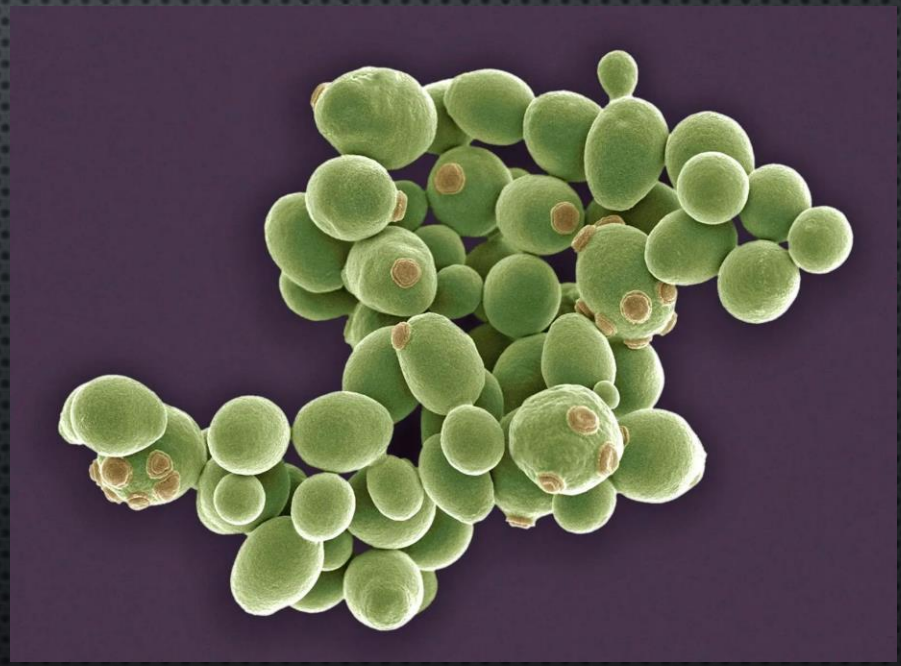
DOUBLE, DOUBLE TOIL AND TROUBLE

FRIENDS WITH BEER HBC

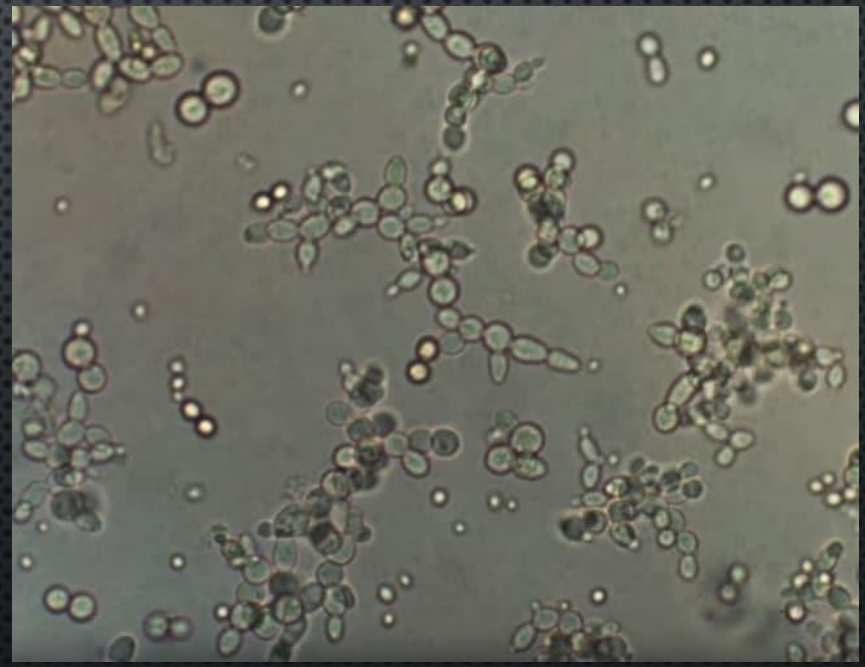
YEAST

- Single celled eukaryotic fungus
  - Eukaryote – "True Nucleus"
  - ~1,500 species
  - Reproduce asexually via "budding"
  - *Saccharomyces cerevisiae* (Top Fermenting yeast)
  - *Saccharomyces pastorianus* (Bottom Fermenting Yeast)



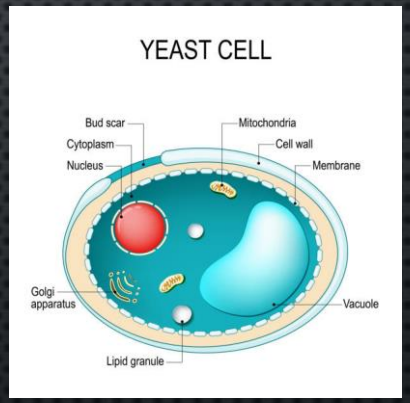
YEAST

- Can Produce
  - Alcoholic
    - Beer, wine, Industrial Ethanol
  - Nonalcoholic
    - Breads, Root Beer, Kvass, Kefir, Kombucha
- Other uses
  - ~20% of biopharmaceuticals use *S. cerevisiae* for insulin, vaccines, human serum albumin



