Carbohydrates and the Mashing Process

Bay Area Mashers June Meeting 2017

Overview

- Overview of chemistry of carbohydrates
- Enzymes and the mashing process
- Tasting beer mashed at different temperatures

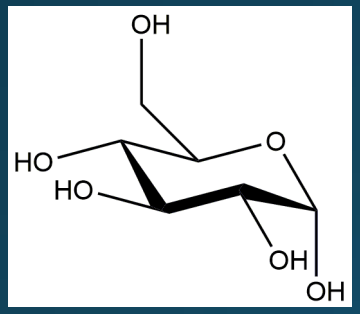
Chemistry of Carbohydrates

Organic (carbon-containing) molecules with chemical formula $C_m(H_2O)_n$

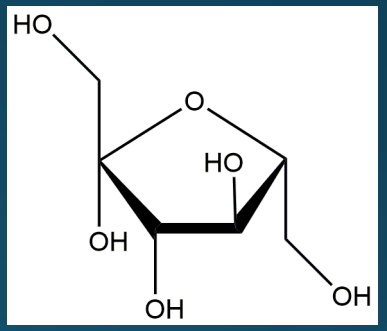
Acts as fuel for most living organisms and provides structure for plants (cellulose)

Structure of Simple Carbohydrates

Simple carbohydrates such as glucose form "pyranose" or "furanose" ring structures



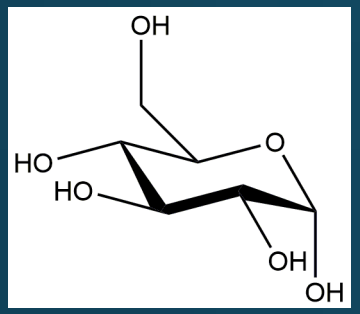
Glucose pyranose

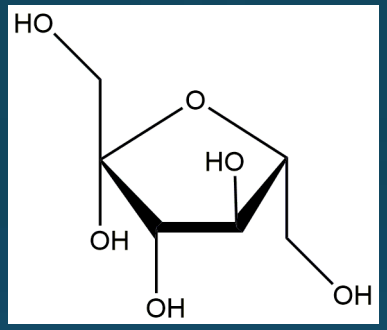


Fructose furanose

These simple units can combine to form more complex carbohydrates

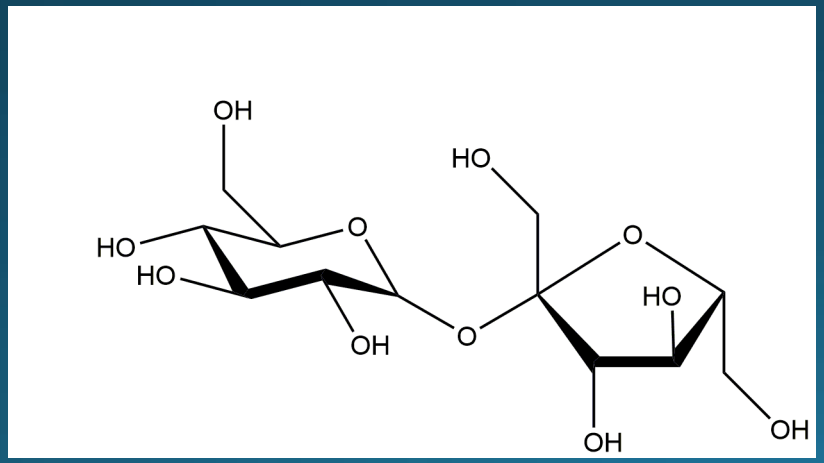
Combining Simple Carbohydrates





Monosaccharides

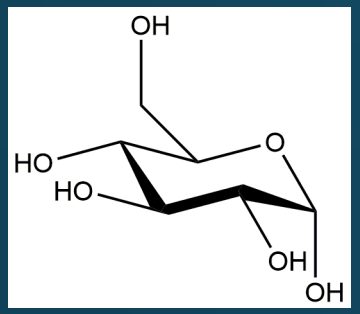
Glucose + Fructose

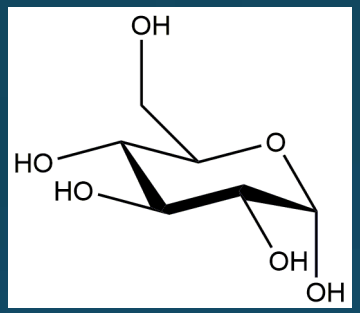


Disaccharide

Sucrose (Table Sugar)

