The Internet of Brewing (IoB)

UBC Envision | CHBeer | Engineering Design Team

The University of British Columbia, Vancouver

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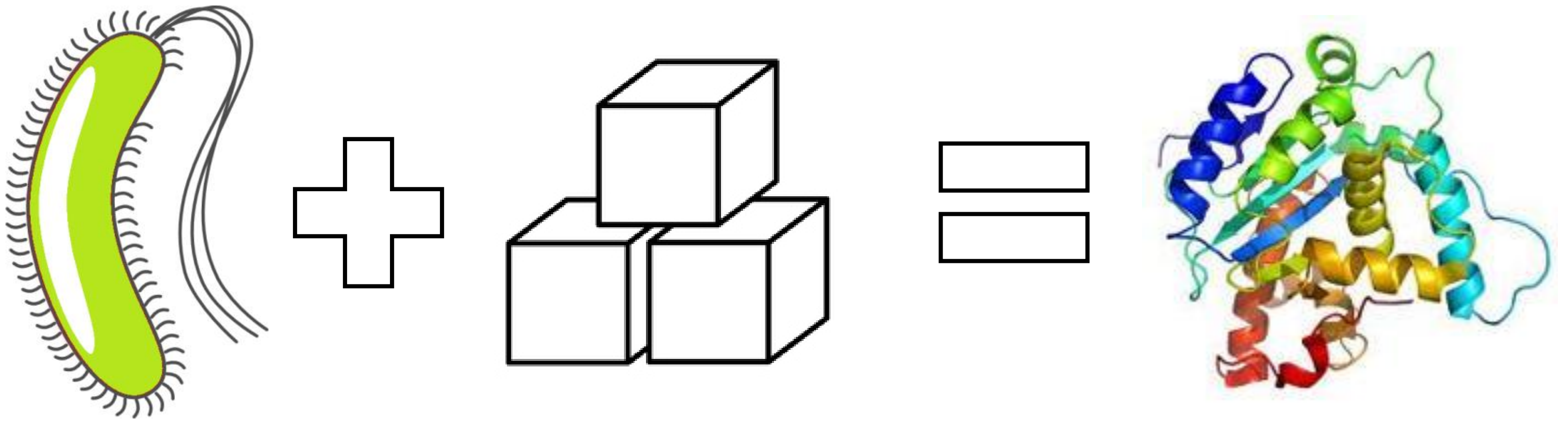
What is a Bio-Process?

Definition: “ The conversion of raw materials to value added products using micro-organisms”



Factory (micro-organism)

Substrate (raw material)

Product

Is Brewing a Bio-Process?

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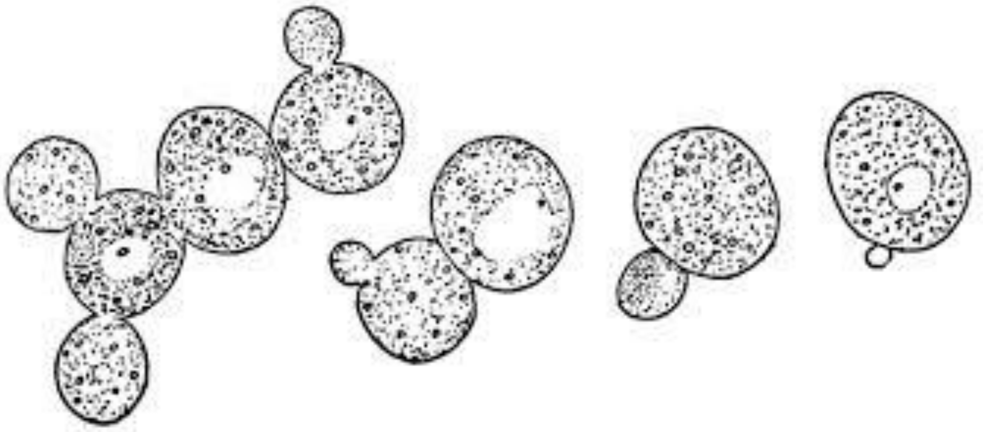
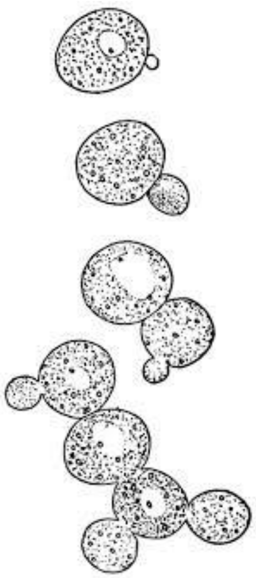


Need: Factory(Yeast)

Is Brewing a Bio-Process?



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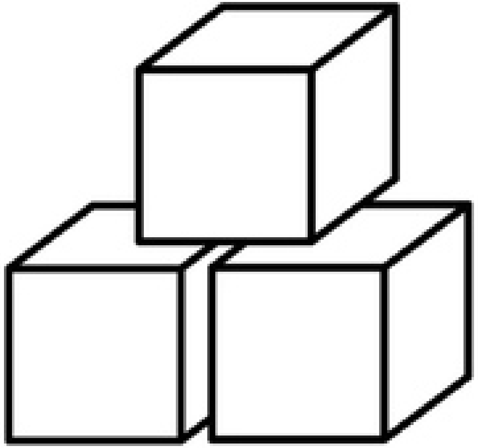
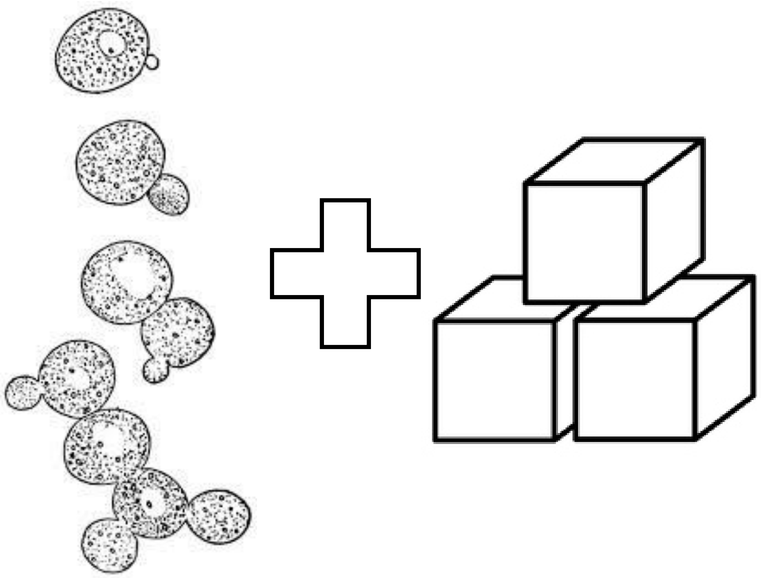


Raw Material & Energy Source
(Simple Sugars)

Is Brewing a Bio-Process?



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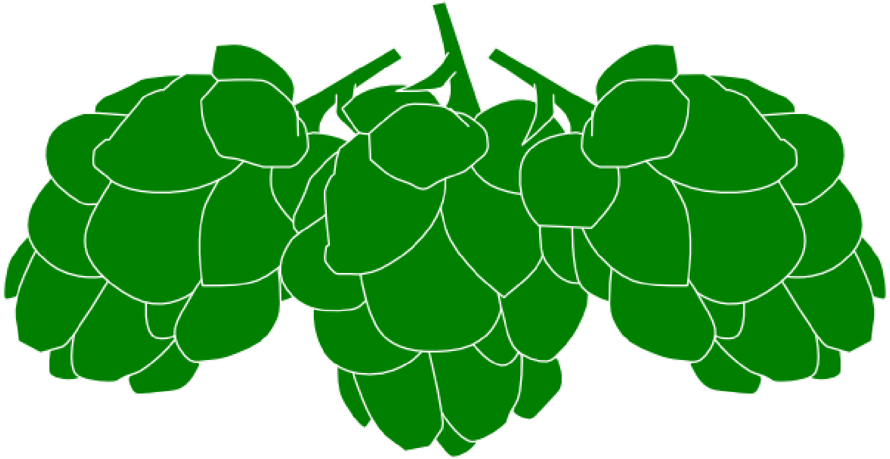
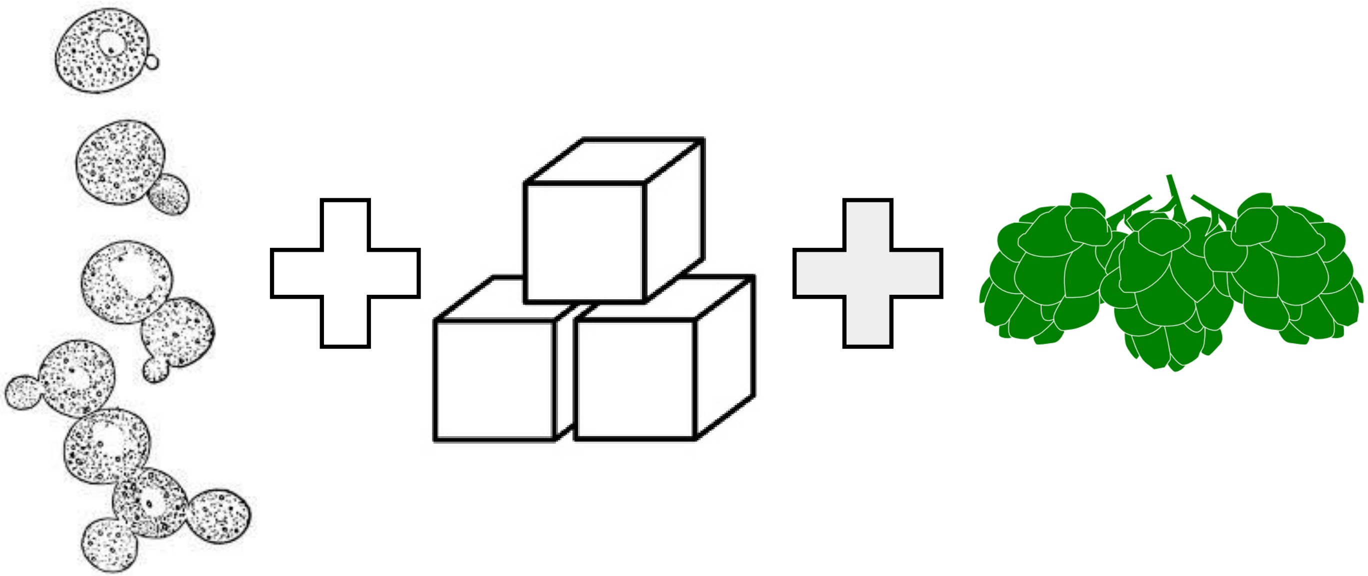


Flavor!
(Hops)

Is Brewing a Bio-Process?