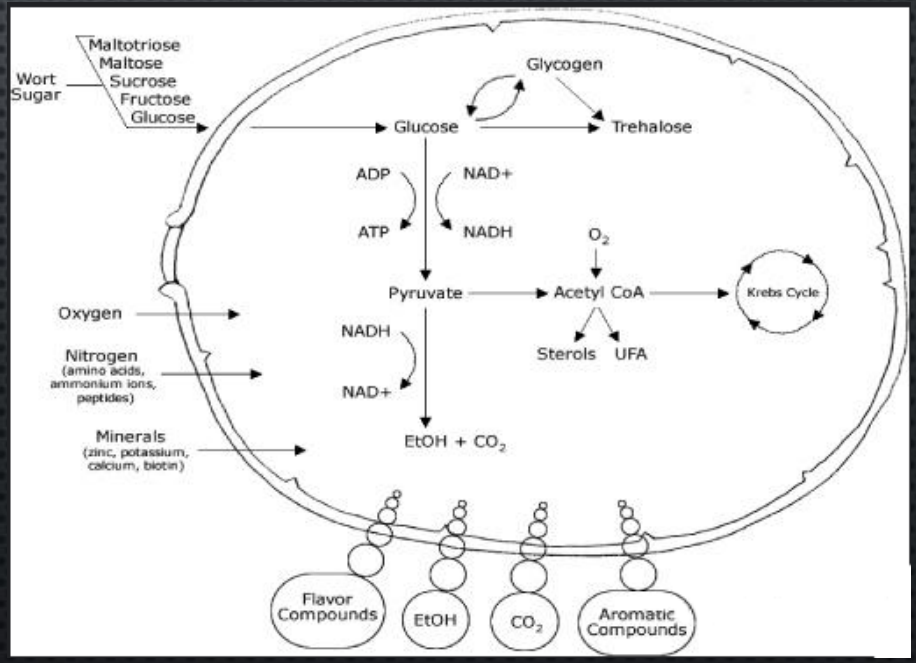
CELL STRUCTURES

- NUCLEUS – "BRAIN" OF THE CELL, CONTAINS THE DNA
- MITOCHONDRIA – "POWERHOUSE" OF THE CELL
- CYTOSOL – GEL-LIKE SUBSTRATE CONTAINS ALL THE ORGANELLES, CONTAINS THE ENZYMES RESPONSIBLE FOR ANAEROBIC FERMENTATION
- VACUOLE – STORAGE STRUCTURE
- GOLGI – PACKAGING STRUCTURE



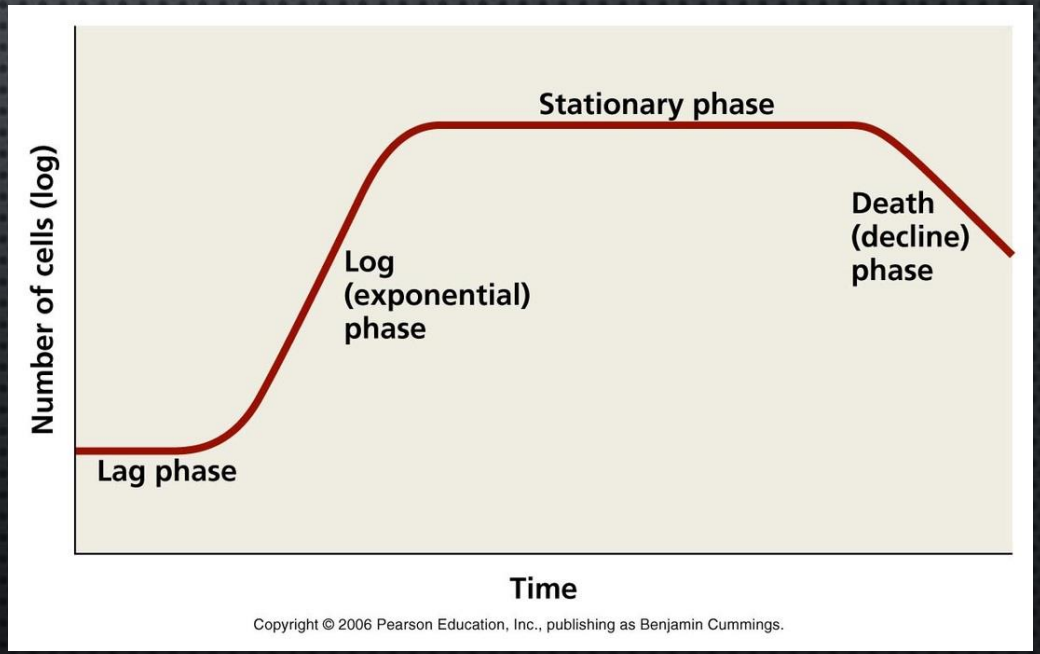
CHEMOORGANOTROPHS

- USES ORGANIC COMPOUNDS AS ELECTRON DONORS, I.E. RESPIRATION
- ORGANIC COMPOUNDS
  - ANY MOLECULE THAT CONTAINS A CARBON-HYDROGEN BOND
  - IN BREWING – SUGARS
    - GLUCOSE, SUCROSE, FRUCTOSE, ETC.



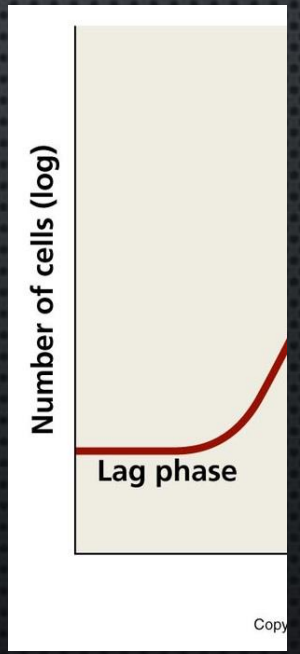
Life Cycle

- Lag Phase
  - Adaptation of cells to the wort
  - Little to no cell division
- Log (Exponential) Phase
  - Cells double at a constant rate
  - *S. cerevisiae* doubles approximately every 90 minutes
- Stationary Phase
  - Growth limited due to depletion of required nutrient
  - Cell Growth Rate = Cell Death Rate
- Death (Decline) Phase
  - Flocculation Occurs



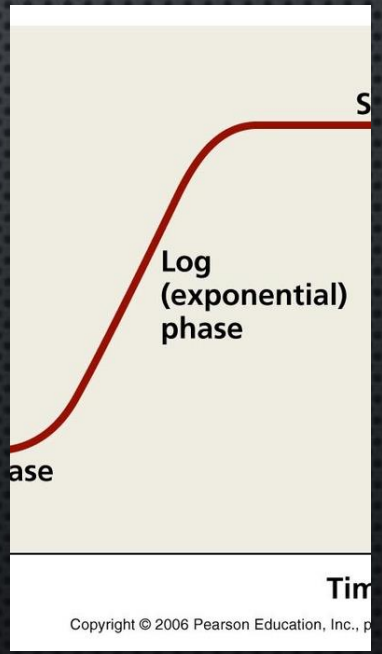
LAG PHASE

- 0 – 15 HOURS AFTER PITCHING
  - LENGTH DEPENDS ON WORT TYPE, GRAVITY, YEAST STRAIN, YEAST HEALTH, PITCHING RATE, AND AERATION
- PATHWAYS FOR SUGAR UPTAKE AND REPRODUCTION (REPLICATION) TURN ON
- OXYGEN IS NEEDED FOR PRODUCTION OF VITAL COMPOUNDS
- HIGH LAG PHASE TEMPERATURES MAY PRODUCE PRECURSORS TO DIACETYL
- OVER PITCHING WILL DECREASE LAG PHASE BUT MAY PRODUCE OFF-FLAVORS AT THE END OF FERMENTATION