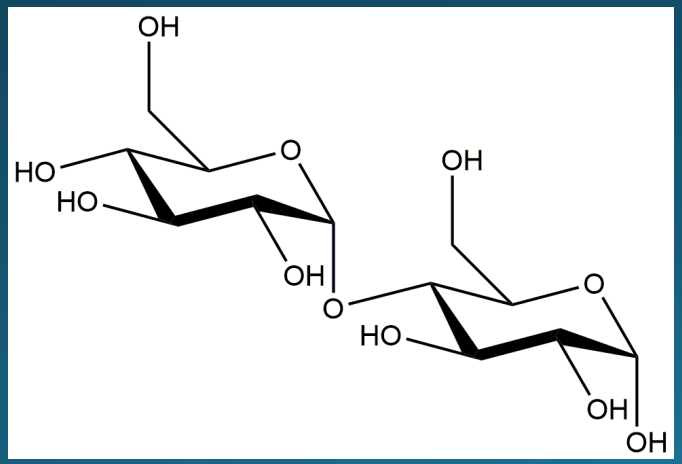
Combining Simple Carbohydrates





Monosaccharides

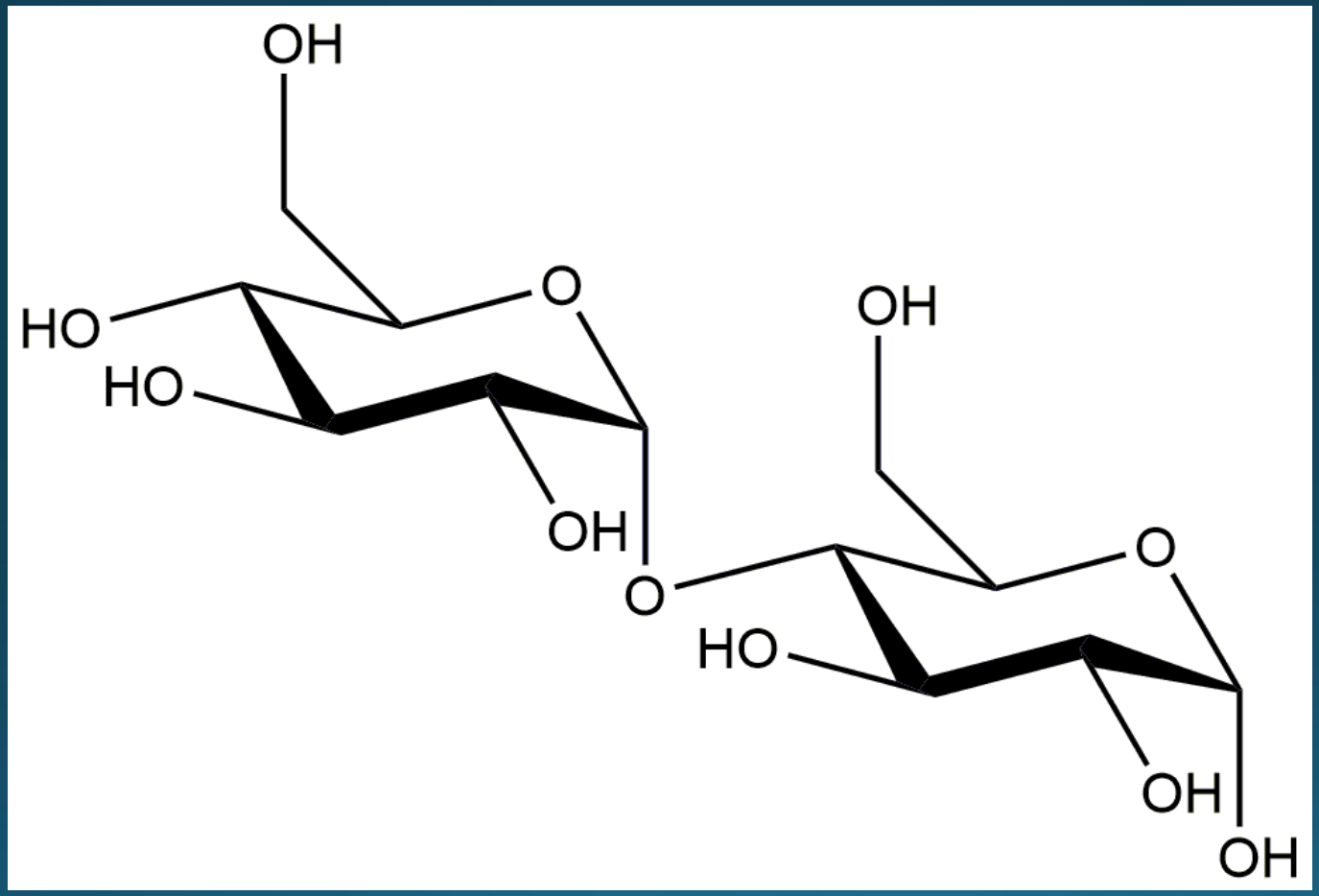
Glucose + Glucose



Disaccharide

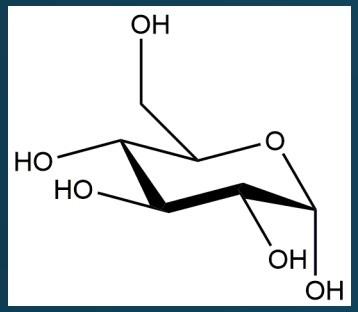
Maltose

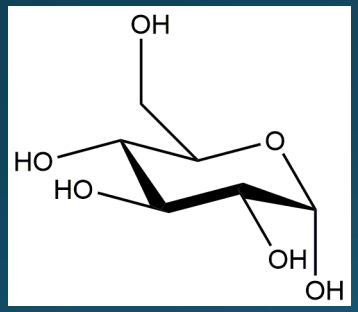
Closer Look at Maltose

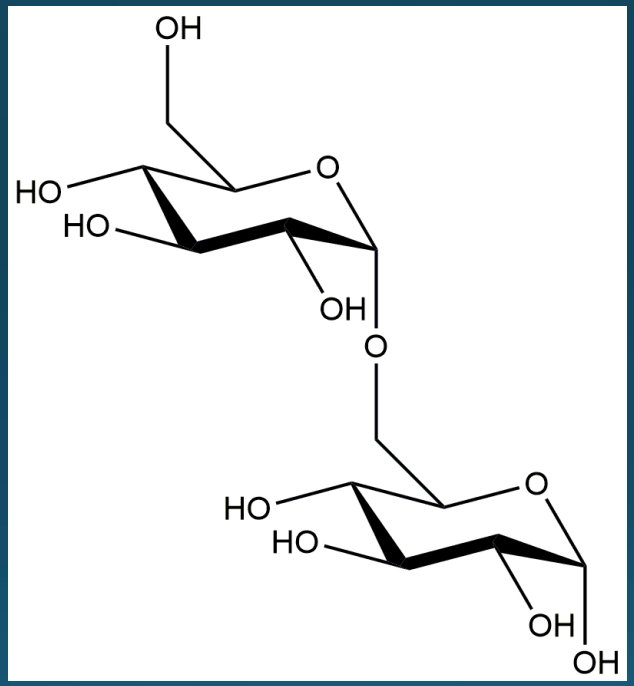


Glucose units bonded through oxygen at the 1st and 4th carbon

Another Form of Maltose



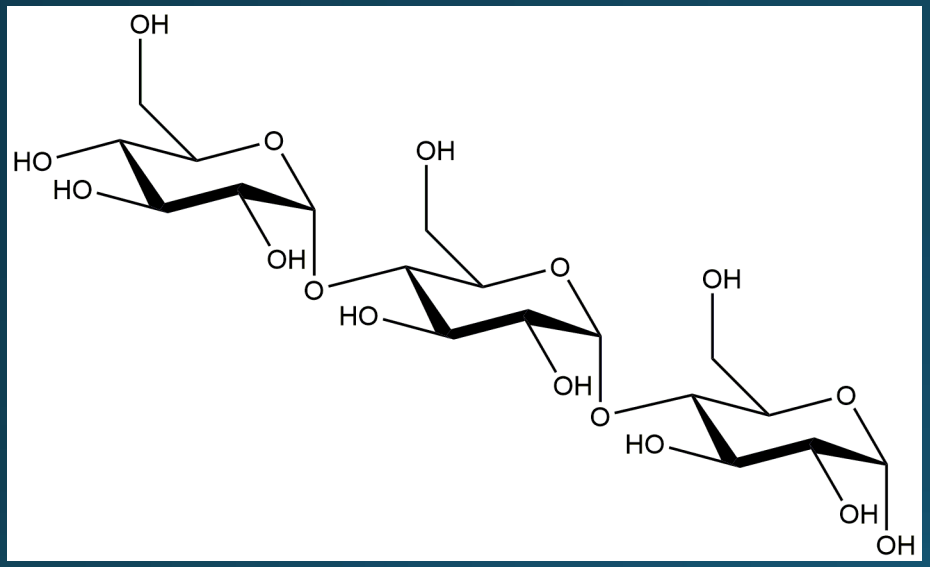




Glucose + Glucose Isomaltose

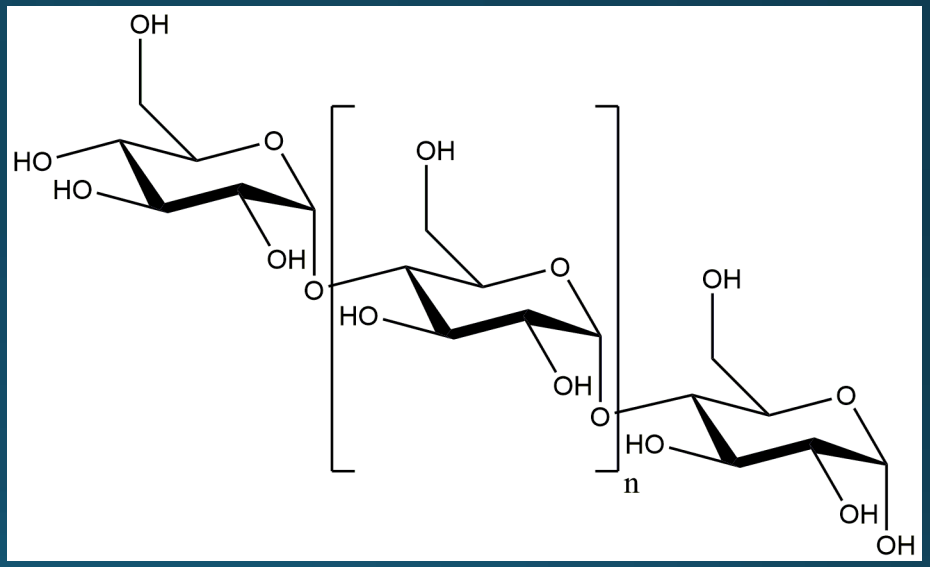
Glucose units bonded through oxygen at the 1st and 6th carbon

