



Coffee Matters

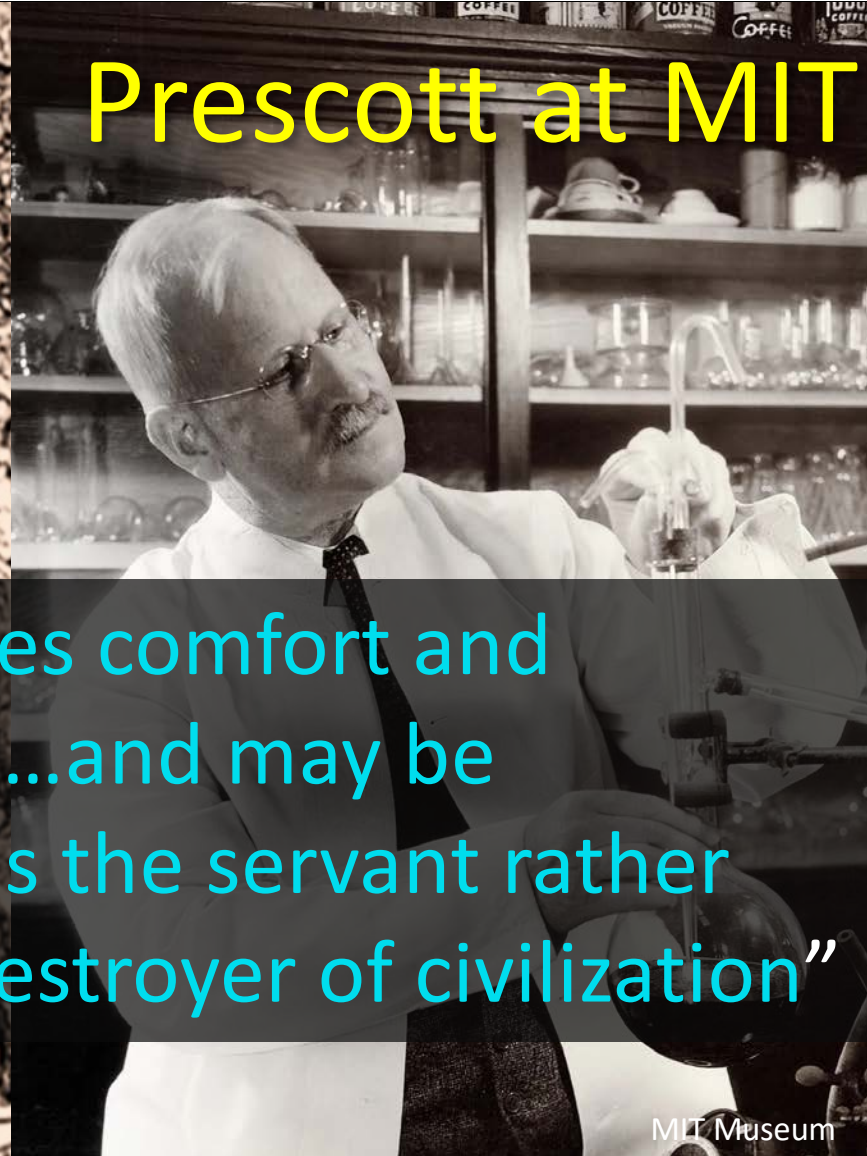
Jeffrey C. Grossman
Materials Science & Engineering, MIT

Kaldi in Ethiopia



All About Coffee, by William Ukers

Prescott at MIT



MIT Museum

“coffee gives comfort and inspiration...and may be regarded as the servant rather than the destroyer of civilization”

The value of hands-on learning

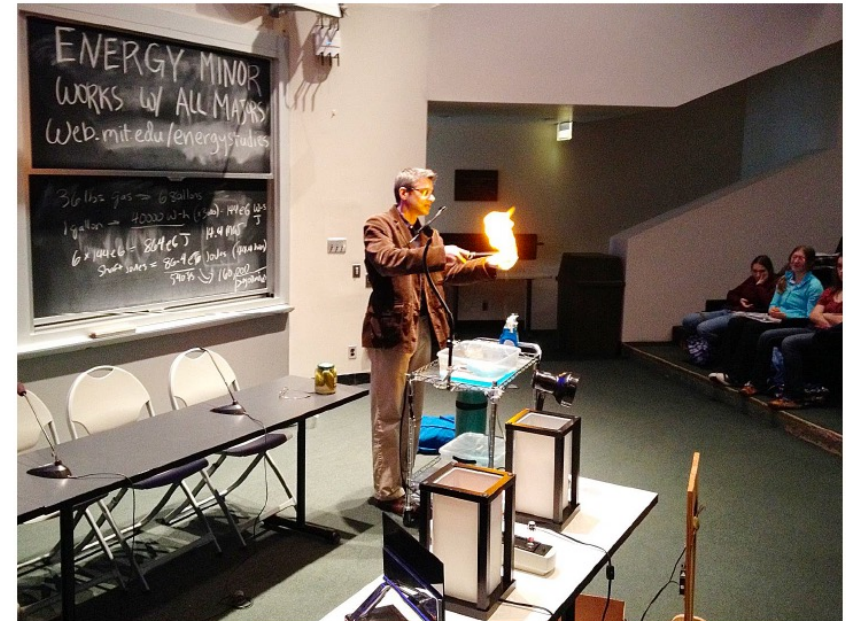
Some examples from my own teaching journey...