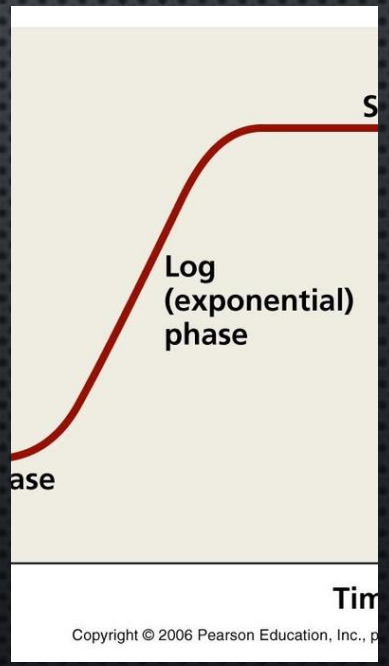
LOG PHASE

- 1 – 4 DAYS AFTER PITCHING
- CONSUMPTION OF SUGAR BEGINS
- CO_2 PRODUCTION BEGINS
- CELL COUNTS INCREASE RAPIDLY
- ETHANOL AND FLAVOR COMPOUNDS ARE PRODUCED



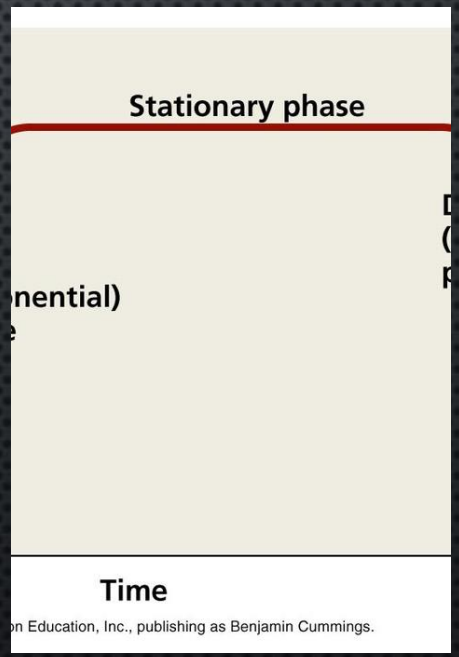
Log Phase

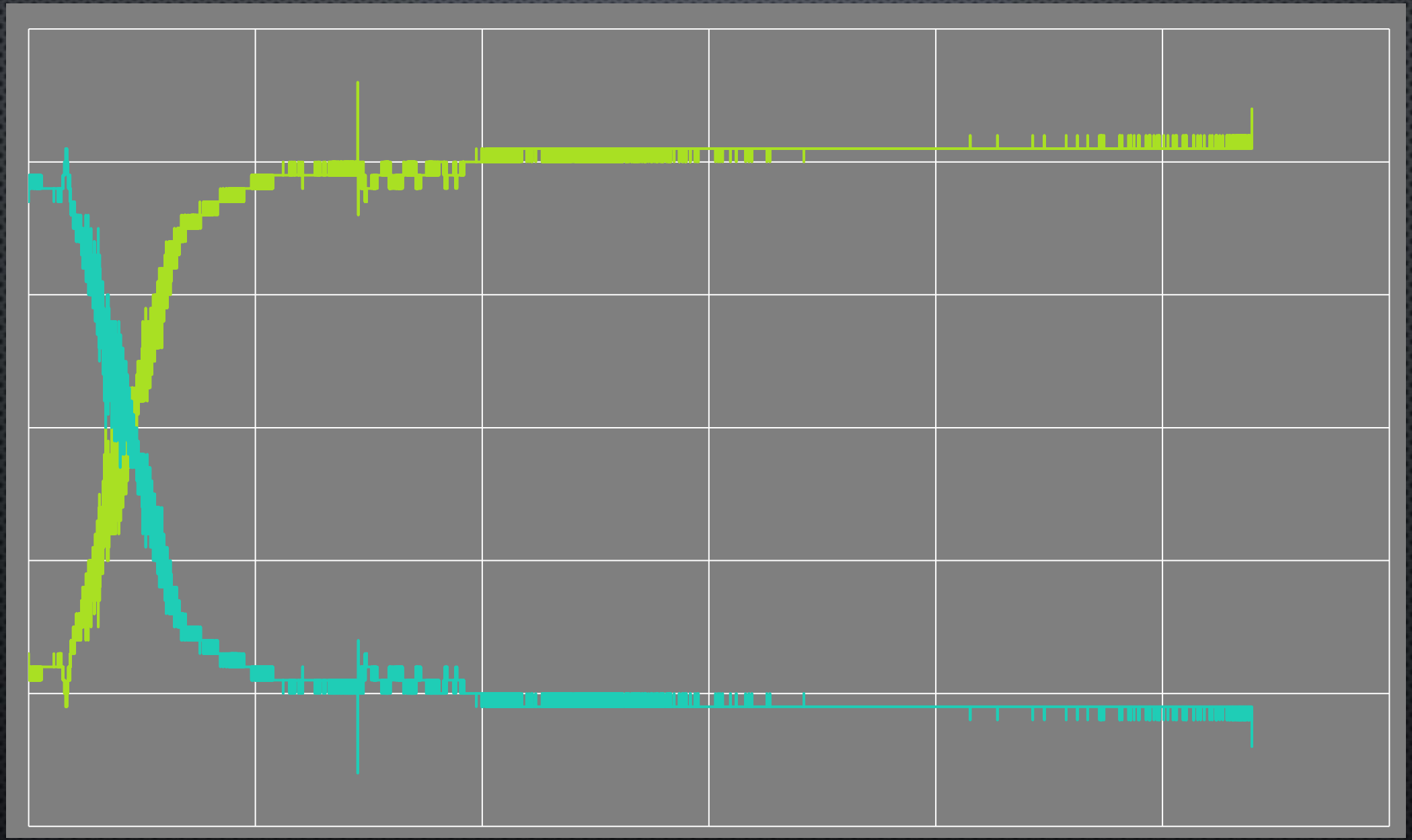
- Sugar Usage
  - Glucose (~14% of Wort) used first
  - Maltose (~59% of Wort) is converted to Glucose and then used
    - Center piece of the beer flavor
  - Maltotriose is the last used
    - Greater flocculation the less Maltotriose is used