More Complex Carbohydrates



Maltotriose

Oligosaccharide (3-10 units)

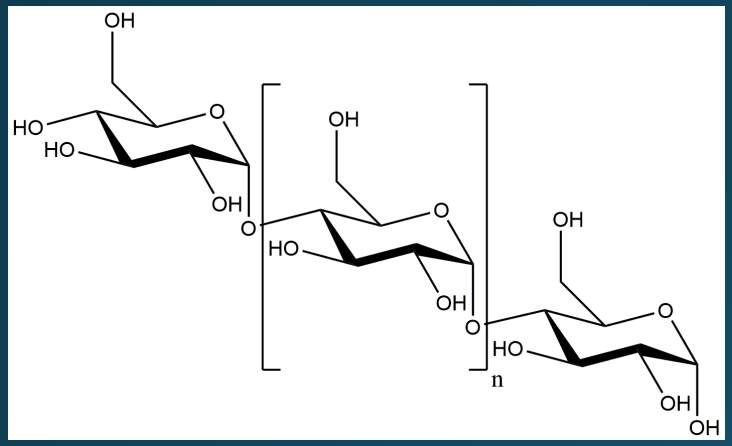


Amylose (component of starch)

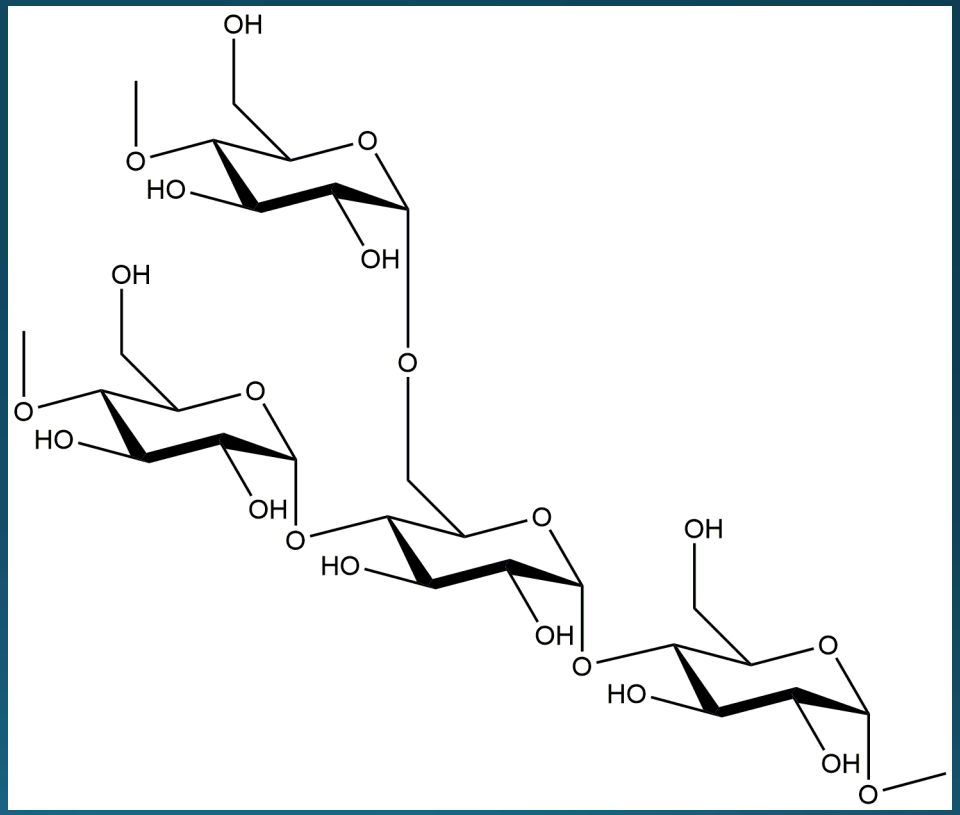
Polysaccharide (>10 units)