- Physics of music and motion
- Demo-driven thermodynamics
- The Latke vs. Hamantaschen debate
- Freshman Chemistry Lectures --> Goodie Bags
- Sleep Study
- The Breakerspace
- Coffee Matters

My first teaching assignment at MIT was thermodynamics



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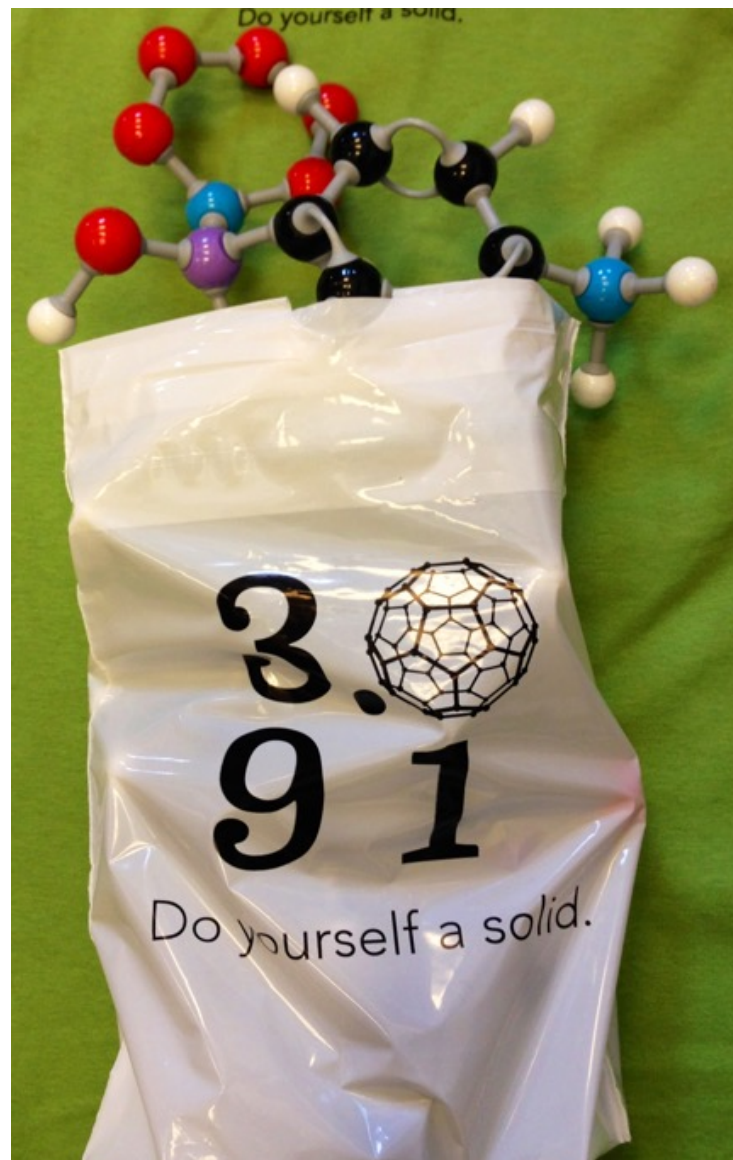