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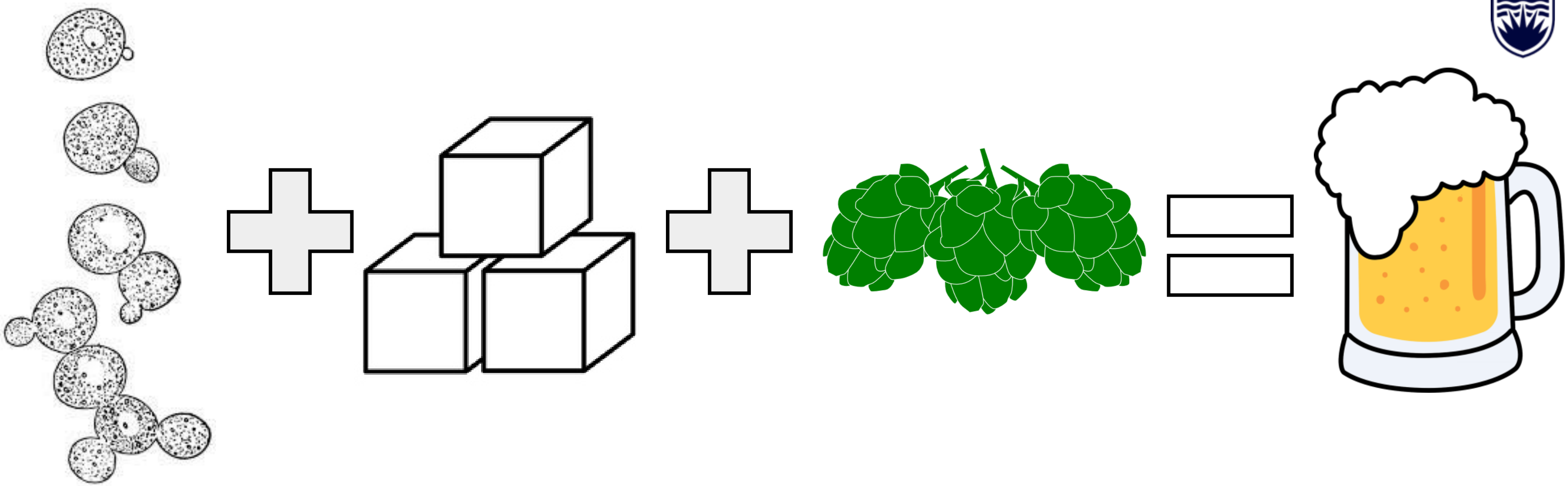

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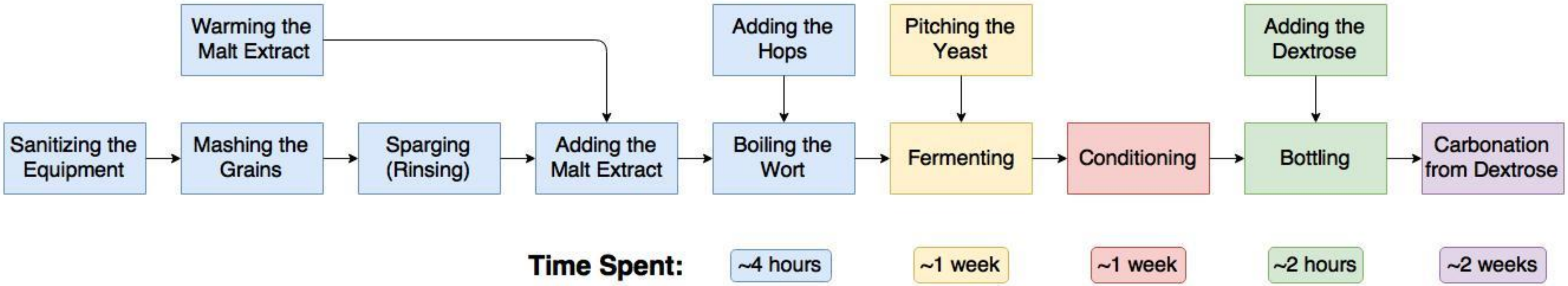

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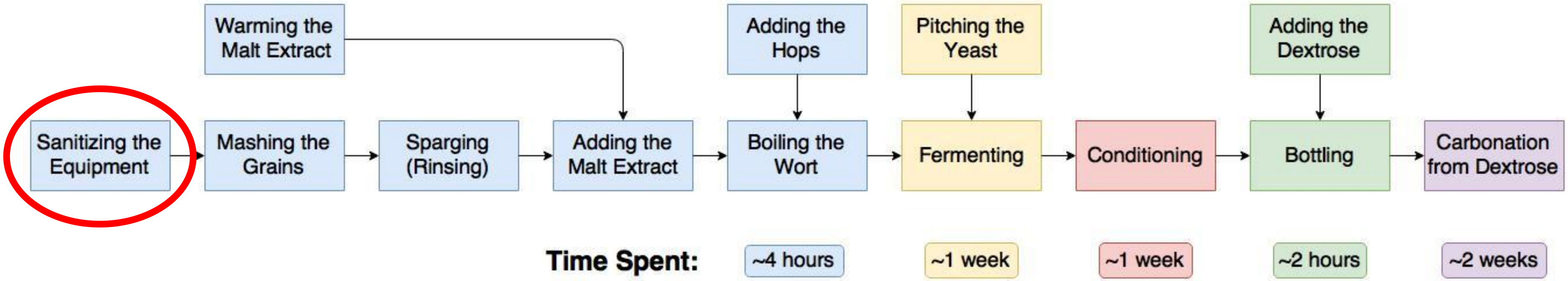
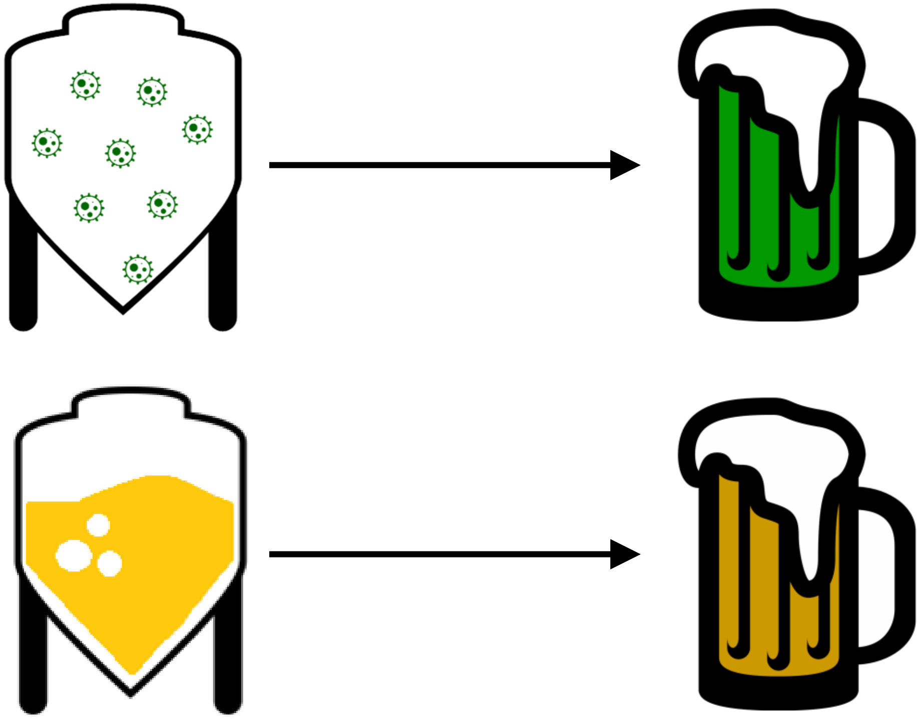


Proper Sanitation is Key!