300-600 sugar units

Starches and Branching

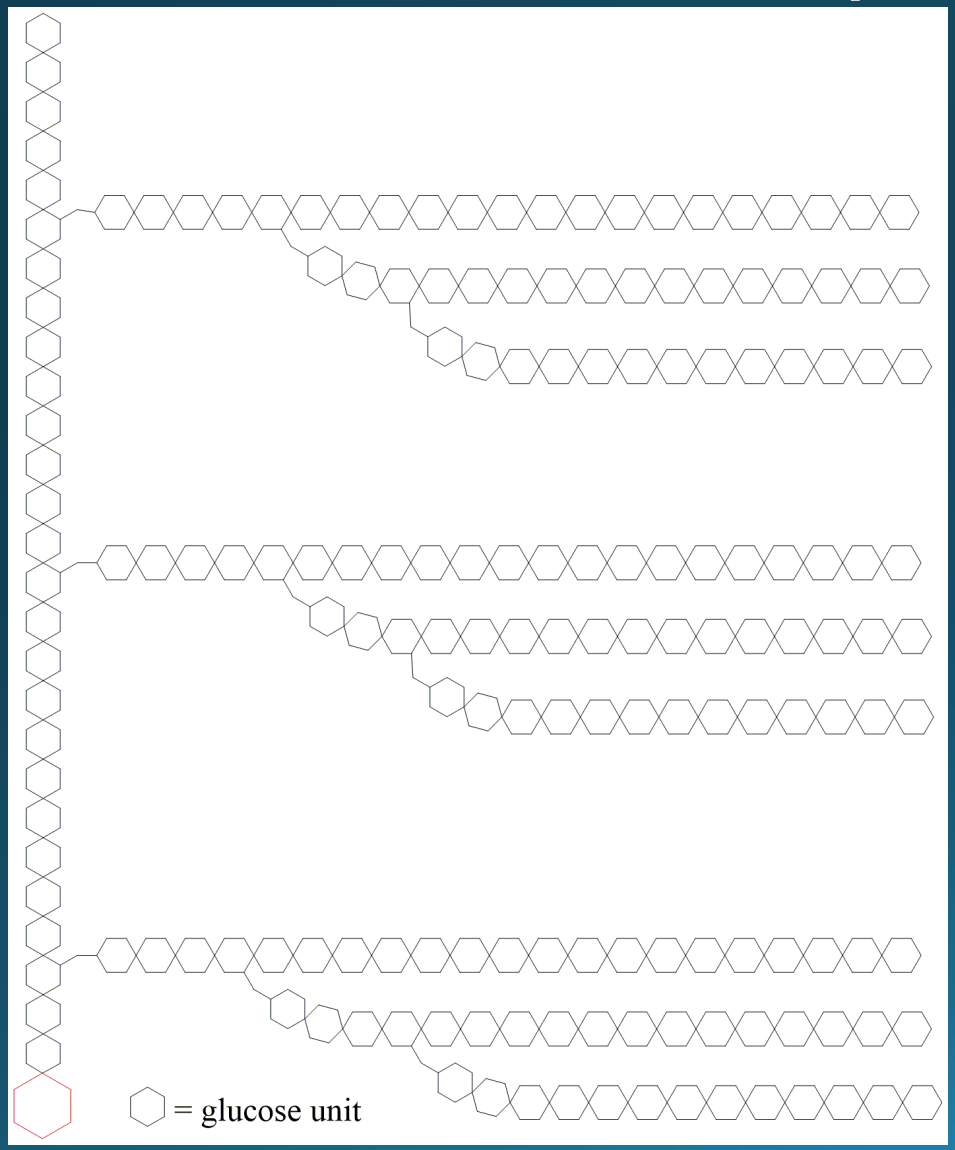


Amylose (25% of barley malt starch)
Forms helical structure



Amylopectin (75% of barley malt starch)
Branch points every ~24-30 units

Schematic of Amylopectin



Actual amylopectin contains between 2,000 and 200,000 glucose units

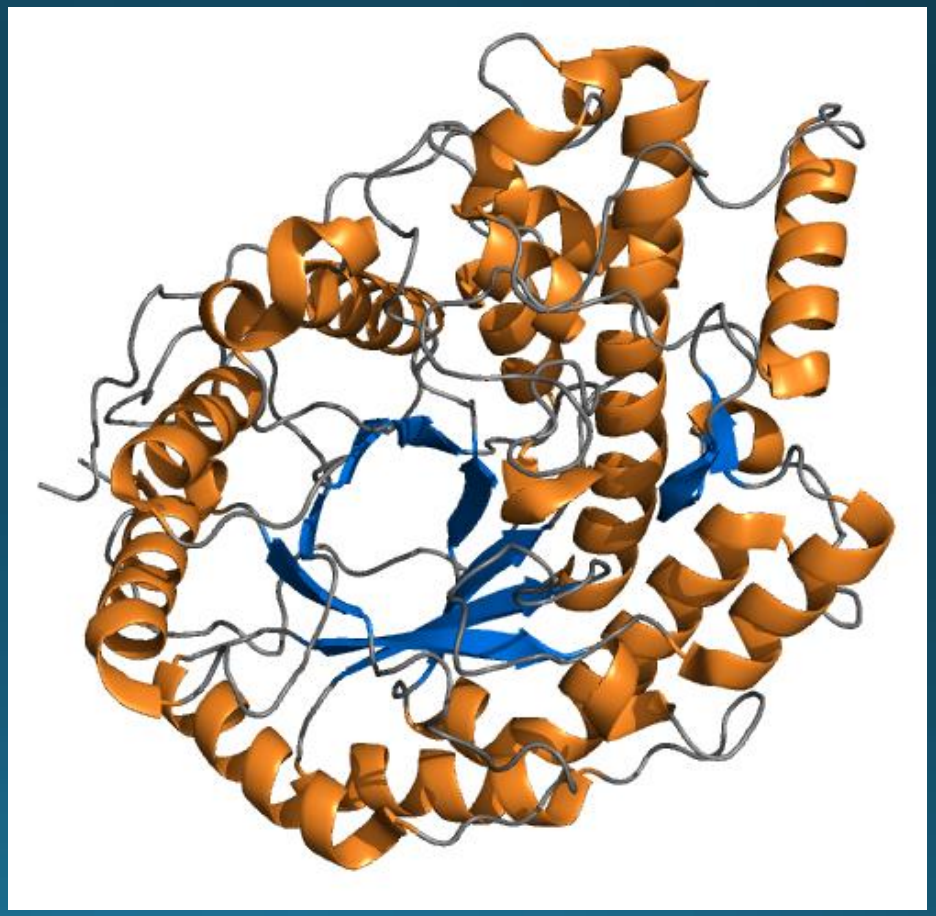
This structure has important consequences for the mashing process

Enzymes and the Mashing Process

Proteins that catalyze a specific (bio)chemical reaction

Contain cavities called "catalytic sites" that accelerate certain chemical reactions

Enzymes also have "binding sites" that help them attach to their target reactants



Malt and Enzymes

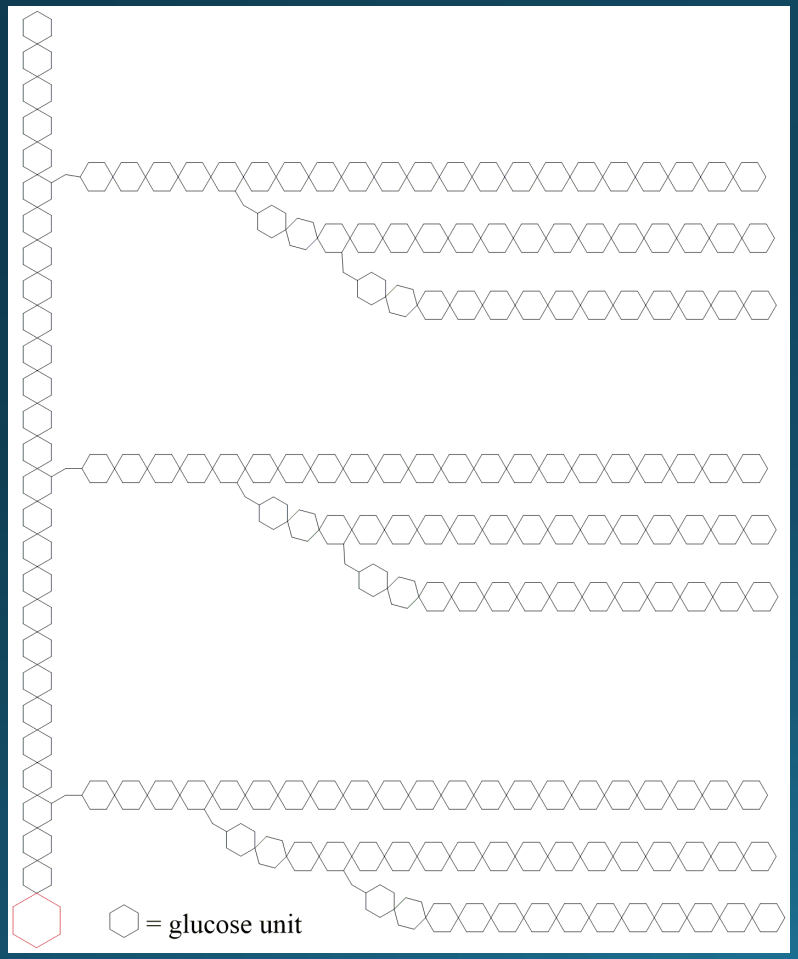
Malting barley partially germinates the seeds and breaks down cell walls