**Next major teaching assignment: 3.091 Solid State Chemistry
...a large GIR class of mostly freshmen**

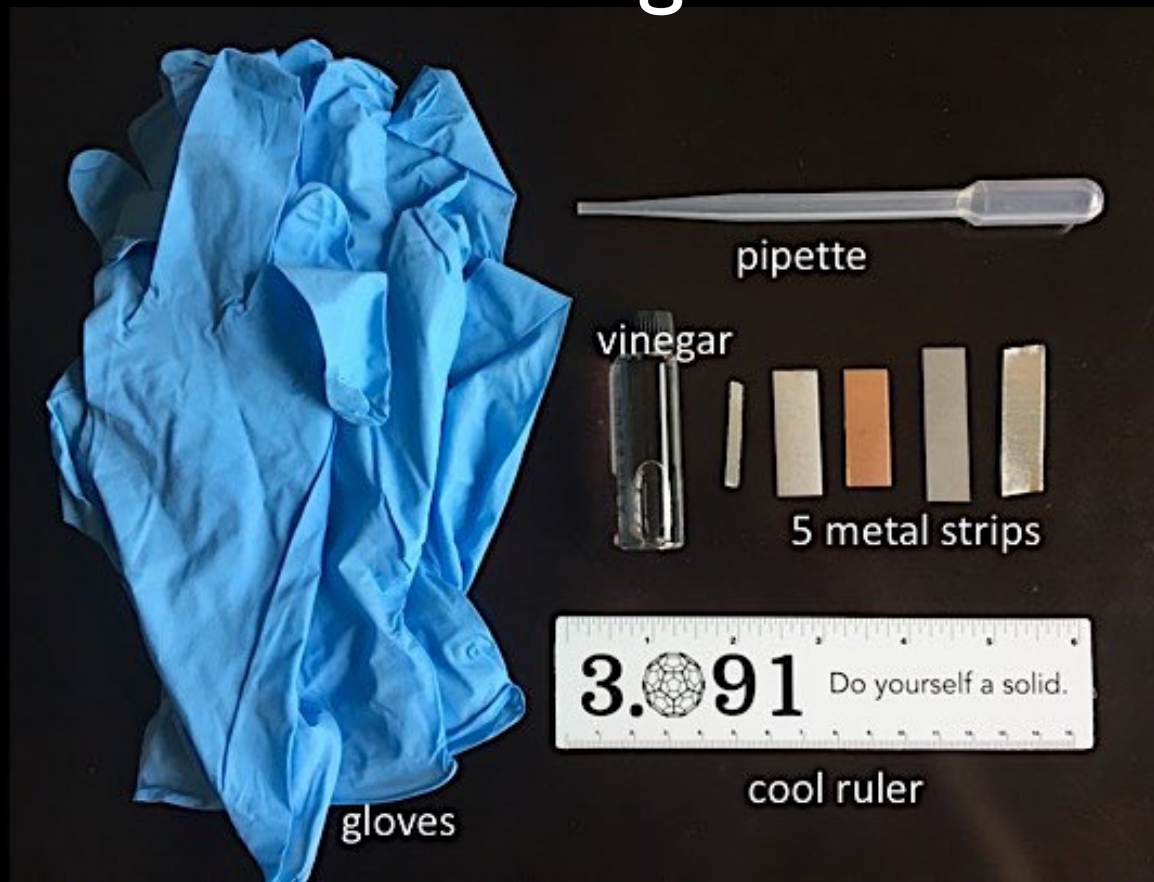


Chemistry Goodie Bags

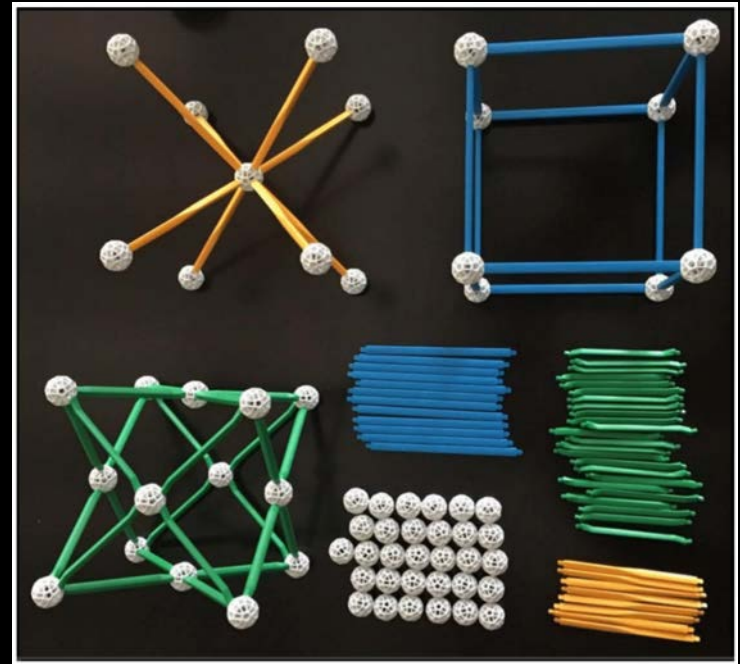
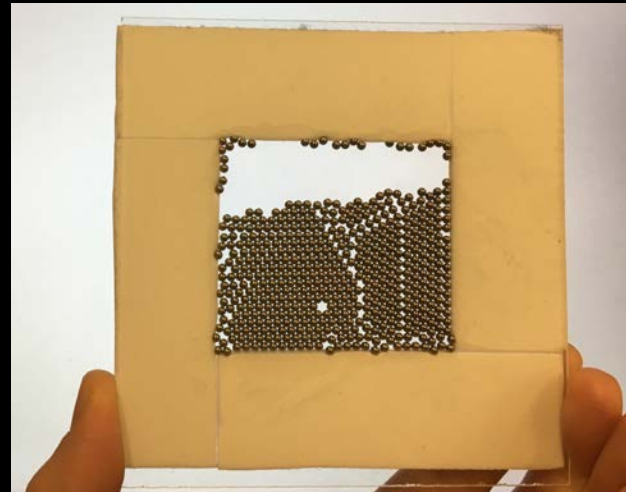
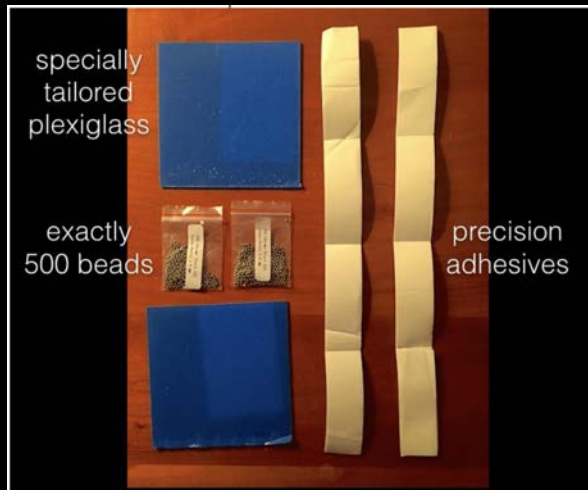
- Take-home mini-experiments offer hands-on, discovery-based learning
- Distributed to each student weekly.