1.5 L of water per Litre of reactor capacity cleaned



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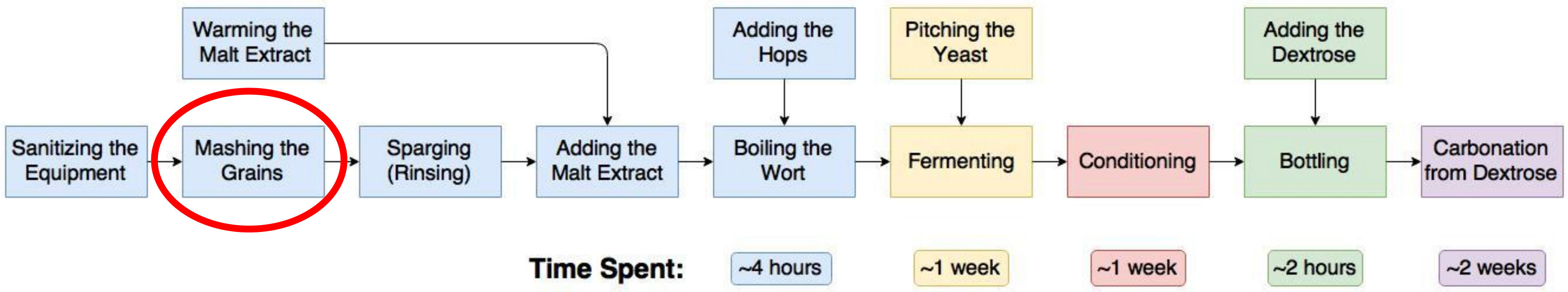

Mashing: Sugar Extraction

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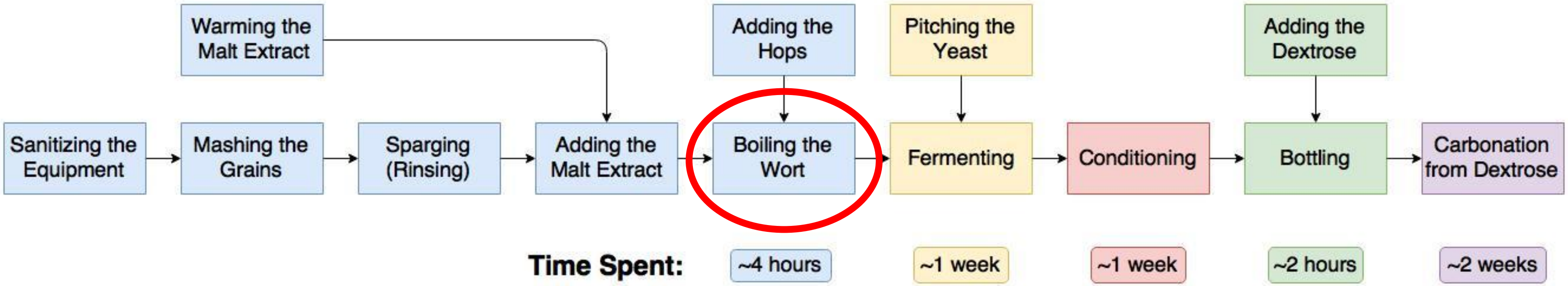
Brewing is a Bio-Process!



Boiling Wort; Unleashing the Flavor!

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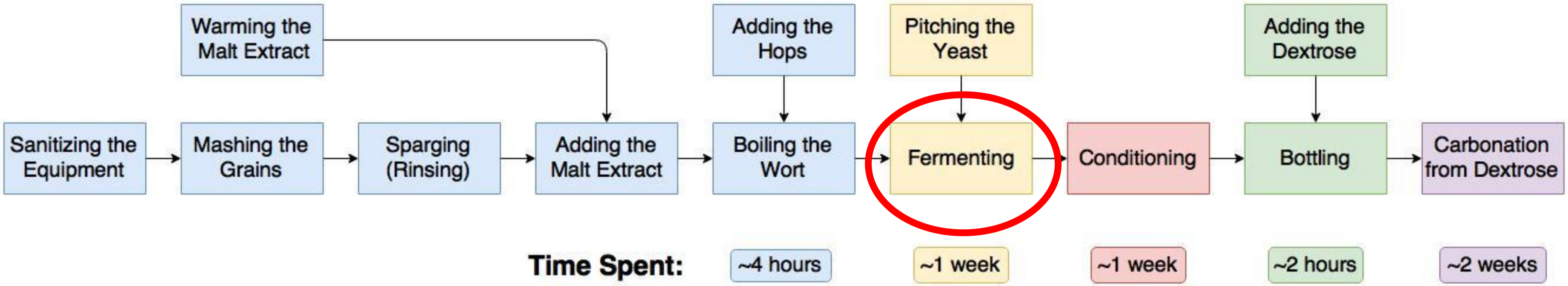
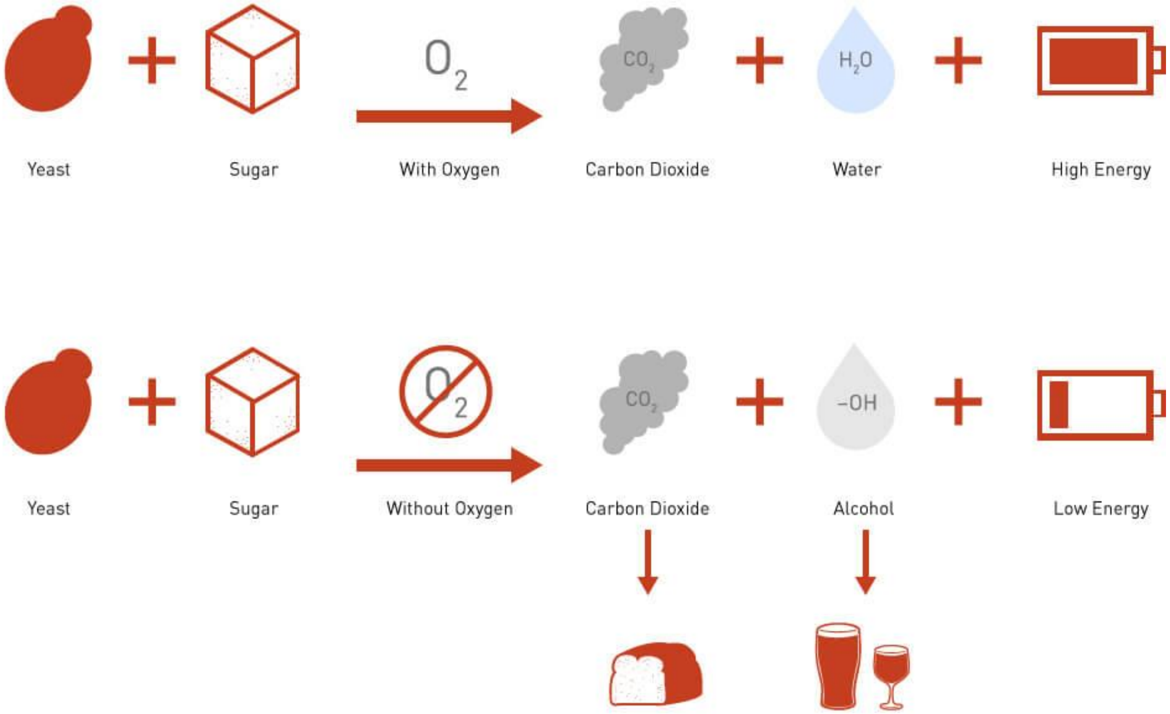
Brewing is a Bio-Process!