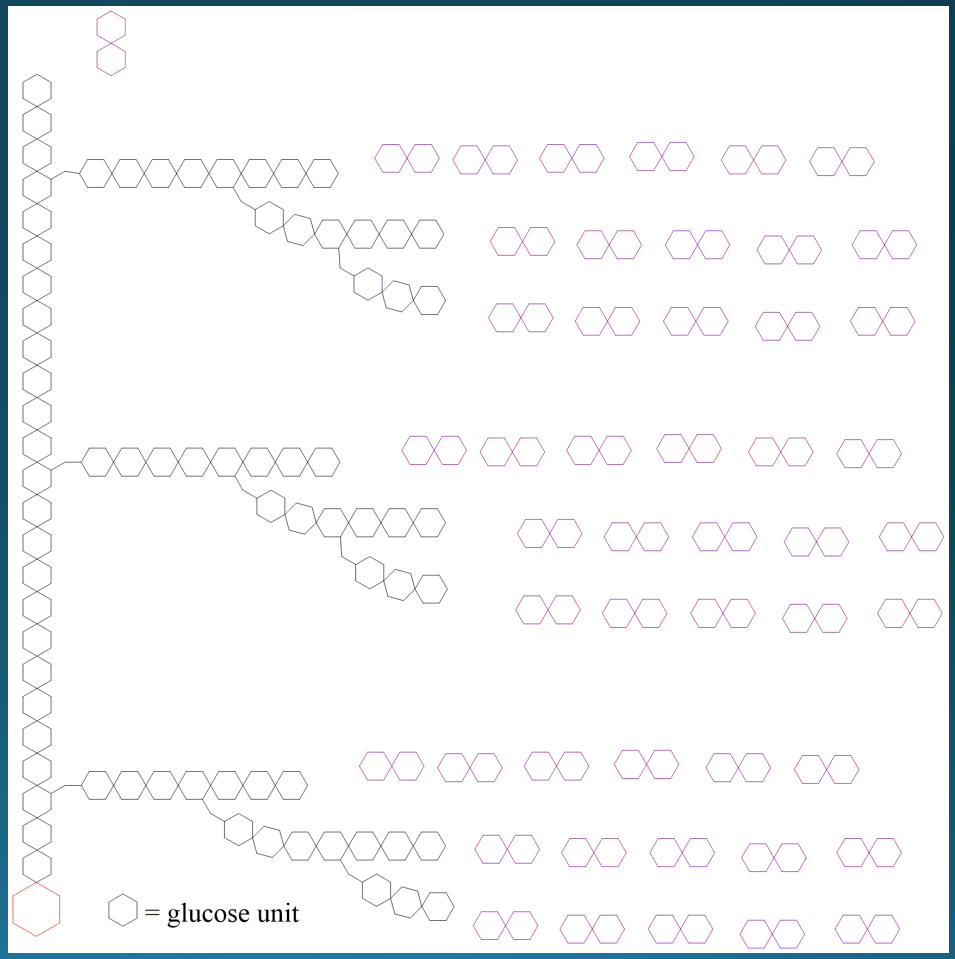
Starches are released

Many enzymes, including ones to break down starch, are produced

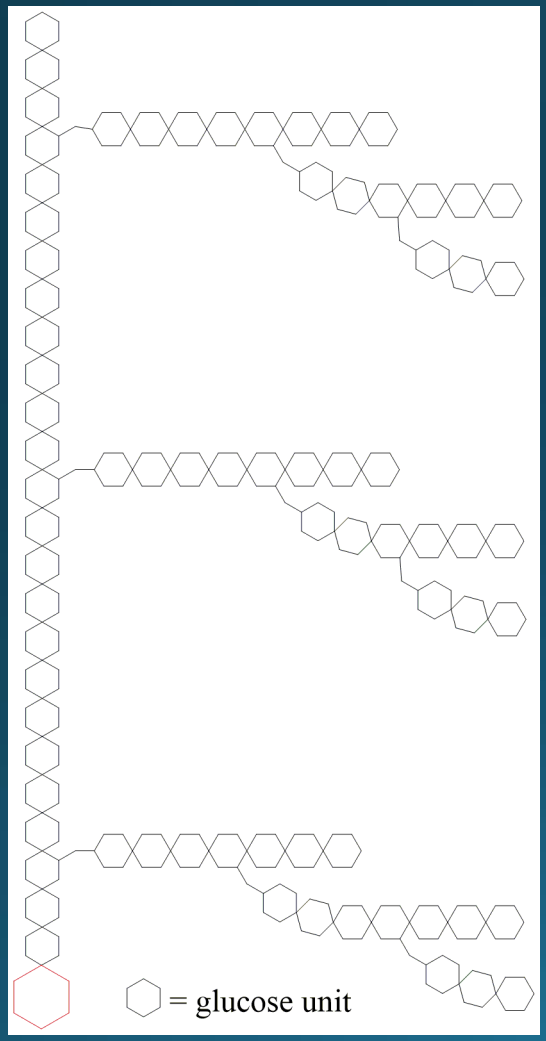
Placing malt in hot water can utilize these enzymes to break down starch into fermentable sugars

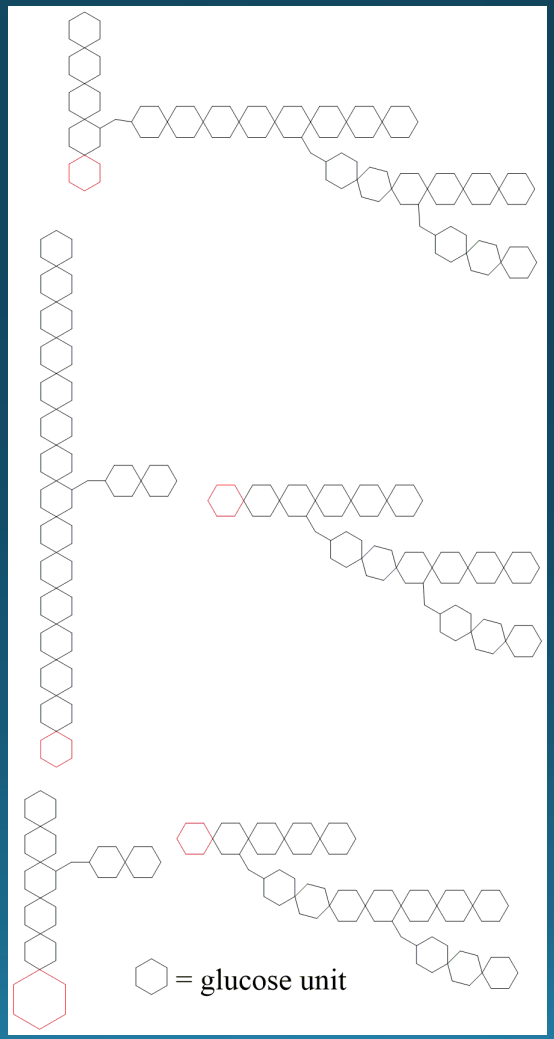
Beta-amylase chops off maltose units until branches