Example: Goodie Bag #1, Discovering Metals

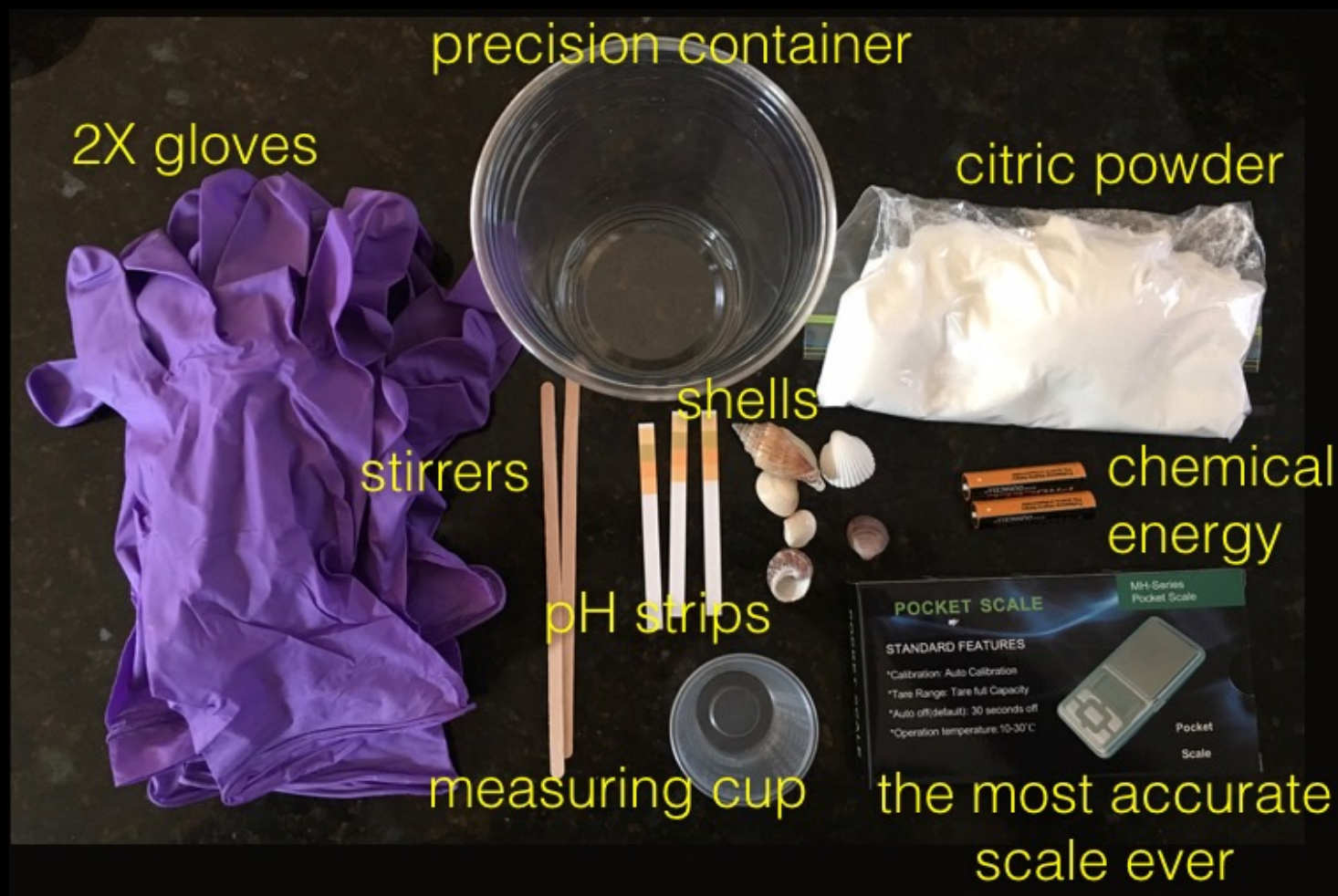


Goodie Bag #5 Crystallography



Goodie Bag #7 Defects

Goodie Bag #8, Reactions



Why did you choose 3.091?

3.091 seems to have a more hands-on focus on learning and an engineering approach which I appreciate.

mini labs / goodie bags. can't learn chemistry without labs

It seemed like a more hands-on and exciting approach to chemistry.

Grossman's speech
Application to engineering
Goodie Bags

Why did you choose 3.091?

I wanted more hands-on approach over sitting in a lecture hall without any interaction.