Fermentation Basics: Cellular Respiration



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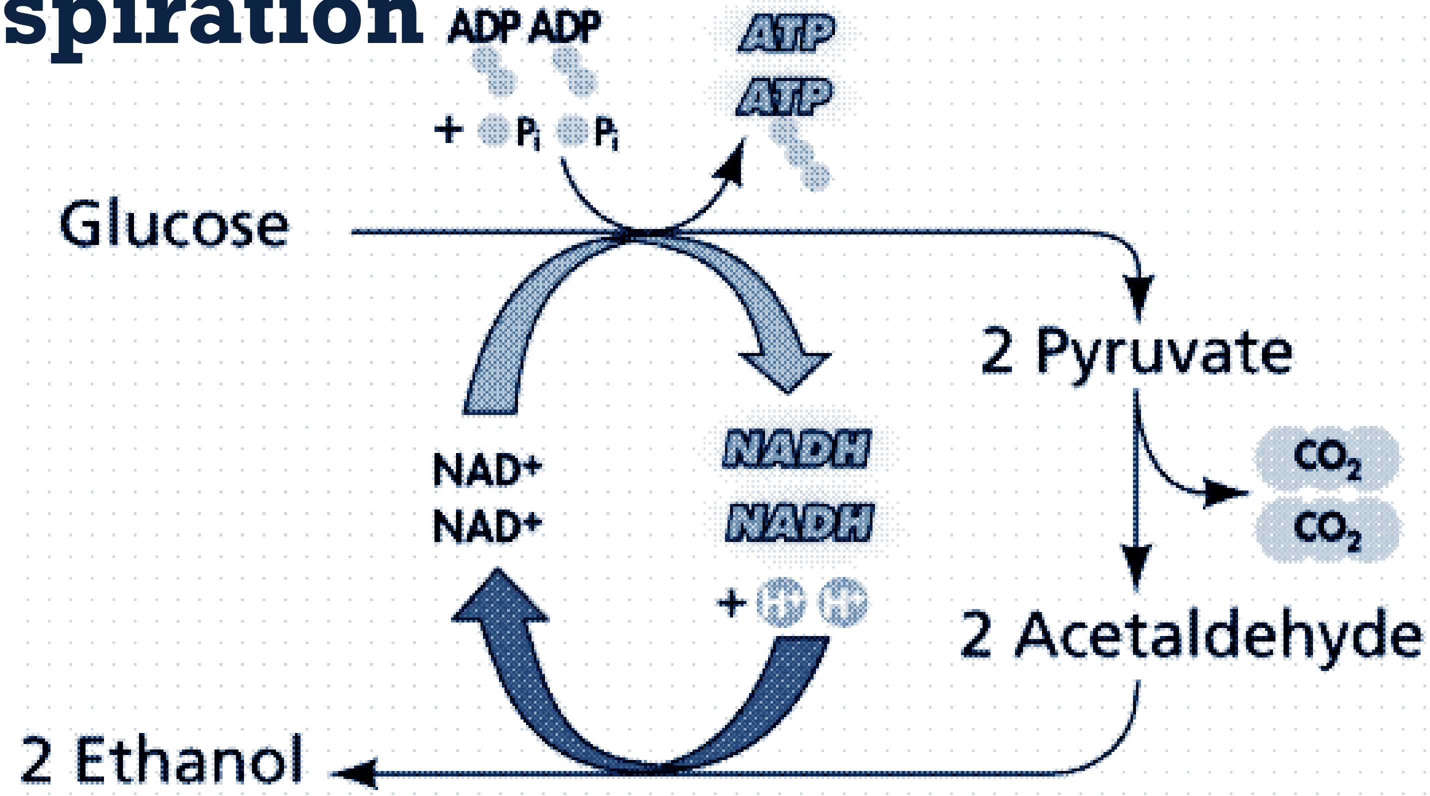
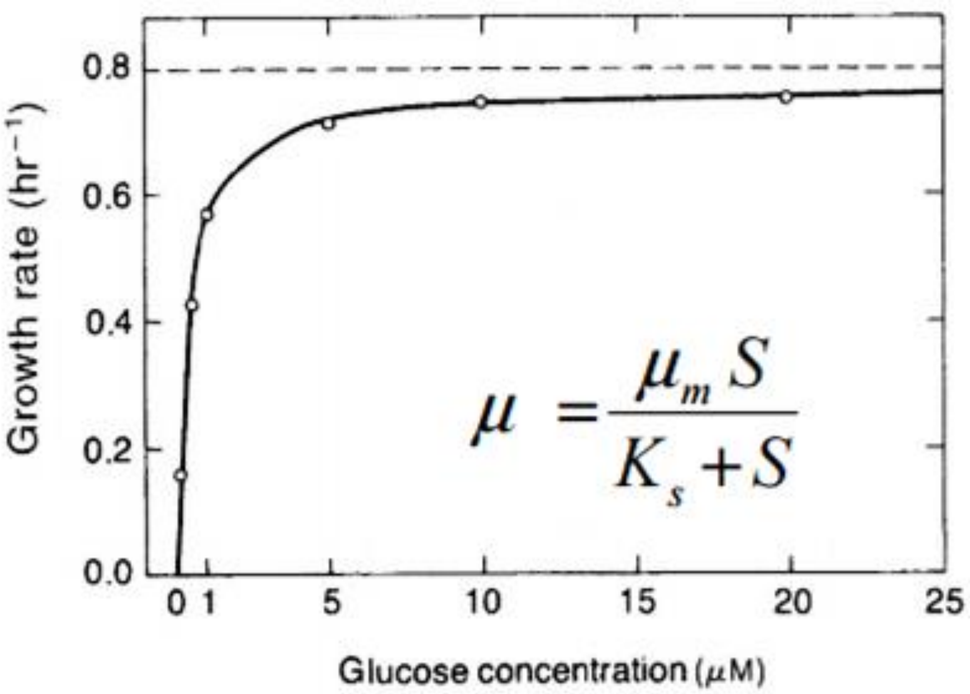
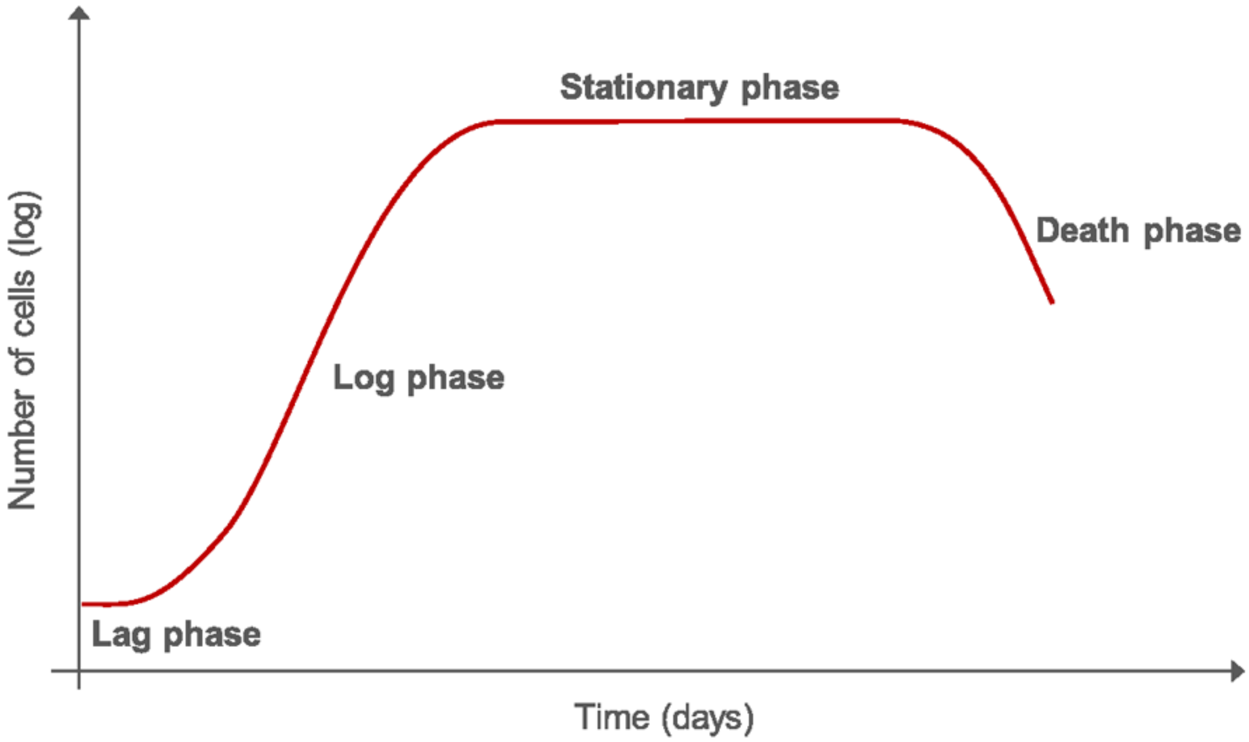