Alpha-amylase breaks amylopectin at random points





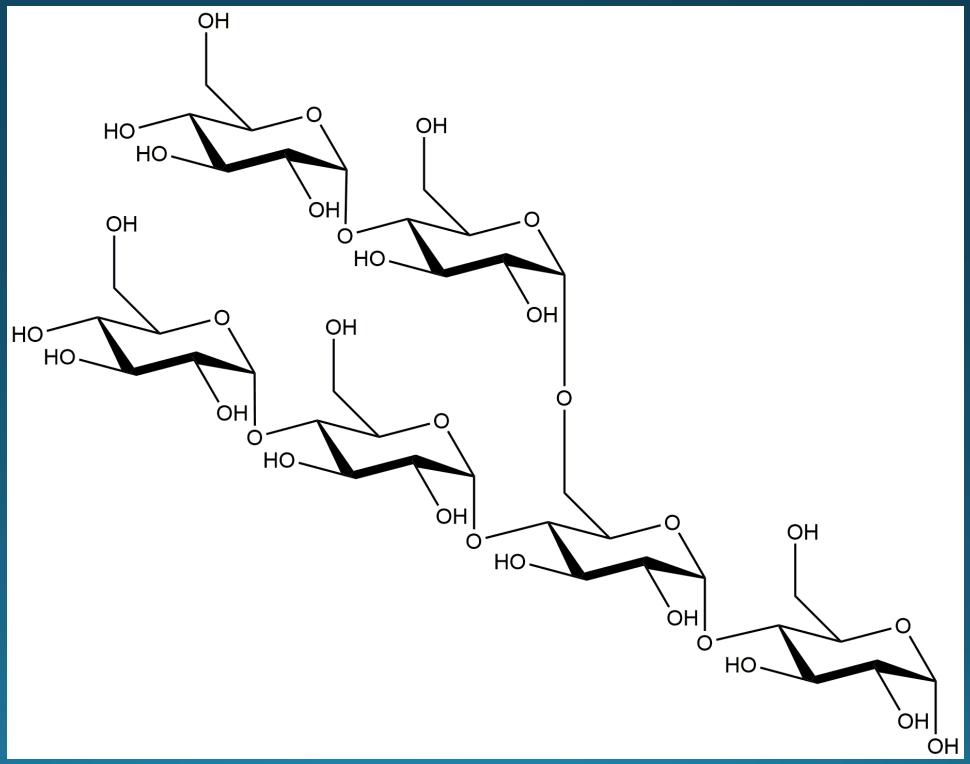
There's a limit…

Beta-amylase can no longer remove maltose units

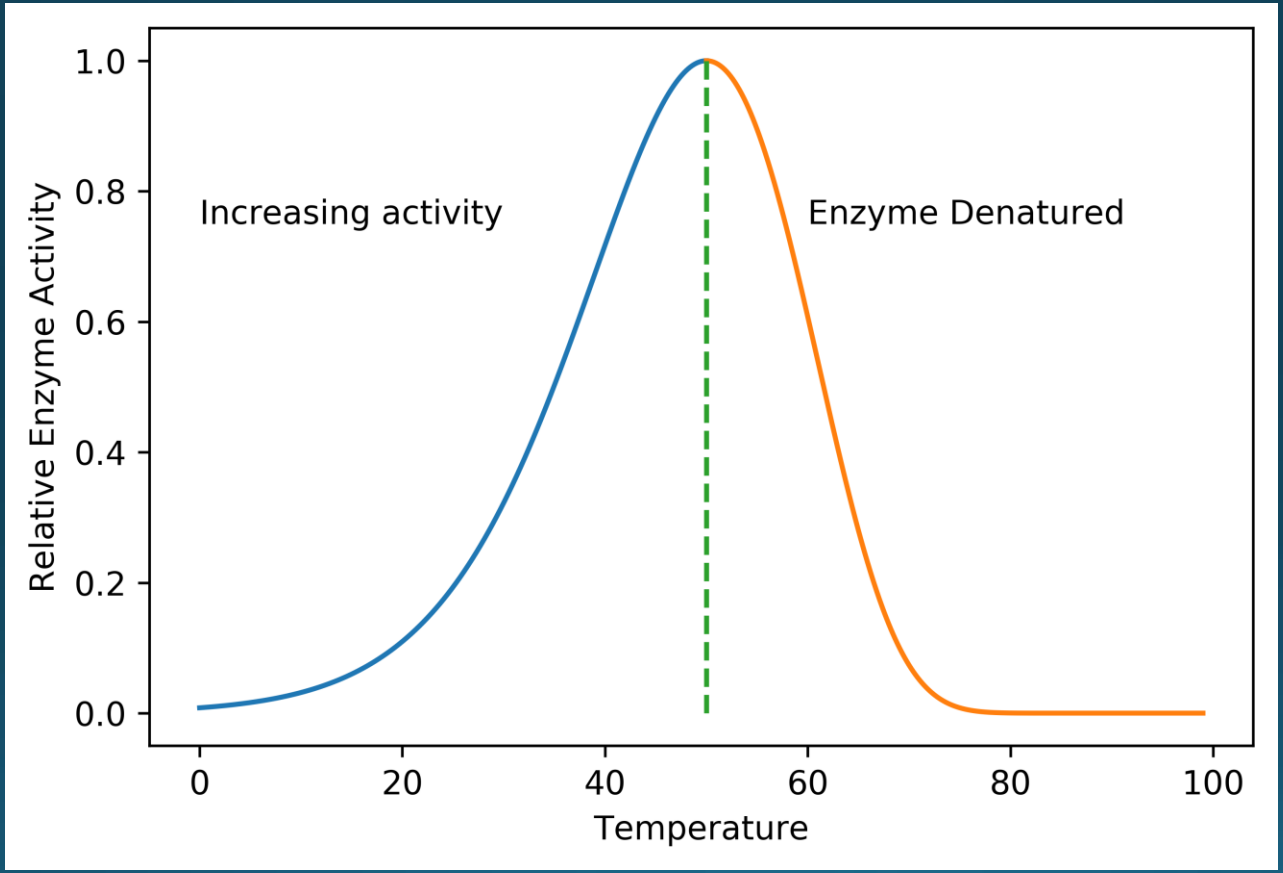
Alpha-amylase is too bulky to attach to bonds linking sugar units

Not a problem, though!