- It was more applied to engineering

- Seems more interesting

- heard professor was great

Link to engineering (and Goodies Bags, of course)





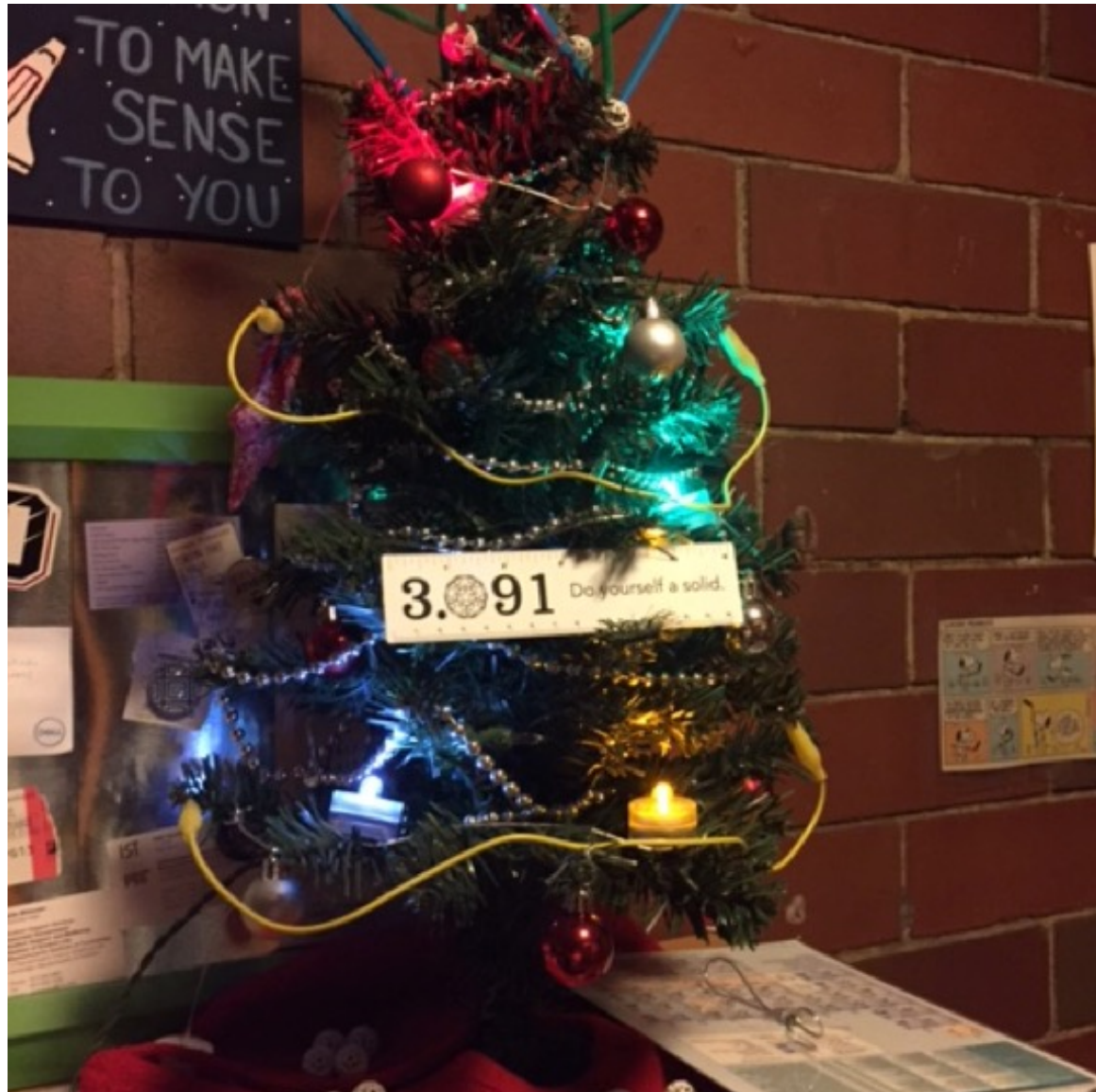




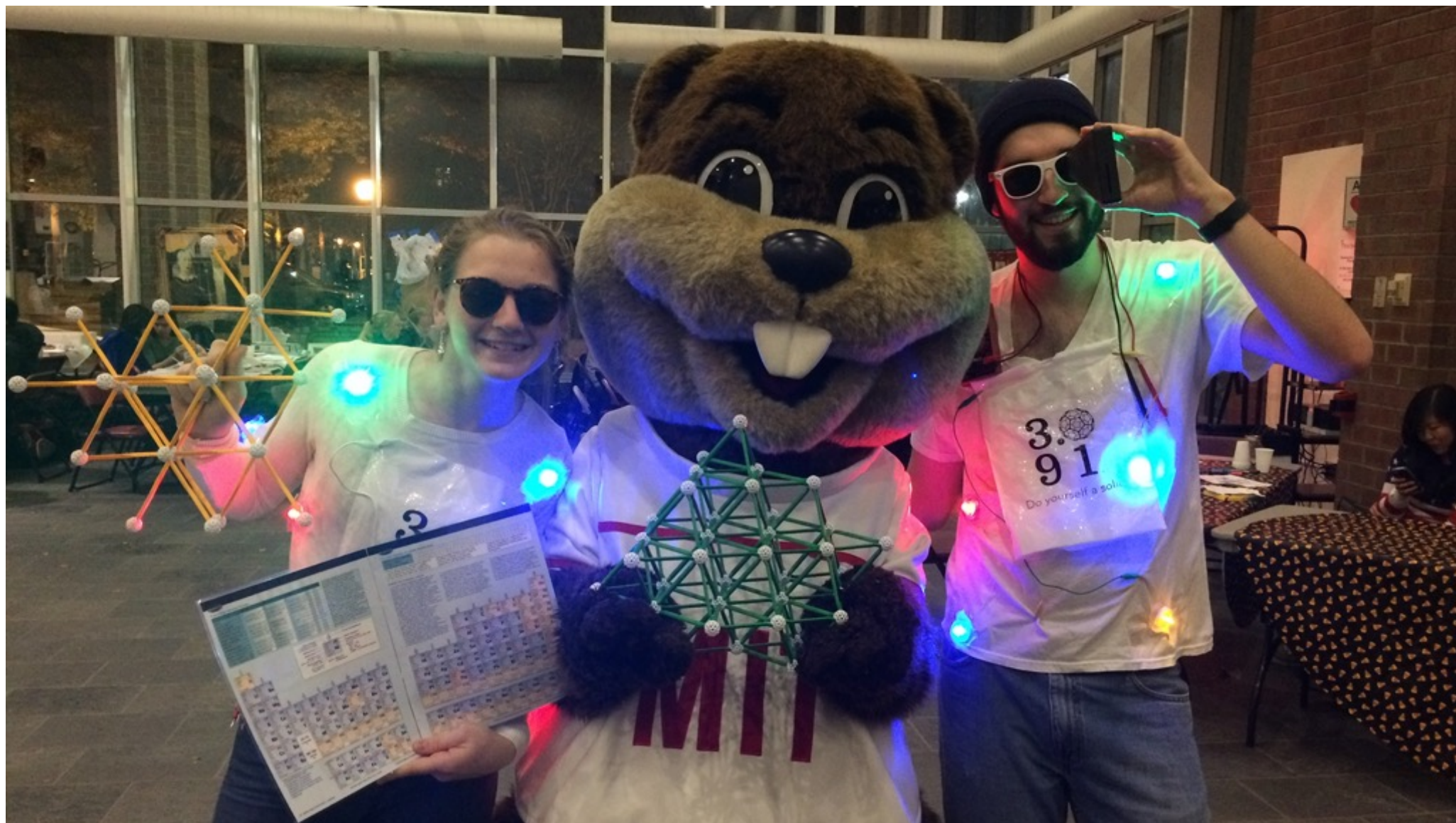














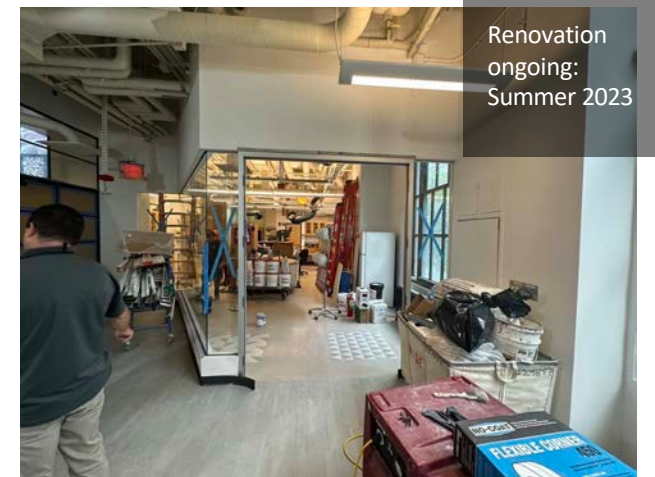


The Breakerspace

(the ultimate Goodie-Bag)

Learn about materials w/ state-of-the-art characterization:

- Access with minimal barriers, maximum “exploration”
- Combined “lounge & learn” materials discovery space
- Create new learning opportunities across MIT



Renovation
ongoing:
Summer 2023

First Breakerspace Class!

MIT 3.000
Coffee
Matters



Lab Opens for
general use



Discover the DMSE Breakerspace,
a materials exploration space for all undergraduates



Coffee Class Mission

The mission of this class is to educate, inspire, and explore the **taste of coffee** through the tools of **materials characterization**.

Coffee Variables

- Bean selection
- Roast
- Grind
- Water, additives
- Brew/extraction
- Chemistry

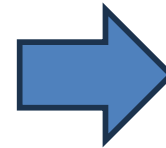
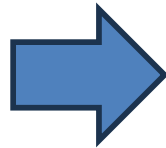
Breakerspace Tools

- Optical Microscope
- Scanning Electron Microscope
- Fourier Transform Infrared Spectroscopy (FTIR)
- Ultraviolet-Visible (UV-Vis) Spectroscopy
- Particle Size Analyzer
- X-Ray Diffraction
- Raman Spectroscopy
- Hardness, Stress/Strain, Impact Testers

Coffee Variables

- **Bean selection**
- Grind
- Chemistry
- Roast
- Brew/extraction
- Water, additives

Tree → Ripe Cherry



- Ripe cherries are bright red, slightly soft to the touch
- Unripe cherries are bitter, and possess overall poor taste profile