Fermentation basics: The Monod Equation

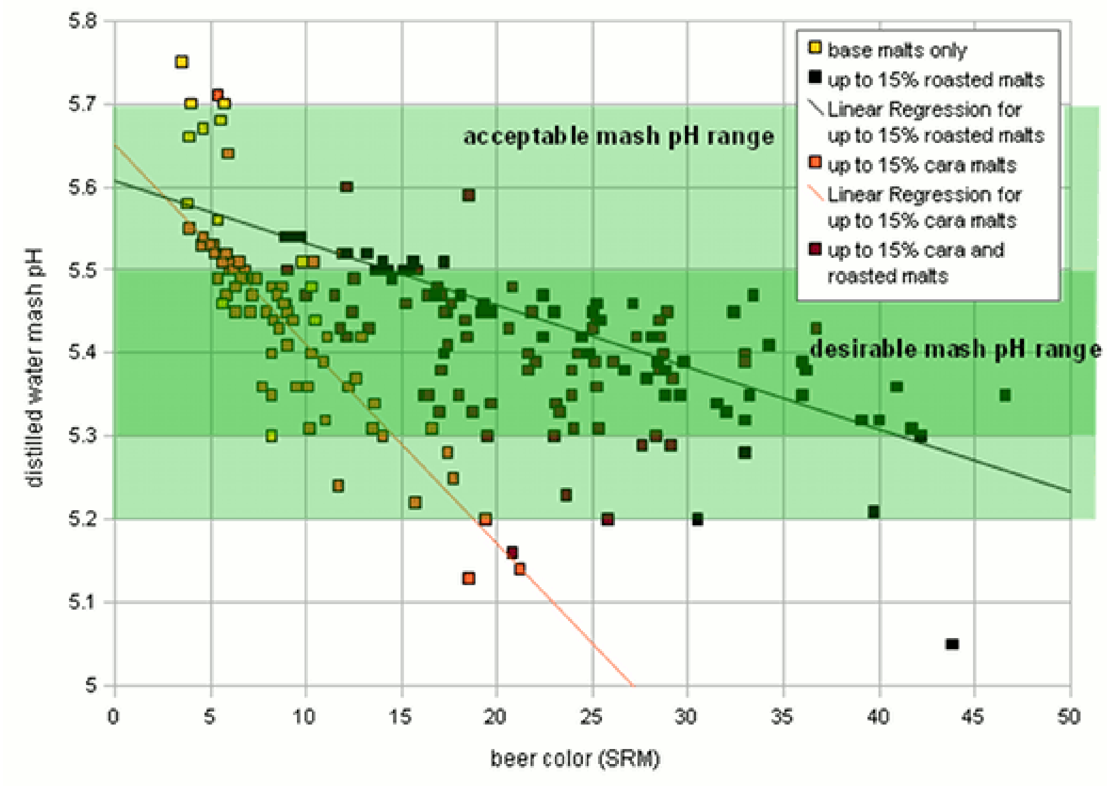


$$\mu = \frac{\mu_m S}{K_s + S}$$

Fermentation basics: Cell Growth Kinetics

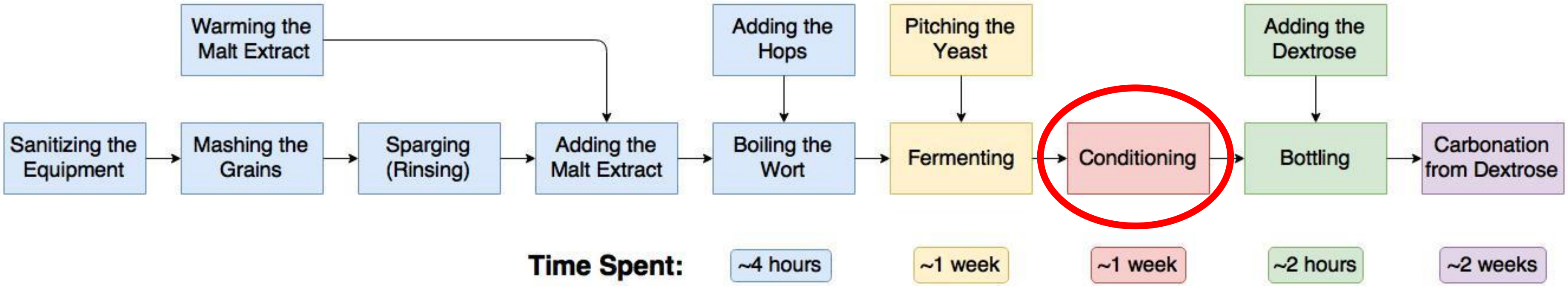


Fermentation basics: pH Changes

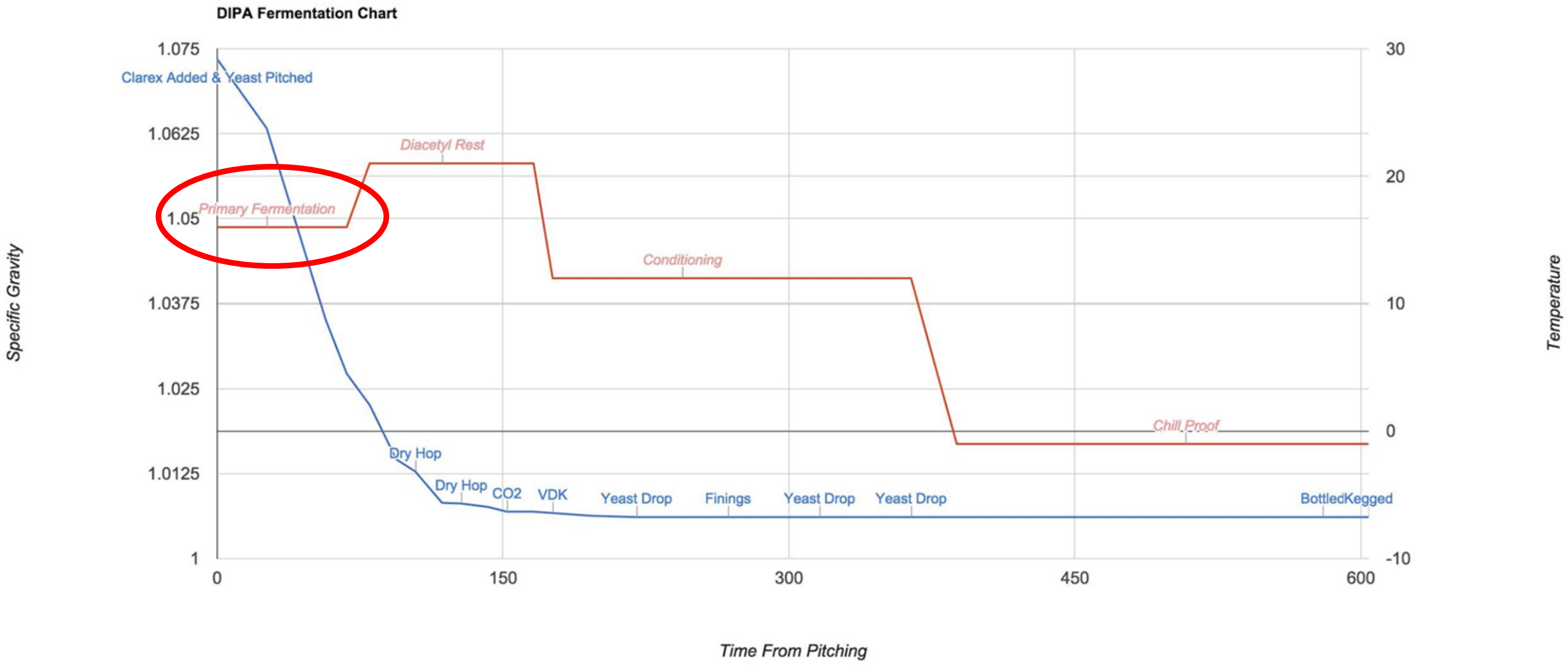


Graph Sourced From: www.braukaiser.com

Brewing is a Bio-Process!



Temperature Control: Product Quality Optimization



Temperature Control: Product Quality Optimization

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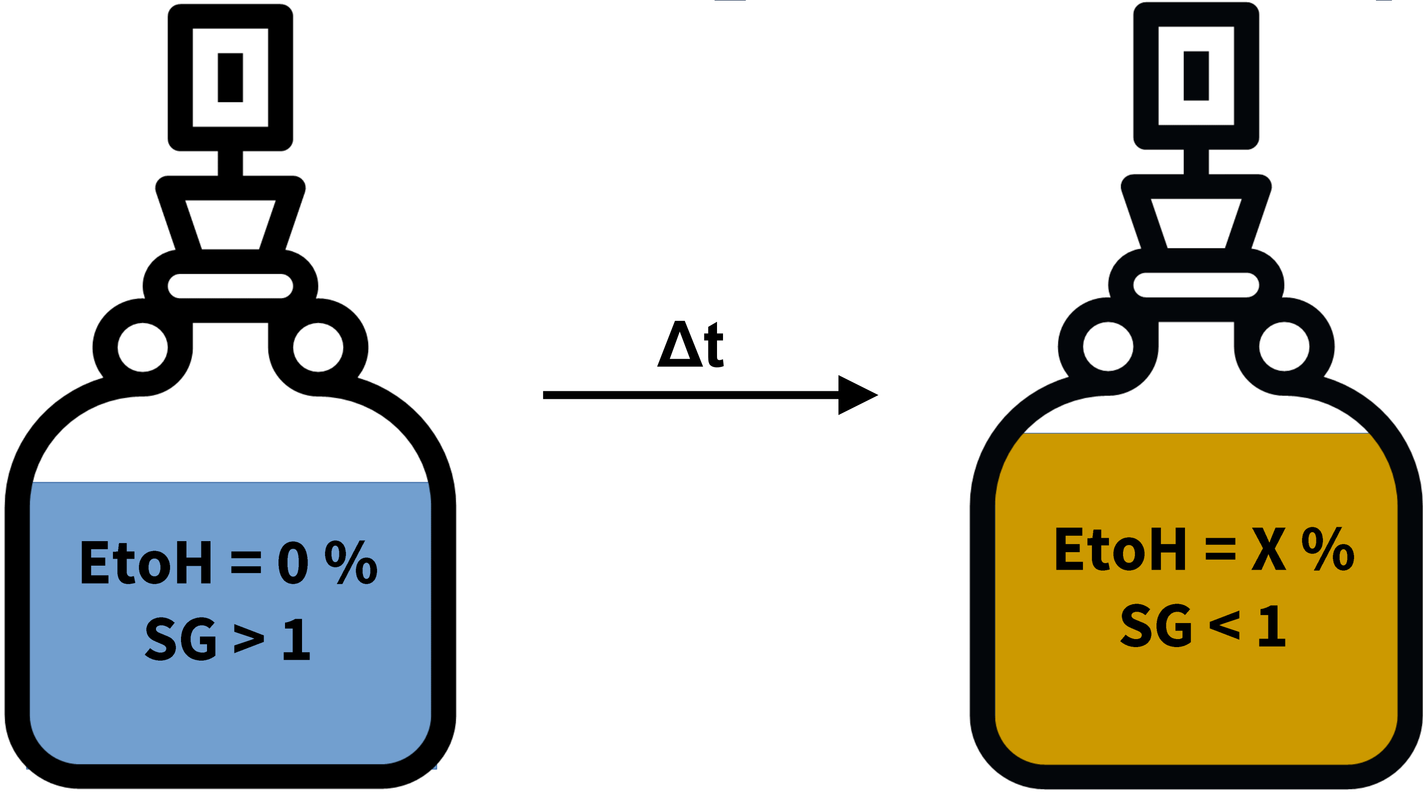
Product Monitor: Measuring Yield as a function of Specific Gravity