STATIONARY PHASE

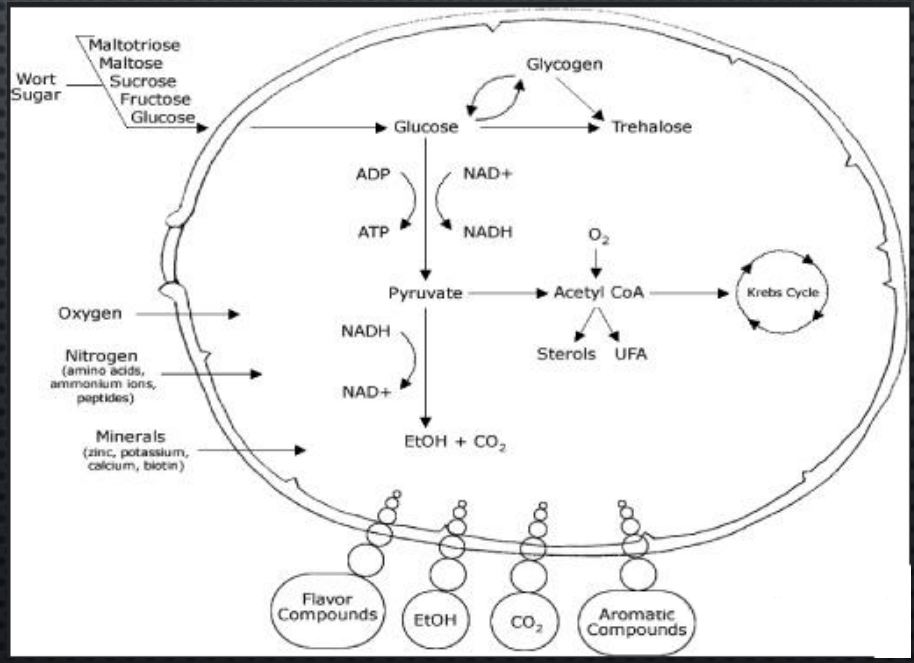
- 3 – 10 DAYS
- MOST FLAVOR AND AROMA COMPOUNDS HAVE BEEN PRODUCED
- BEER MATURATION OCCURS HERE
  - DIACETYL IS REABSORBED
  - FLOCCULATION OCCURS
    - SOME STRAINS MAY BEGIN TO FLOCCULATE BEFORE REACHING TERMINAL GRAVITY
    - "COLD-CRASHING" CAN FORCE FLOCCULATION

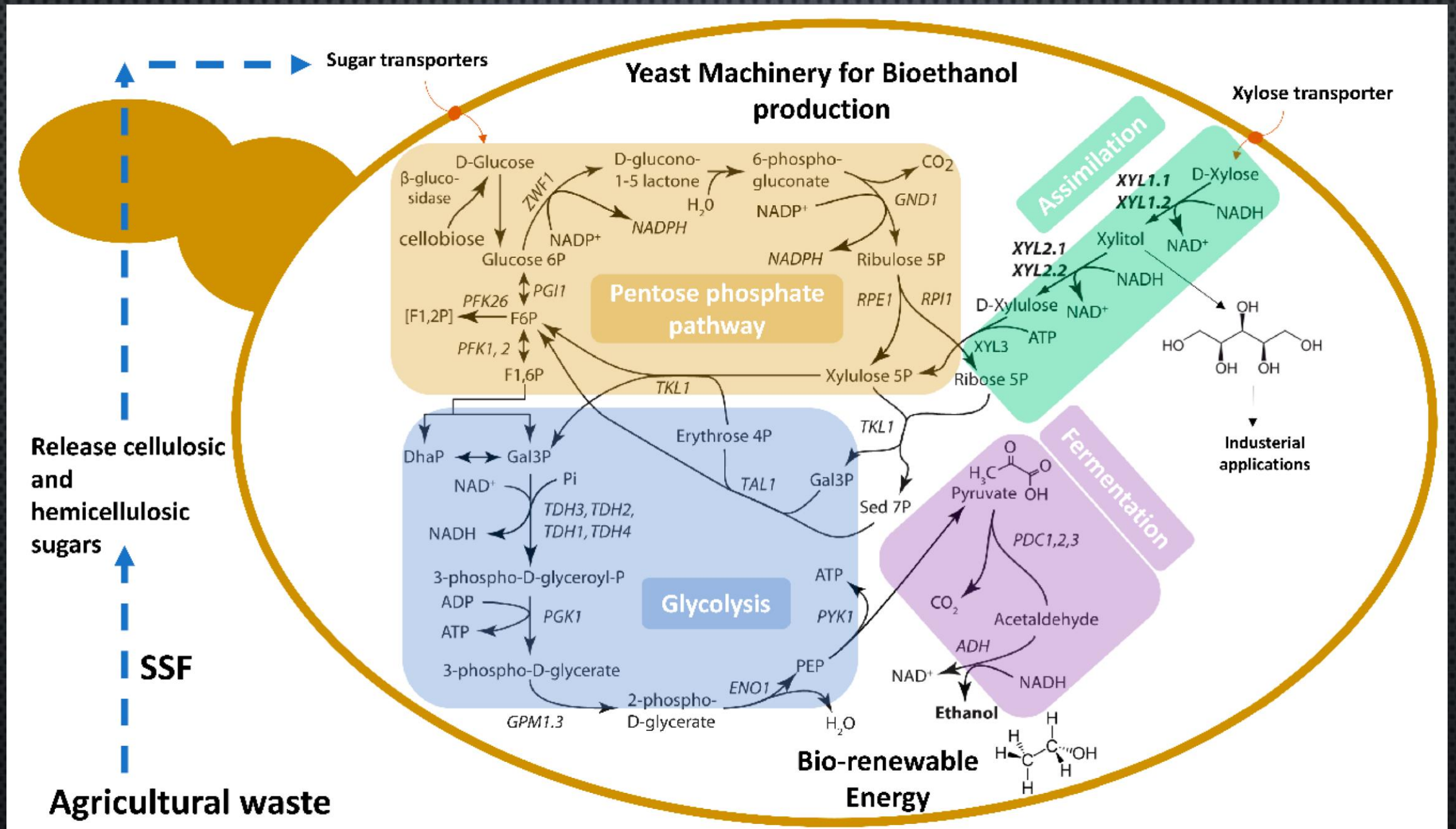




FERMENTATION

- Anaerobic energy production
  - Sugars → alcohol, CO_2 and Energy
- Temperature is critical to good fermentation
- *S. cerevisiae*
  - "Top fermenters" (ales)
  - Fermentation temperatures are typically higher (65 – 75 °F)
- *S. pastorianus*
  - "Bottom Fermenters" (lagers)
  - Fermentation temperatures lower (40 – 58 °F)