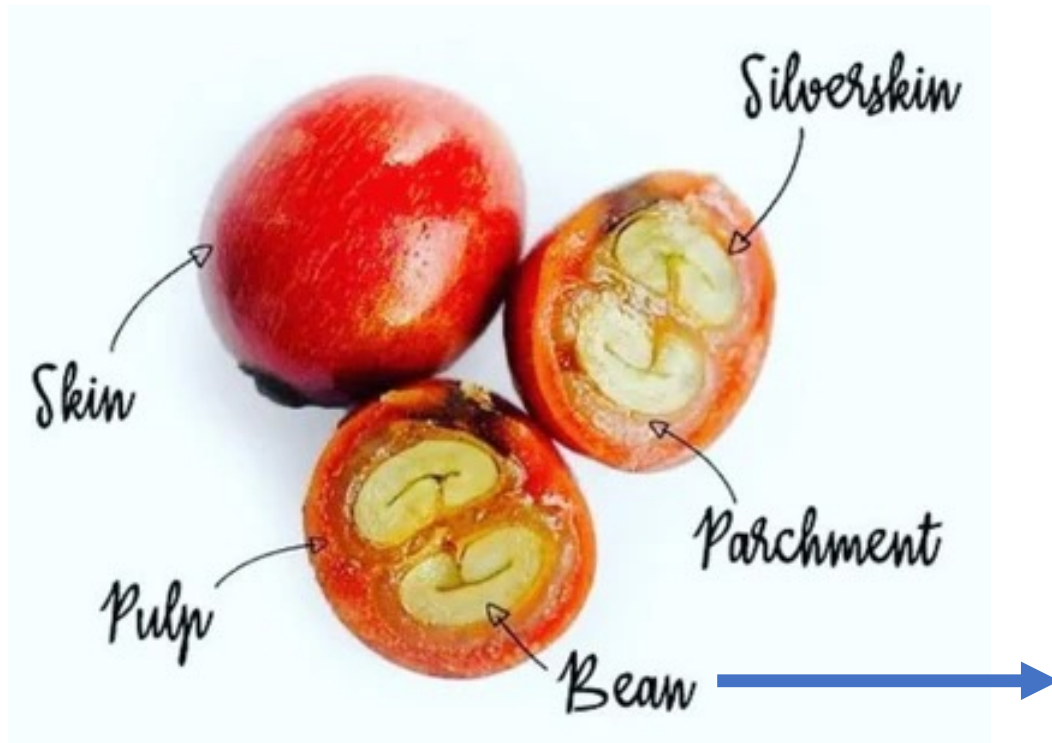
Automated sorting (tomatoes)