Dextrins contribute to body and mouthfeel

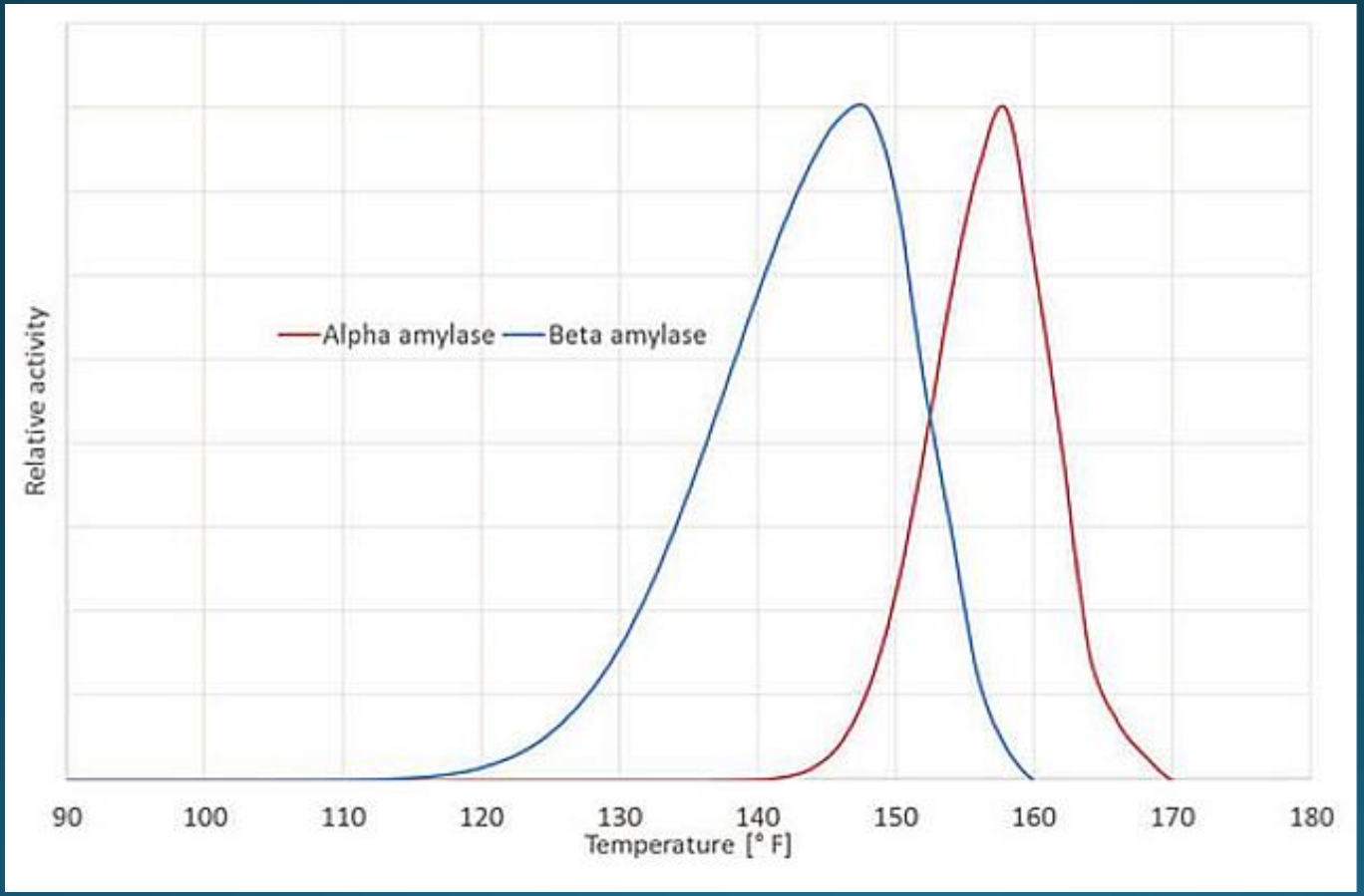


Temperature and Enzyme Activity



You can't go back! Once an enzyme is denatured, it will no longer catalyze its biochemical reaction

Our key enzymes have different operating ranges



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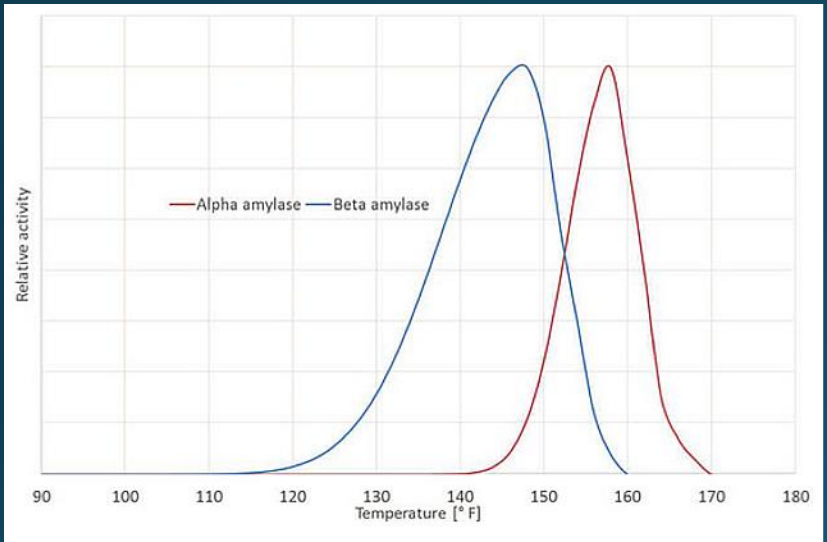
At lower temperatures



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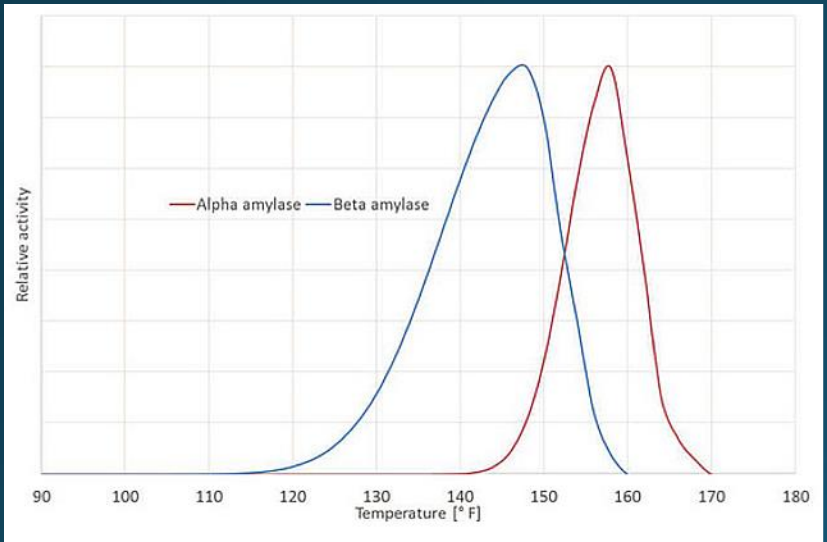
At lower temperatures:

Beta amylase is more active and will not be denatured, leading to more fermentable sugars

Alpha amylase is less active, thus beta amylase may get stuck at branch points

At higher temperatures



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At higher temperatures:

Alpha amylase is more active, opening up amylopectin more

Beta amylase will only be active for a short period before being permanently denatured

Infusion mashing

Hold malt at single temperature usually between 146-158°F

Initially, starch undergoes gelatinization (dissolves in water)