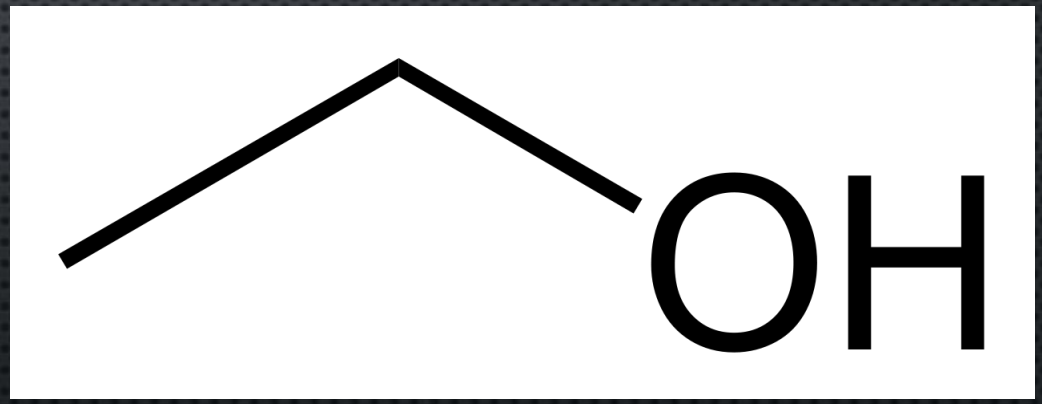

Sugar transporters
Yeast Machinery for Bioethanol production
Xylose transporter
Assimilation
Pentose phosphate pathway
Glycolysis
Fermentation
D-Glucose
β-gluco-sidase
cellobiose
ZWF1
D-glucono-1-5 lactone
6-phospho-gluconate
GND1
NADPH
NADP+
Glucose 6P
Ribulose 5P
PGI1
PFK26
[F1,2P]
F6P
PFK1, 2
F1,6P
RPE1
RPI1
Xylulose 5P
Ribose 5P
TKL1
TAL1
Erythrose 4P
Sed 7P
XYL1.1
XYL1.2
D-Xylose
Xylitol
XYL2.1
XYL2.2
D-Xylulose
XYL3
ATP
Industerial applications
DhaP
Gal3P
Pi
TDH3, TDH2, TDH1, TDH4
3-phospho-D-glyceroyl-P
PGK1
3-phospho-D-glycerate
GPM1.3
2-phospho-D-glycerate
ENO1
PEP
PYK1
Pyruvate
PDC1,2,3
Acetaldehyde
ADH
Ethanol
Release cellulosic and hemicellulosic sugars
SSF
Agricultural waste
Bio-renewable Energy

Stalled Fermentation

- Causes
  - Unhealthy yeast cells
  - Underpitched
  - Overpitched
  - Low yeast nutrients
  - Incorrect temperatures
- Fixes
  - Add more yeast
  - Add some other "bugs"
  - Add yeast nutrient during mash
  - Make a starter and pitch appropriate amount of yeast

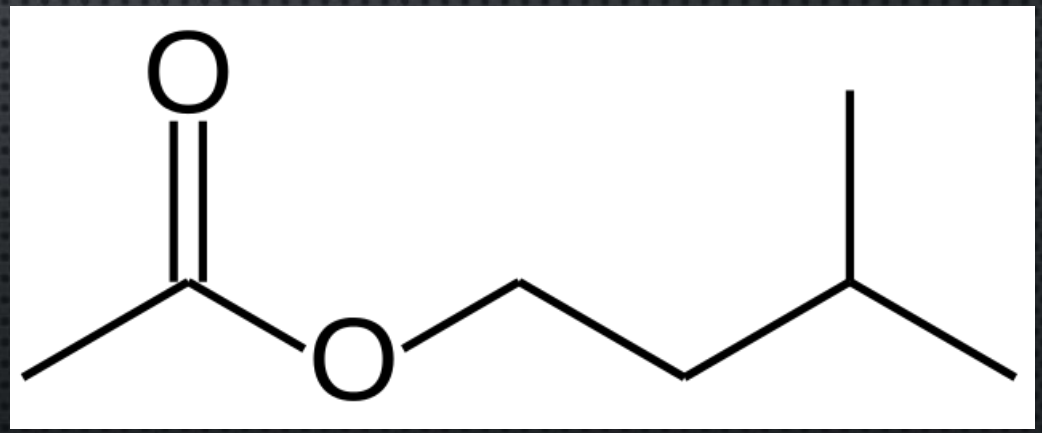
Fermentation Flavors - Alcohols

- Ethanol is the main alcohol produced
  - traces of methanol, propanol, iso-butanol, 2-methylpropan- 1-ol, iso-amylalcohol, tyrosol, and phenylethanol
- Fusel alcohols
  - Higher Alcohols – as many as 45 types can be produced
  - Gives the "hot" flavor
  - High temperature during fermentation
  - Responsible for the headaches



