sparge.
- No Sparge
  - A method in which no water is added to the mash during the lauter process and the mash liquid (wort) is simply drained from the mash into the boil kettle. In practical terms, the method has similarities to BIAB and batch sparging.
  - Pros
    - Saves time, reduced steps = reduced variability = more consistency
    - Don’t need separate HLT and sparge apparatus
    - Mashing at higher water to grain ratio supports completer conversion and good attenuation
    - Mitigates risk of over sparging
  - Cons
    - Requires a larger mash tun
    - Method requires full drain of mash which can impact the grain bed and cause mash to stick or tunneling

        - Typically gets less volume of wort than you might with continuous sparging.
        - Significant inefficiency when brewing high OG beers
    - Techniques
        - Determine pre boil kettle volume
            - Add additional ½ quart of brewing liquor per pound of grain to account for absorption
            - Add additional amount of brewing liquor to account for dead space in mash tun (approx. 1-gallon)
- Using Wort as Sparge Liquor
    - This method involves creating a wort from a mash (or extract) then using that wort as HL to sparge a second mash.
    - Pros: The method is used to achieve a higher all grain OG than the size your MT typically allows.
    - Cons: Difficult to calculate gravity (it's a gravity unit thing)
    - Alternatives
        - Add LME/DME/sugar to boil
        - Add LME/DME/sugar to fermentation
- Kettle Sour
    - A method for quick souring beer that occurs on the hot side of process. Therefore, you can boil wort (kill souring organisms) and add hops after souring without inhibiting lactobacillus
    - Pros
        - Much quicker overall
        - Reduces chance to infect cold-side equipment
        - More controllable/predictable
        - Able to make hoppy sour beers
    - Cons
        - Sour is more 1-note (lacto)
        - Increase hot side brew time (2-3 days)
        - Requires additional equipment
        - Scoffed at by many traditionalists
    - Method
        - Conduct mash, run off wort, flash pasteurize (15-minute boil)
        - Reduce wort temp – hold at 95-115 degree (100-105 optimal)
        - Pitch lacto (culture, malt, yogurt, probiotics)
        - Keep kettle covered, inhibit O2 which is catalyst for undesired nasties
        - Wait 24-72 hours until pH reaches target
        - Rack and boil/hop as usual
- Warm Ferment
    - This technique enhances yeast character and activity
        - Esters
        - Phenols
        - Fusels (bad)
    - Can help drive higher attenuation (dry out beer)

    - Entirely appropriate for some beers (Belgians, saisons, farmhouse ales, weisse biers …)
        - Know your yeast
        - Increase temps after primary
        - Careful to avoid too aggressive of an early fermentation
        - Allow time for the beer to condition
            - Diacetyl and acetaldehyde will form and yeast will clean given time
            - Some alcohols will esterify and take on a spicy character
            - You're fucked with fusels
- Lagering
    - Refers to the process of cold-conditioning beer for an extended time
        - Typically with bottom fermenting, lager yeast (saccharomyces pastorianus)
        - A yeast that thrives in colder temperatures and which was isolated during the process of lagering
    - Any beer can be lagered and many will profit as a result
        - Clarity
        - Cleaner flavor (given time, yeast "conditions" or cleans up many off flavors)
        - Better attenuation
        - Hoppy beers shouldn't be lagered – hop oils will oxidize and cellulose material becomes vegetal tasting in beer
    - Methods
        - Temperature control
            - Chest freezer with controller
        - Follow yeast parameters, start towards high end (54 for lagers, 64 for ales). After 3 days or so (as primary krausen begins to settle) drop the temps 2 degrees per day until you reach lower end of range (44/55) and rest for several days
        - After rest, conduct diacetyl rest, where temp is raised 5-6 degrees to rouse yeast and spur activity.
        - Give a few weeks
            - Not about reaching terminal gravity, it's about conditioning and smoothing out flavors.