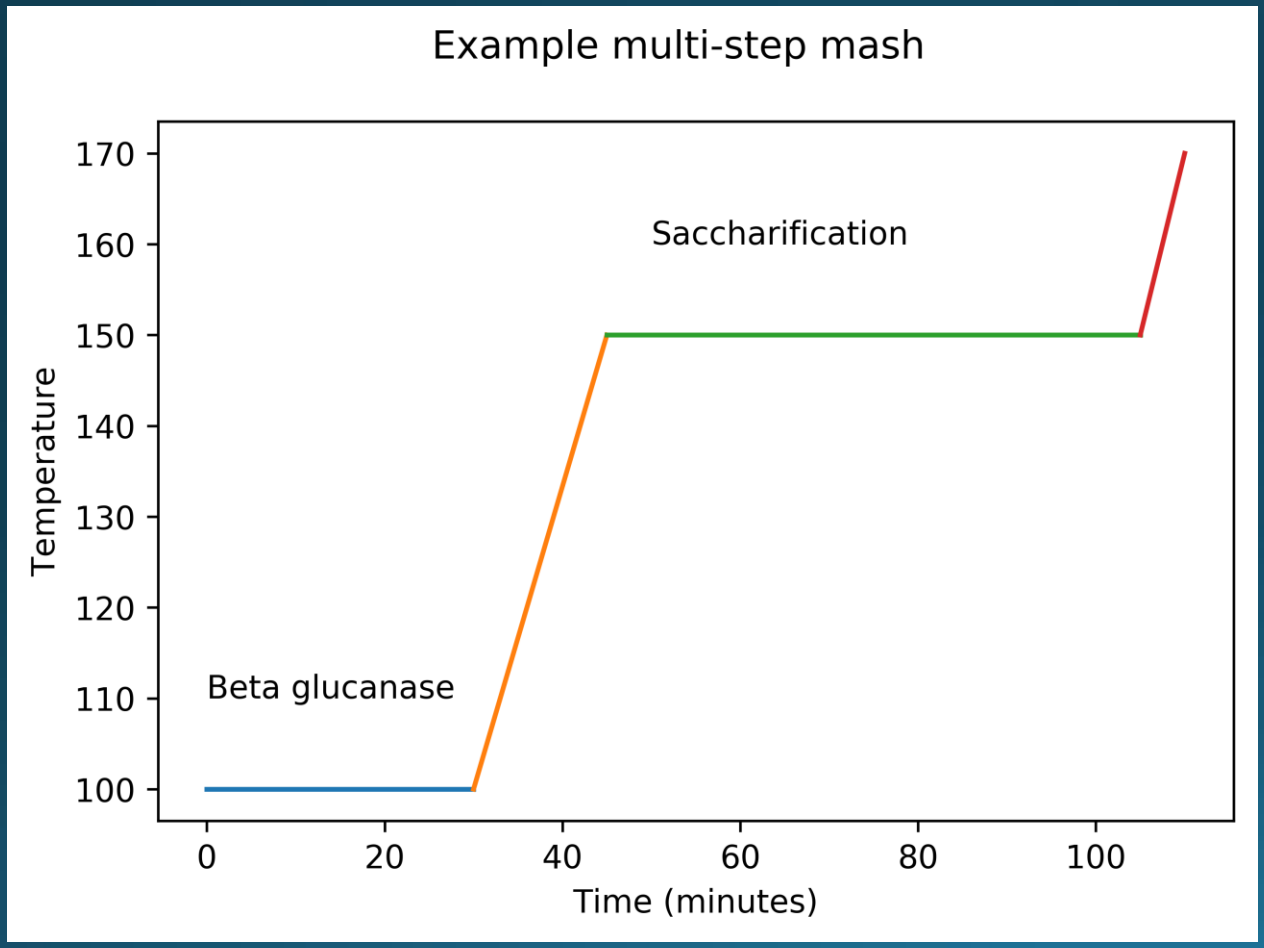
Both enzymes are active to a certain extent

Afterwards, lautering denatures remaining enzymes, extracts remaining sugar from grains, and sparges (rinses) sugars into boil kettle (166-170°F)

Some other enzymes for multi-rest mashes

Enzyme	Temperature	Effect
Beta-Glucanase	95-113°F	Breaks down beta-glucans present in unmalted adjuncts
Protease	111-131°F	Breaks down proteins to improve clarity
Cytase	113-131°F	Breaks down cellulose husk in unmalted adjuncts

Example multi-rest mash



Best for grain bills containing >25% unmalted adjuncts (oat, wheat, etc.)

Choose saccharification temperature to style

Lower temperatures produce more fermentable, drier beers with thinner body but may require longer mash times

Some suggested styles: Saison, Dry Stout

Higher temperatures produce less fermentable, sweeter beers with thicker body but produce less alcohol

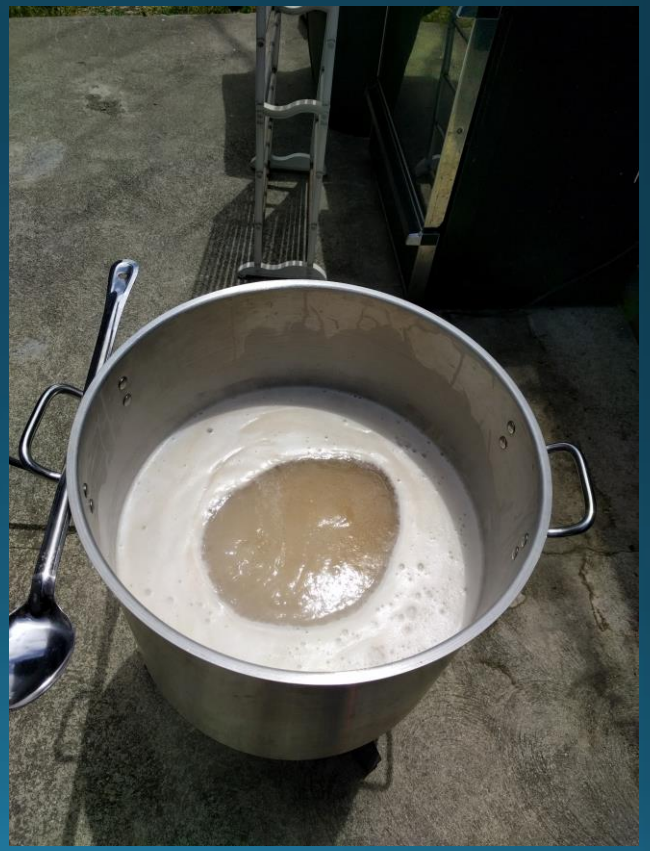
Some suggested styles: anything session (please), Sweet Stout, Pale Ale

Let's test this out!

Double Blind Pale Ale (5 gallons)
8 pounds American two-row barley malt
Expected OG: 1.043
(Mash conditions on next slides)

Boil additions:
0.25 oz Warrior hops (60 min)
Whirlfloc
2 oz Cascade hops (flame-out)

Yeast: WLP001 (California Ale Yeast)



Infusion Mash procedure

60 min saccharification rest with 2.5 gal water
1 tsp of 5.2 pH phosphate buffer

Drain to kettle

Batch sparge for 30 minutes with 3 gal water (168°F)

Slowly drain to kettle (~15 minutes)

Rinse through with additional 3 gal water (168°F)

Mash #1: High temperature

Mash Temperature = ~156-160°F

Definitely seemed more "foamy"

Actual O.G.: 1.039

F.G.: 1.013

ABV: 3.3%

Incomplete extraction of sugars?

Mash #2: Low temperature

Mash Temperature = ~144-148°F

Extra 20 minutes in mash tun (waiting to finish cooling of previous boil…)

Actual O.G.: 1.046

F.G.: 1.009

ABV: 4.9%

Much higher alcohol content

Let's taste both these beers

Try to pick up on which beer is dry/thin versus sweet/full bodied

Which do you like better for this style? (American Pale Ale)

Remember:

High Temp -> Sweet, full body, less alcohol

Low Temp -> Dry, thin body, more alcohol

Results?

Summary

Amylopectin, a highly branched polysaccharide, is a major component of barley malt

The enzymes in barley malt act in different ways to break down amylopectin into fermentable sugars

Lower temperatures lead to dry, thin, and high alcohol beers

Higher temperatures lead to sweet, full-bodied, and low alcohol beers