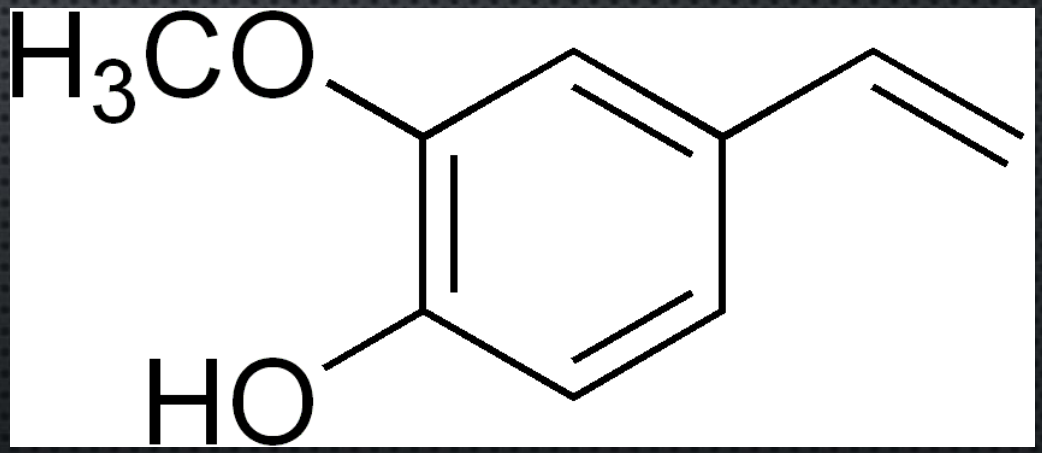
Fermentation Flavors - Esters

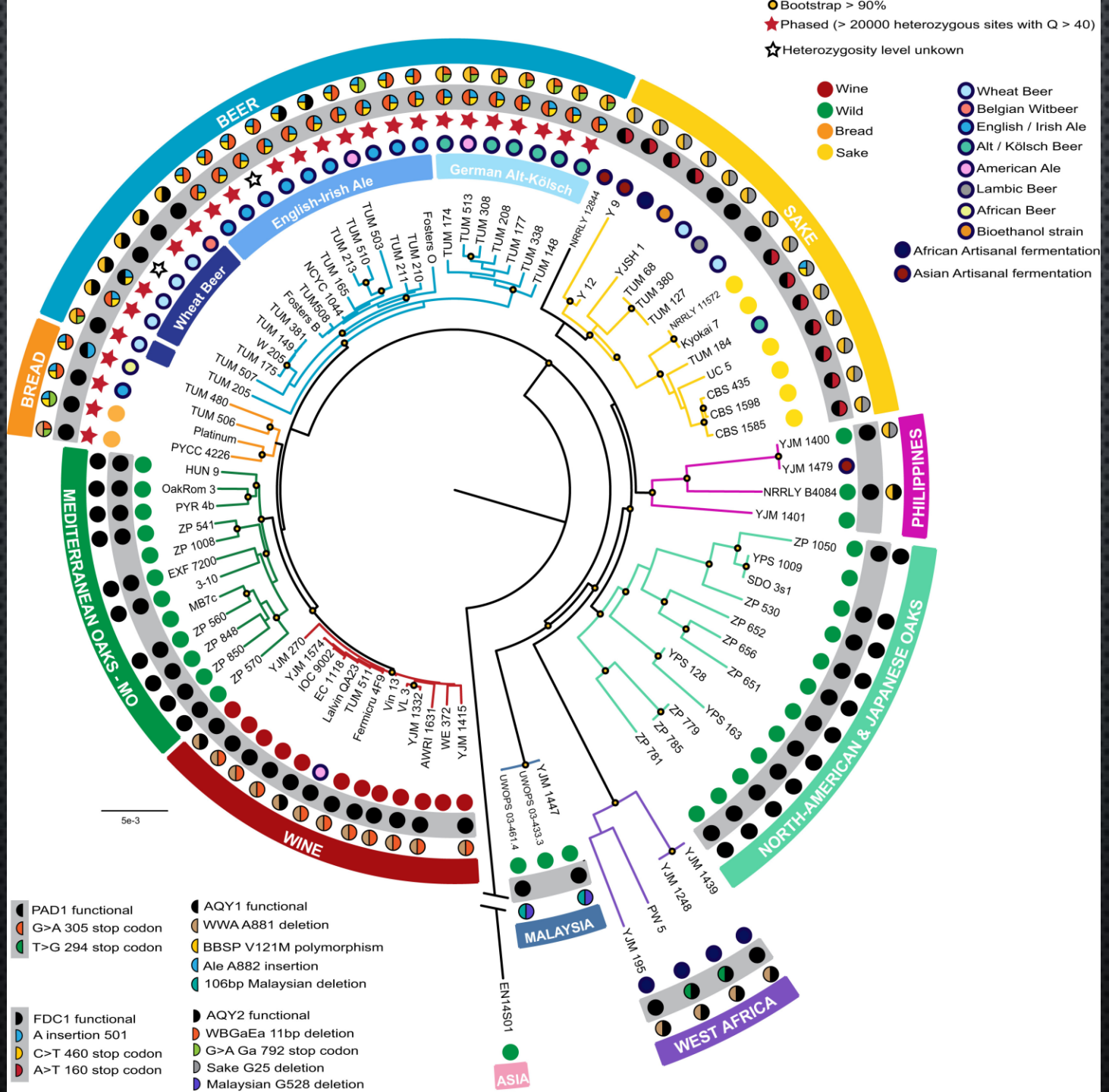
- One of the main flavors in beer
- Most are fruity in flavor
  - Isoamyl acetate – e.g. banana
  - Ethyl caprylate – apples/pears/anise
- Others are bad
  - Ethyl Acetate – Nail Polish Remover
- Warm fermentation produces more esters



Fermentation Flavors - Phenols

- Produced by yeast and some chemicals found in water
  - I.E. Chlorine – Band-Aid flavor
- Tannins are a type of phenol
- 4-vinyl guaiacol – Clove flavor
- 4-ethyl phenol – Horse Blanket or Barnyard flavor
- 4-vinyl syringol – Vanillin, can add the "tobacco-like" flavor




Bootstrap > 90%
Phased (> 20000 heterozygous sites with Q > 40)
Heterozygosity level unkown
Wine
Wild
Bread
Sake
Wheat Beer
Belgian Witbeer
English / Irish Ale
Alt / Kölsch Beer
American Ale
Lambic Beer
African Beer
Bioethanol strain
African Artisanal fermentation
Asian Artisanal fermentation
BEER
SAKE
BREAD
WINE
MEDITERRANEAN OAKS - MO
NORTH-AMERICAN & JAPANESE OAKS
PHILIPPINES
MALAYSIA
WEST AFRICA
ASIA
English-Irish Ale
German Alt-Kölsch
Wheat Beer
TUM 503
TUM 510
TUM 213
TUM 165
NCYC 1044
TUM508
Fosters B
TUM 381
TUM 149
W 205
TUM 175
TUM 507
TUM 205
TUM 480
TUM 506
Platinum
PYCC 4226
HUN 9
OakRom 3
PYR 4b
ZP 541
ZP 1008
EXF 7200
3-10
MB7c
ZP 560
ZP 848
ZP 850
ZP 570
YJM 270
YJM 1574
IOC 9002
EC 1118
Lalvin QA23
TUM 511
Fermicru 4F9
Vin 13
VL 3
YJM 1332
AWRI 1631
WE 372
YJM 1415
TUM 211
TUM 210
Fosters O
TUM 174
TUM 513
TUM 308
TUM 208
TUM 177
TUM 338
TUM 148
NRRLY 12844
Y 9
Y 12
YJSH 1
TUM 68
TUM 380
TUM 127
NRRLY 11572
Kyokai 7
TUM 184
UC 5
CBS 435
CBS 1598
CBS 1585
YJM 1400
YJM 1479
NRRLY B4084
YJM 1401
ZP 1050
YPS 1009
SDO 3s1
ZP 530
ZP 652
ZP 656
ZP 651
YPS 128
YPS 163
ZP 779
ZP 785
ZP 781
YJM 1447
UWOPS 03-433.3
UWOPS 03-461.4
YJM 1439
YJM 1248
PW 5
YJM 195
EN14S01
5e-3
PAD1 functional
G>A 305 stop codon
T>G 294 stop codon
FDC1 functional
A insertion 501
C>T 460 stop codon
A>T 160 stop codon
AQY1 functional
WWA A881 deletion
BBSP V121M polymorphism
Ale A882 insertion
106bp Malaysian deletion
AQY2 functional
WBGaEa 11bp deletion
G>A Ga 792 stop codon
Sake G25 deletion
Malaysian G528 deletion