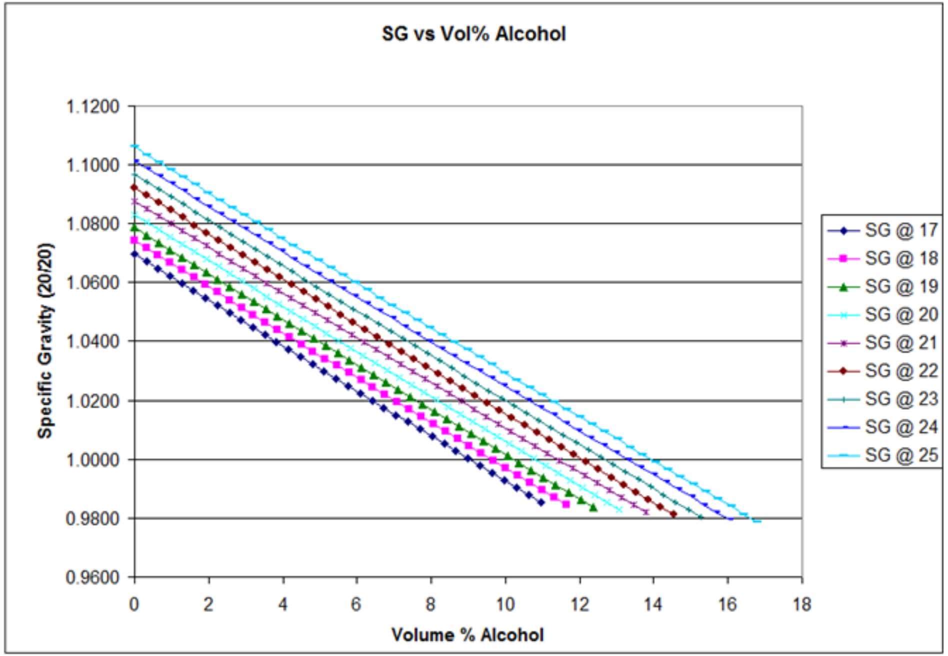


Product Monitor: Measuring Yield as a function of Specific Gravity

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_6O + 2ATP$$

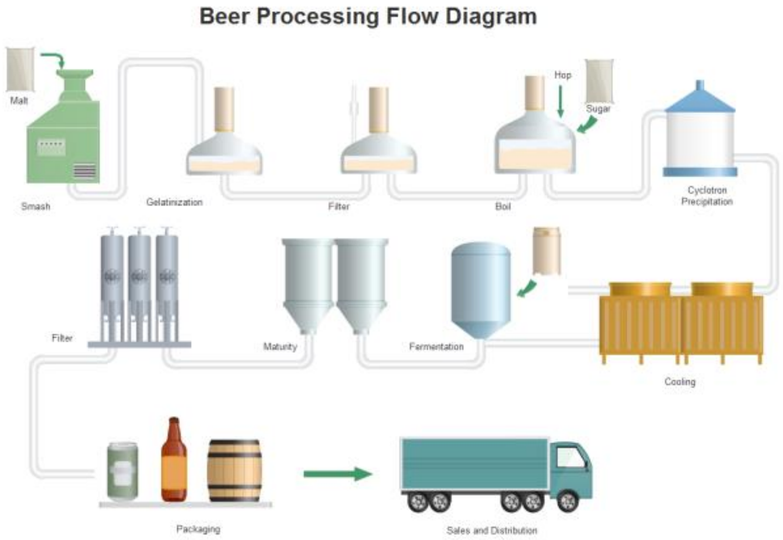
$$glucose \longrightarrow carbon\ dioxide + ethanol + 2ATP$$

$$\%ABV = \frac{Original\ SG - Final\ SG}{7.36} \times 1000$$



Applications of Process Engineering for Brewing

- Unit Operations
  Mashing, Fermentation, Filtration etc.
- Process Control & Automation
  Flow rates, temperatures, product yield
- Biochemistry
  Yeast strains screening, metabolic engineering
- Modelling & Simulations
  Reaction kinetics, reactor sizing, fluid dynamics



Process Control

- Quantitatively determine the effects of process variables on beer characteristics

- Mathematically define the process conditions to produce the desired beer style

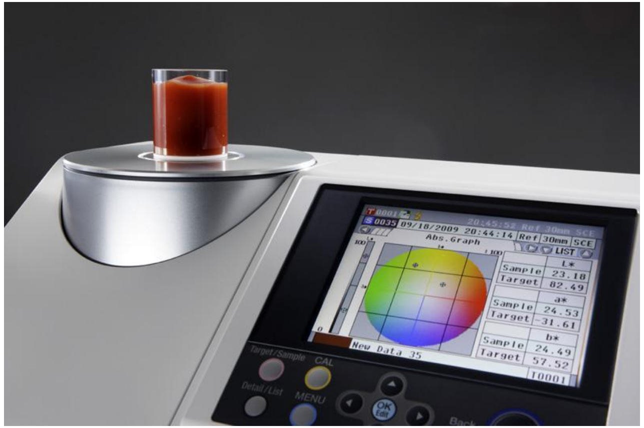
- Detection of process deviations and faults to increase product reproducibility

Beer Characteristics

Temperature → Hops, grains, yeast ← pH

Flavor
Bitterness (IBU)

Alcohol Content
Strong, weak



Appearance
Color (SRM or Standard Reference Method)

Aroma
Fruity, floral, spicy etc.

Measurement & Analysis:
Gas chromatography, spectrophotometry etc.

Quality Control using Gas Chromatography

- Monitor Alcohol Content

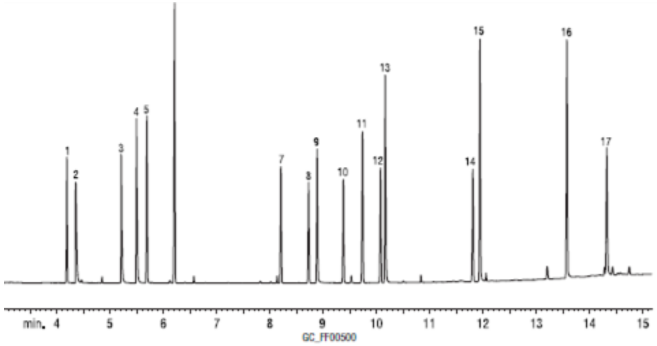
  Determine amount of ethanol and trace amounts of methanol

- Determine Volatile Profile of Product

  Analyze what compounds contribute to aroma and flavor

- Detect Trace Level Impurities

  Determine parts per million amounts of undesired products



Quality Control using Spectrophotometry

- Monitor IBU (International Bitterness Unit) (275 nm)
  Detect how bitter the beer will taste

- Measure diacetyl acetate (530 nm)
  Ensure there are low levels of diacetyl in beer

- SRM (430 nm)
  Determine color of beer

- Turbidity (700 nm)
  Determine clarity of beer

How Do We Characterize Beer?

Recipe	OG	FG	IBU	Colour (SRM)	ABV
Premium American Lager	1.046-1.056	1.008-1.012	15.0-25.0	2°-6°L	4.6%-6.0%
German Pilsner	1.044-1.050	1.008-1.013	25.0-45.0	2°-5°L	4.4%-5.2%
American Pilsner	1.044-1.060	1.010-1.015	25.0-40.0	3°-6°L	4.5%-5.2%
American Stout	1.050-1.075	1.010-1.022	35.0-75.0	30°-40°L	5.0-7.0%
Oatmeal Stout	1.048-1.065	1.010-1.018	25.0-40.0	22°-40°L	4.2-5.9%
Sweet Stout	1.044-1.060	1.012-1.024	20.0-40.0	30°-40°L	4.0-6.0%
American Wheat	1.040-1.055	1.008-1.013	15.0-30.0	3°-6°L	4.0-5.5%
Straight Lambic	1.040-1.054	1.001-1.010	0.0-10.0	3°-7°L	5.0-6.5%
Berliner Weisse	1.028-1.032	1.003-1.006	3.0-8.0	2°-3°L	2.8-3.8%

Industry Collaboration & Opportunities

We reached out to several local breweries to identify their issues and needs in the brewing industry.

Potential side projects & research projects for AIChE student chapters.

Top 3:

- Water & Wastewater Issues
- Product Quality Control
- Low-cost Instrumentation

Water Reduction & Wastewater Treatment

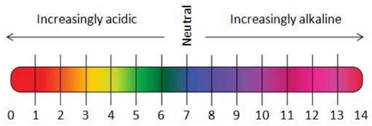
Scenario 1: Operating costs increases with water usage

- Expensive! One of the major expenses in a brewery, because of volume.
- Can we find strategies to reduce water consumption in a brewery?
- **Want ideas to streamline operations** and increase efficiency from a process engineering viewpoint.

Scenario 2: City of Vancouver is narrowing their wastewater pH range

- Breweries must be careful to keep their wastewater pH within threshold
- Important to them because of hefty fines for violations
- Most breweries are doing this manually, **can they automate this?**

  Mixing tank contents, collecting samples, measure pH, add chemicals for pH adjustments



Production Quality Issues

Scenario: Maintaining product consistency between batches

- Breweries often have trouble maintaining product consistency, even with the exact same recipe, due to variations in process conditions.
- Very challenging to build a model for large dimensional processes

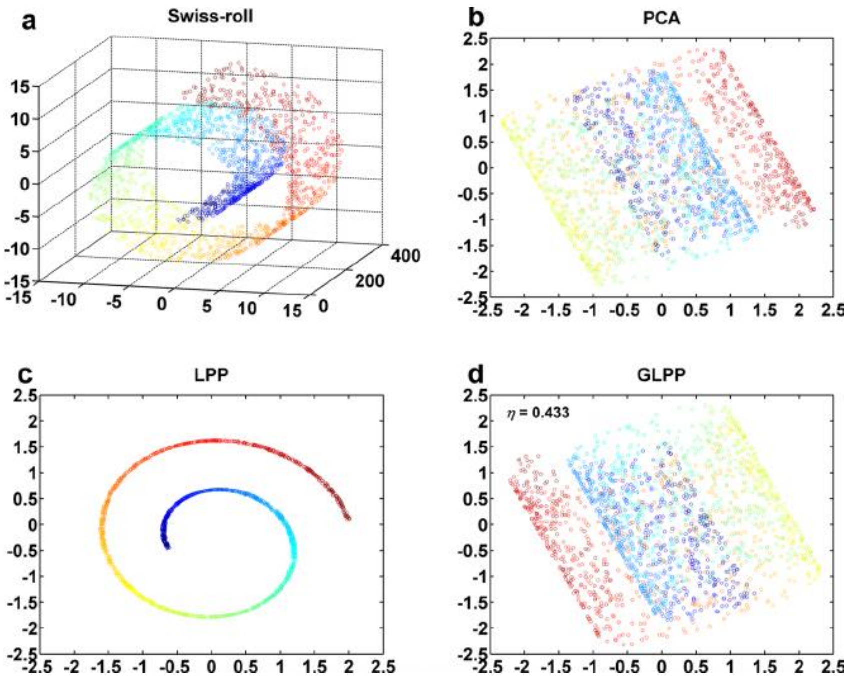
UBC Data Analytics & Intelligent Systems Lab

Website: dais.chbe.ubc.ca

- Can we **predict product qualities** from historical process data, without deriving an explicit model? *- e.g. temperature, pH, yeast strains etc.*
- Can we use these predictions to make a **smart, self-learning controller** that can drive processes to the desired product?
- **Ongoing research projects** with pharmaceutical and mining companies. Can we **extend these ideas to the brewing process**?