American Ale/Cali/Chico Strain

- Most widely used strain of ale yeast
- Clean fermentation
- Emphasizes malt and hop characteristics

- Commercial versions
  - Wyeast American Ale (WY1056)
  - White Labs California Ale (WLP001)
  - Fermentis SafAle American Ale (US-05)
  - RVA Yeast Labs Chico Ale (RVA-101)
  - Imperial Flagship (A07)
  - Omega West Coast Ale I (OYL-004)
  - Lallemand LalBrew West Coast Ale (BRY-97)
  - Mangrove Jack's US West Coast (M44)
  - Bootleg Biology Classic American (BBUSA1)
  - GigaYeast NorCal #1 (GY001)

London Ale III

- Common in NEIPAs
- Soft, smooth, and fluffy mouth feel
- Leaves residual sugar behind for a fuller mouthfeel
- Can produce a fruity profile

- Wyeast London Ale III (WY1318)
- RVA Manchester Ale (RVA-132)
- Escarpment Foggy London Ale
- White Labs London Fog Ale (WLP066)
- Omega British Ale V (OYL-011)
- Imperial Juice (A38)
- GigaYeast British Haze (GY128)
- LalBrew Verdant IPA

Hefeweizen

- German
  - Produces a lot of esters and phenols
  - Banana, nutmeg, bubblegum, clove
  - Can be higher alcohol tolerant (~10%)
  - Low flocculation
- American
  - Typically lighter in appearance and hoppier
  - Does not have the esters and phenols

- German
  - GigaYeast Bavarian Hefe (GY017)
  - Omega Labs Hefeweizen Ale I (OYL-021)
  - White Labs Hefeweizen Ale Yeast (WLP300)
  - Wyeast Weihenstephan Weizen (WY3068)
  - Wyeast German Wheat (WY3333)
  - Imperial Yeast Stefon (G01)
  - Escarpment Labs Weizen I
  - Fermentis SafAle (WB-06)
  - Mangrove Jack's Belgian Wheat (M20)
- American
  - GigaYeast Portland Hefe (GY020)
  - White Labs American Hefeweizen Ale Yeast (WLP320)
  - Wyeast American Wheat (WY1010)
  - Imperial Yeast Whiteout (B44)

KVEIK

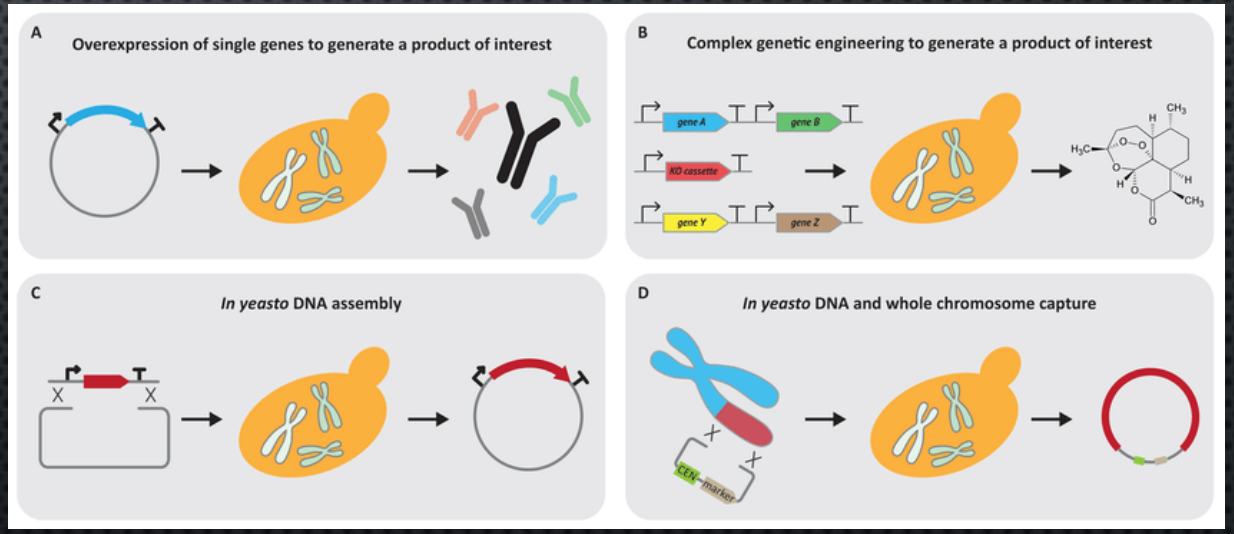
- Family of Yeast from Norway
- Ferment above 90 °F without off flavors
- Completes fermentation quickly
- Some strains can produce tropical fruit esters
- "Pseudo" Lagers