Prof. Bhushan Gopaluni, DAIS Lab, UBC

Machine Learning Algorithms



UBC DAIS Lab: Research on applying machine learning to process data:

- **Dimensionality Reduction**
  Visualize large-dimensional systems and brewing conditions in a single plot.
  e.g. Principal Component Analysis

- **Classification & Regression**
  Classify and predict beer styles according to process conditions
  e.g. Neural networks

- **Model-Free Controller Design**
  Deriving control policies for breweries using historical process data without an explicit model
  e.g. Reinforcement Learning

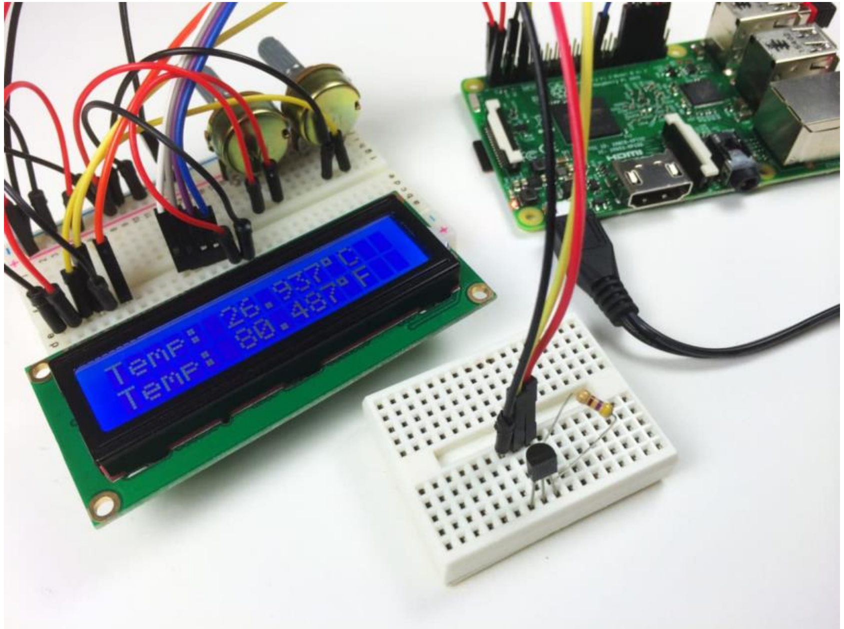
Low-Cost Instrumentation

Scenario: Smaller breweries cannot afford expensive lab equipment

- **Common equipment in university labs** like gas chromatography are usually **too expensive for smaller breweries.**
- Smaller breweries might lack employees with technical backgrounds (engineers, chemists, lab technicians etc.)
- **Several areas to explore**: wastewater pH monitoring system, automated process data collection, document control systems for recipes and brewery inventory, and more!
- There is a **huge market for low-cost, student-built devices** that can replace a commercial product. Smaller breweries will be **very happy** if they can pay $500 instead of $50,000 for a useful device.

What are WE doing?

Integration to Internet of Things



Integration to Internet of Things

- Integrates IOT (Internet of Things) with established engineering technologies to provide a fully automated “smart brewery.”

- Models processes accurately and predicts alcohol yield.

How does it work?

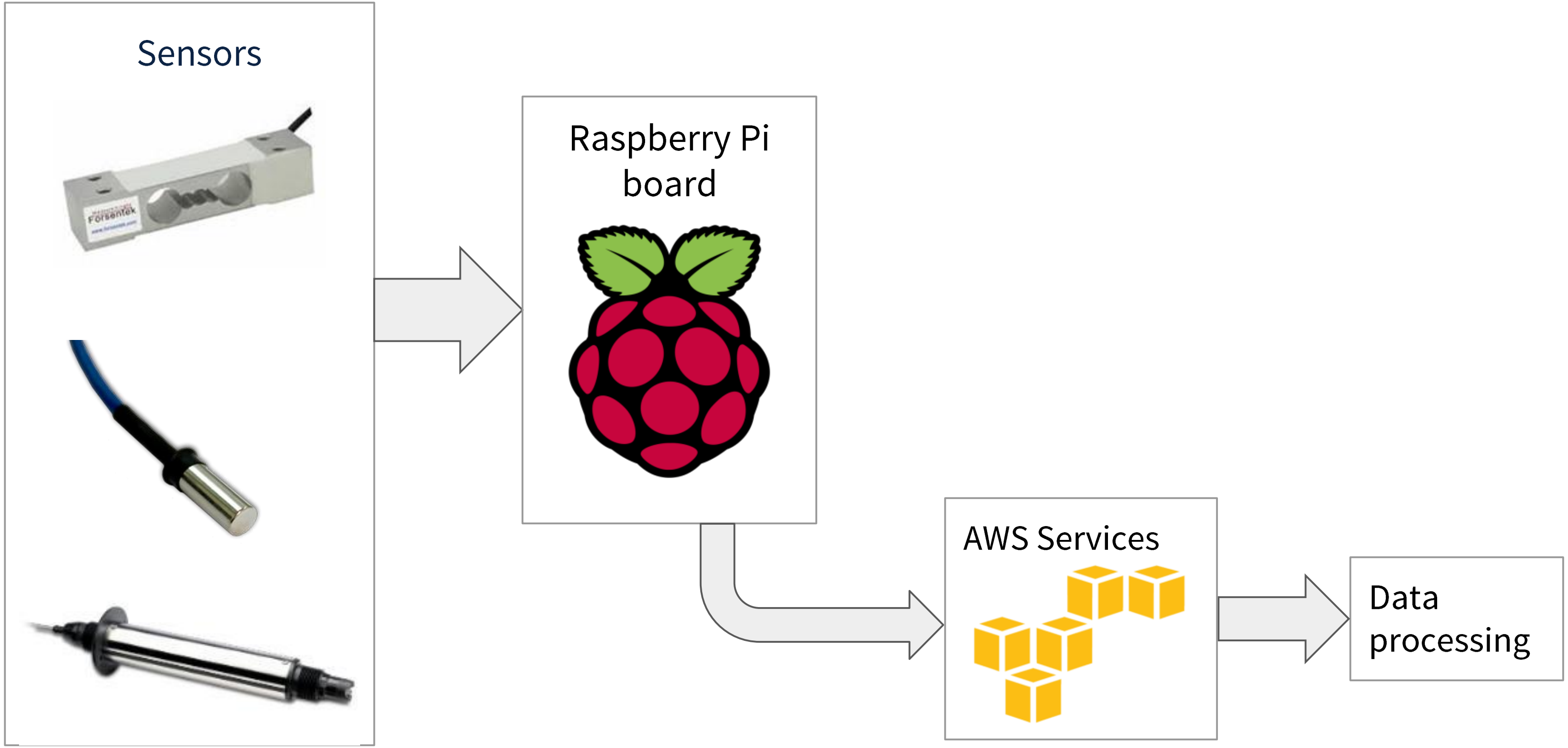
Sensors

How does it work?

Sensors

Raspberry Pi board

How does it work?



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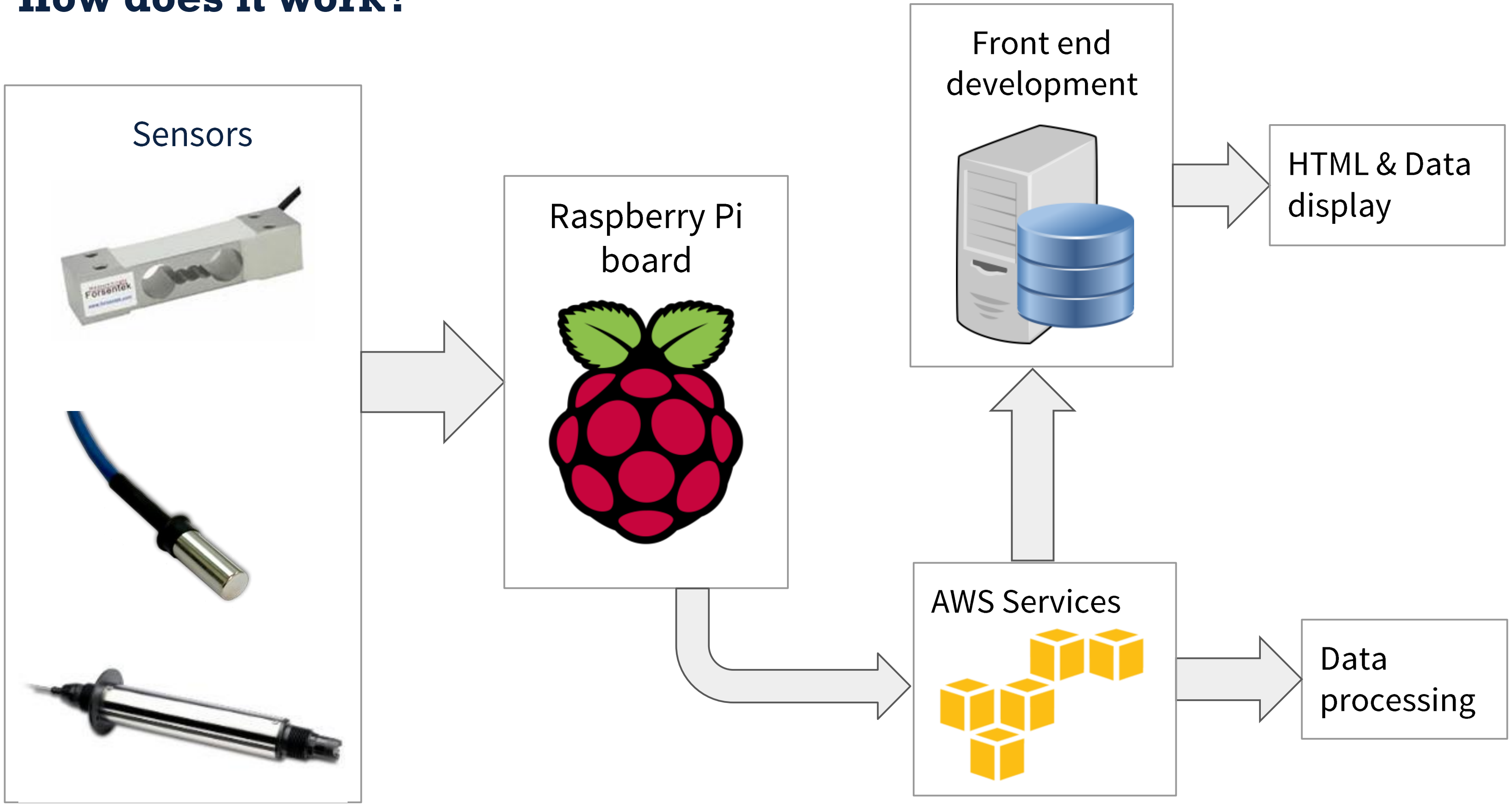

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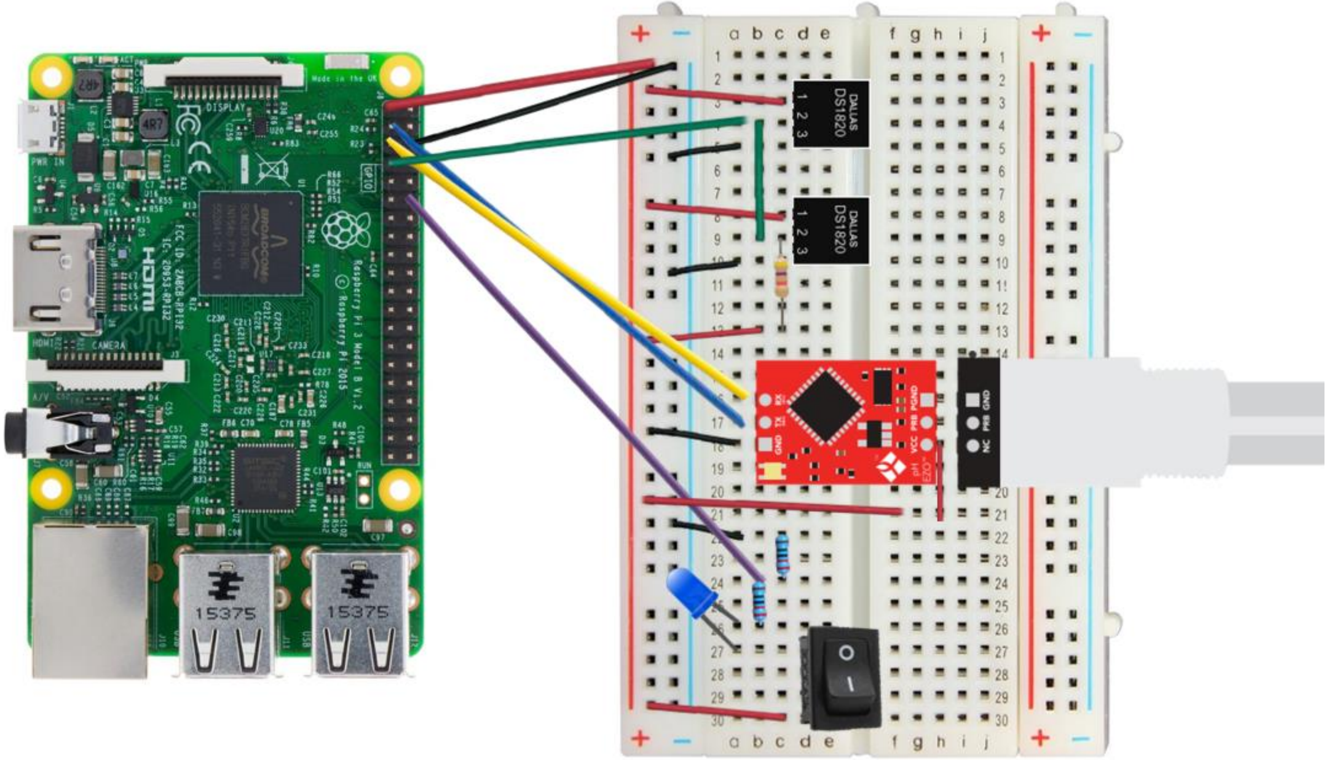
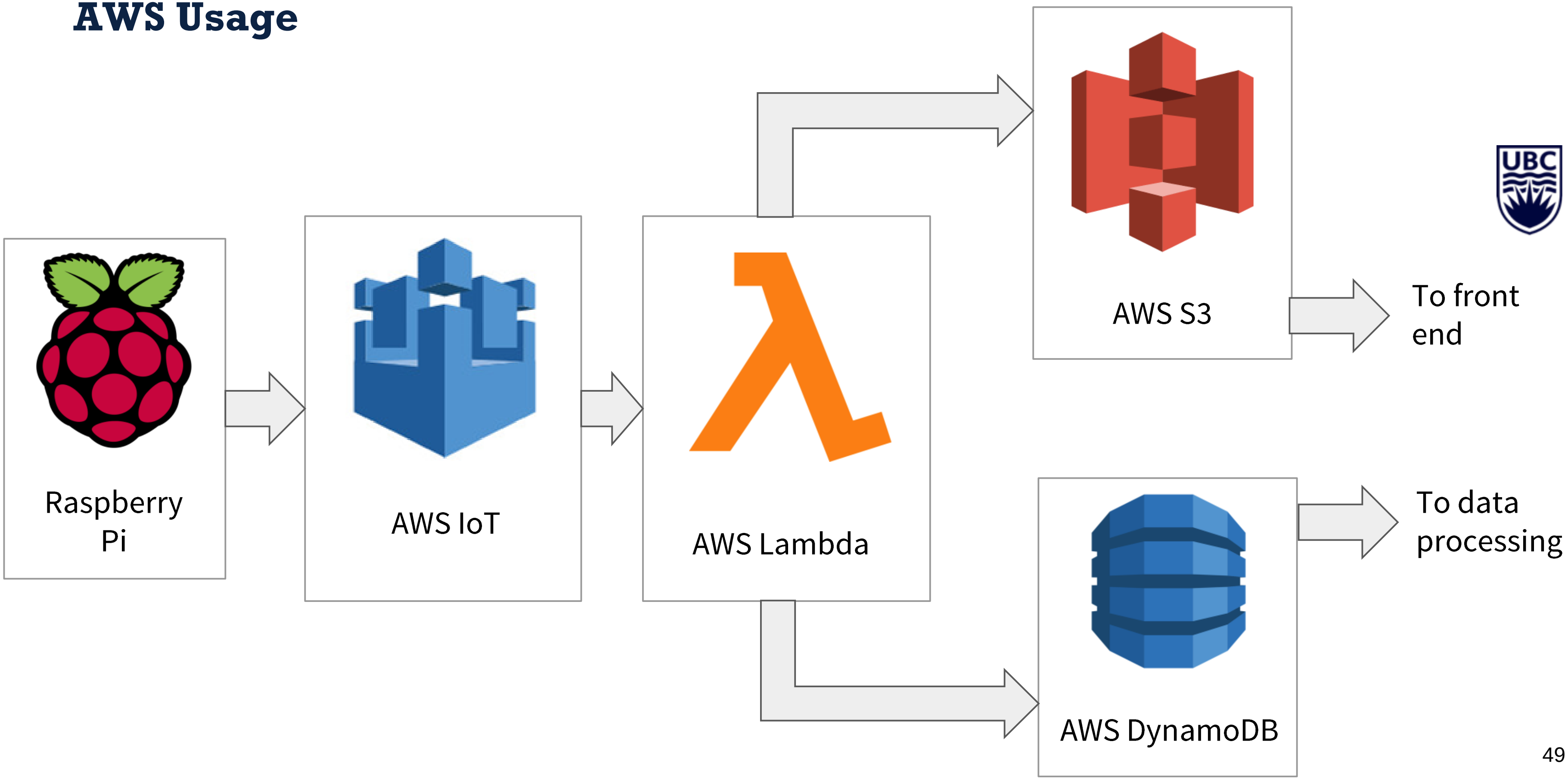


AWS Usage



Raspberry Pi
AWS IoT
AWS Lambda
AWS S3
To front end
AWS DynamoDB
To data processing

We will upload our slides and other resources here

↓

beer.ubcchemecar.com

Acknowledgements

- Alan Vilchis
- Ricardo Rivera
- Shannon McInnes
- Kevin Reilly
- Central City Brewers
- UBC Chemical and Biological Engineering

UBC
a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA
Chemical & Biological Engineering
Faculty of Applied Science

CENTRAL CITY
BREWERS + DISTILLERS

Thank You for Listening!


Questions?
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