KVEIK

Strain	Description	Best Styles
Lutra	Lutra is shockingly clean with unrivaled speed when pitched at 90F (32C). The strain is perfect for brewing a refreshing pseudo-lager without the lead time of a lager. Also an excellent choice to make a fast hard seltzer. Although primary fermentation may be done within days, Lutra still needs some lagering (cold storage) time for the beer to clear. This can be done in the bottle after carbonation has been achieved. Available as both liquid and dry.	Lagers, Hard Seltzers
Voss	Excellent for IPA's, Voss's character changes little over its broad temperature range, with orange citrus notes. It is non-phenolic and pairs well with citrusy, fruity hops. Available as liquid or dry.	IPA, Pale
Hothead	A highly flocculant strain with an astoundingly wide temperature range and little change in flavor across the range. Clean enough for both American and English styles, it has a unique honey-like aroma with overripe mango. Complementary to modern, fruity hops. Non-phenolic and no noticeable fusels, even at higher temperatures.	IPA, Pale Ale, Pale English Ales
Hornindal	Hornindal produces an intense tropical flavor and aroma with notes of fresh pineapple, mango, and tangerine. Compliments fruit-forward hops as well as adding another dimension to beer made with traditional "C" hops. Warmer fermentation temperatures will increase the aromatic profile and fermentation speed.	IPA, Pale Ale, Barleywine
Espe	Originating from the village of Grodås in Norway, Espe offers the unique profile of lychee, pear, and tropical fruit cup. The strain bolsters the sweet aromatics of modern IPAs, but is versatile enough for your flagship pale ale or seasonal brew. Espe is most expressive when fermented at 90F+ (32C+), but still reveals its character at lower ale-pitching temperatures.	IPA, Pale Ale

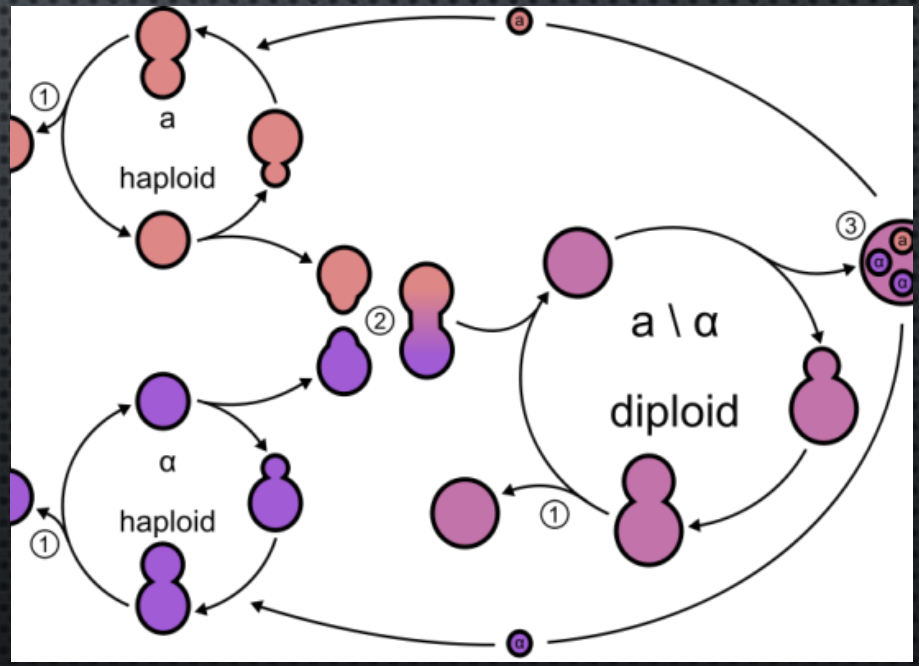
Genetically Engineered (GE) Yeast

- Genetically Engineered (GE/GMO) Yeast
  - Direct Transfer or removal of genes in a yeast
  - CIS – uses no foreign DNA, typically will change the regulation of pathways
  - TRANS – uses DNA from another organism
- Examples:
  - Omega Thiolized Yeasts
- Typically limited to sale in the US and Canada



HYBRID YEAST

- Produced by Sexual Reproduction between two yeast strains
- Extremely difficult to achieve
- Examples:
  - Imperial Mangosteeni, Capi
  - Lallemand NovaLager, Lona



Brettanomyces

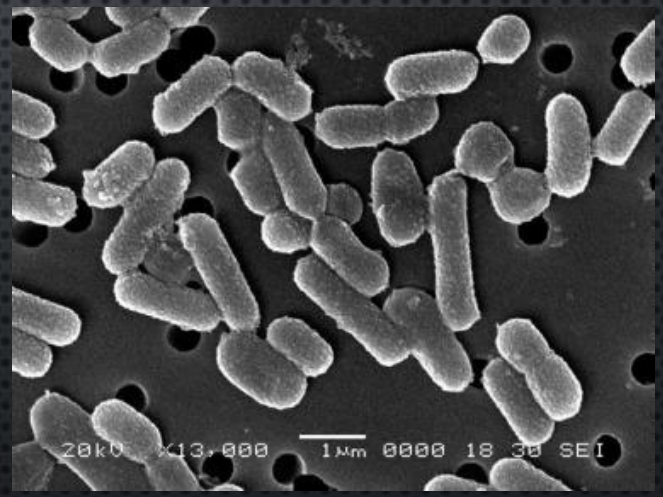
- Wild yeast
- Gives the horse blanket/barn yard flavors
- can produce acetic acid in presence of high oxygen levels
- Used in lambics, Gueze, etc.
- Use different equipment to prevent cross contamination
- Mainly used in co-fermentation, e.g. "normal" yeast first then Brett

PHILLY SOUR

- Isolated from a cemetery in Philly
- Biphasic fermentation, lactic production then ethanol production
- Ferment warm
- Pitch rate affects lactic acid production
- Does not ferment lactose
- Do not co-pitch as other yeast out compete it

LACTOBACILLUS

- Lactic Acid producing bacteria
- Great for kettle souring
- Preferred Temperature 85 – 90 °F
  - Above 95 °F inhibits growth
- Avoid excessive exposure to air during souring, may produce butyric acid (baby vomit)



YEAST HARVESTING

- SANITIZE, SANITIZE, SANITIZE
- STORE AT 33 – 38 °F
- TOP CROPPING
  - SKIM OFF THE TOP OF ACTIVE FERMENTATION
- YEAST SLURRY
  - SCOOP SLURRY AFTER PACKAGING
  - ADD COOLED BOILED WATER TO SLURRY AND MIX
  - LET SETTLE AND DECANT THE TOP LAYER INTO A CLEAN SANITIZED JAR
- POUR SIMILAR OR DARKER BEER ON TOP OF TRUB

HELPFUL LINKS

- Yeast substitution chart: https://beermaverick.com/yeasts/yeast-substitutions-chart/
- Yeast Harvesting: https://brulosophy.com/methods/yeast-harvesting/
- Yeast Wrangling: https://bootlegbiology.com/backyard-yeast-wrangling-tool-kit/