<https://www.youtube.com/watch?v=j4RWJTs0QCK>



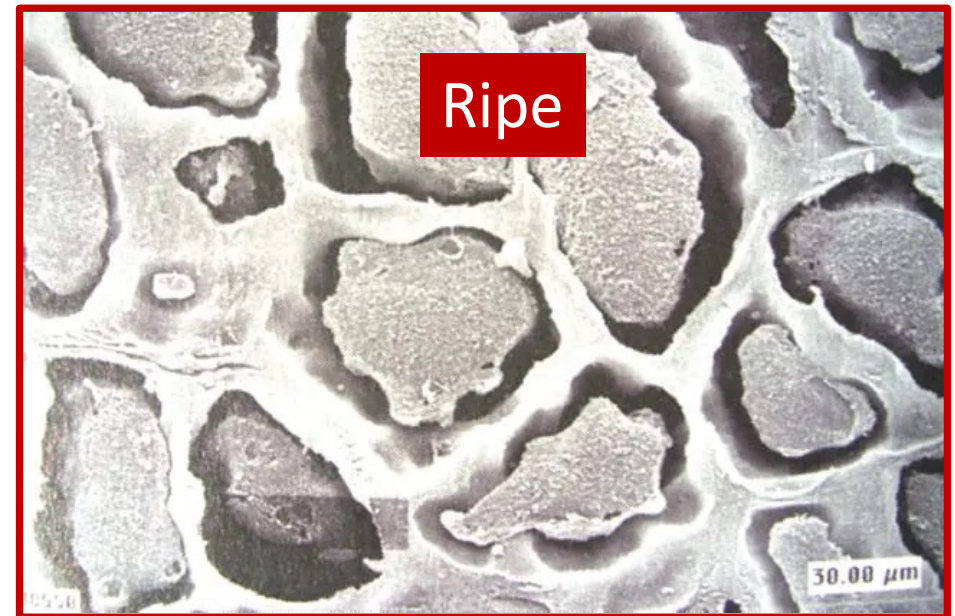
We do a lot of looking inside





The effects of ripeness up close

Scanning Electron Microscope
Using electrons to see inside a coffee bean



<https://library.sweetmarias.com/coffee-seed-structure-and-coffee-bean-defects/>

Coffee Variables

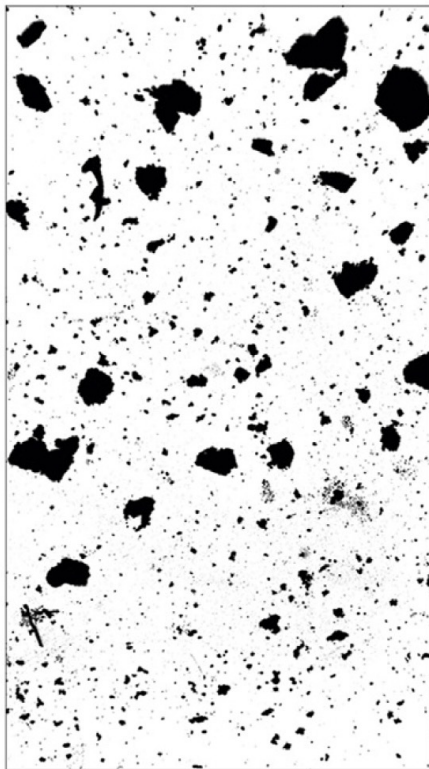
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- **Grind**
- Chemistry
- Roast
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- Water, additives



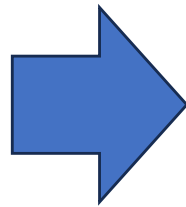
It's hard to break a cracker without creating tiny crumbs...



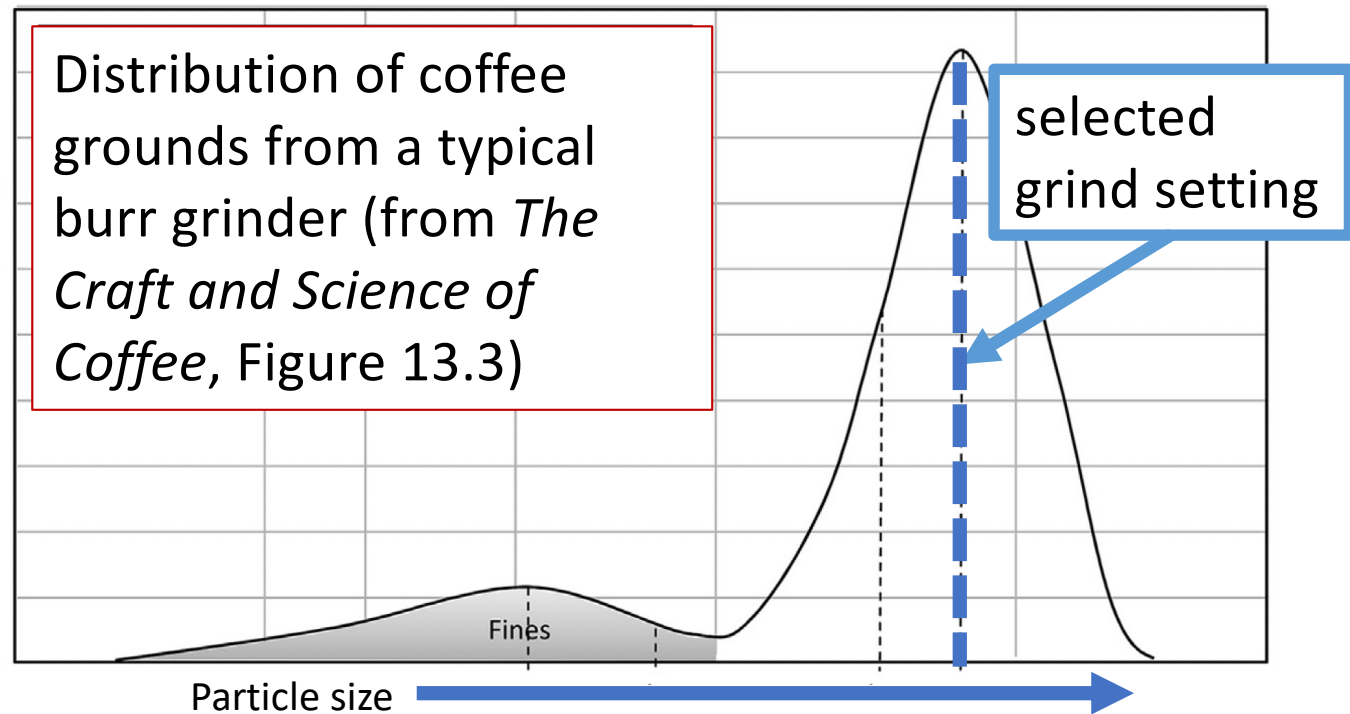
...same for coffee beans



Roasted, ground beans



Distribution of coffee grounds from a typical burr grinder (from *The Craft and Science of Coffee*, Figure 13.3)





History of Grinding Food

Mortar and pestle started the grinding business 35,000 years ago
(note: first known use of fire to cook food: 120,000 years ago)

Bread, ~30000 BC

Metal-Ground by Electricity



4000 kg/hour

<https://www.mpechicago.com/>

Stone-Ground by Hand



Mortar/pestle
(~20,000 BC)

Wikipedia

0.1-.0.2 kg/hour

Stone-Ground by Donkeys



Pompei Bakery
(100 BC)

Penn State Libraries

1 kg/hour

Stone-Ground By water



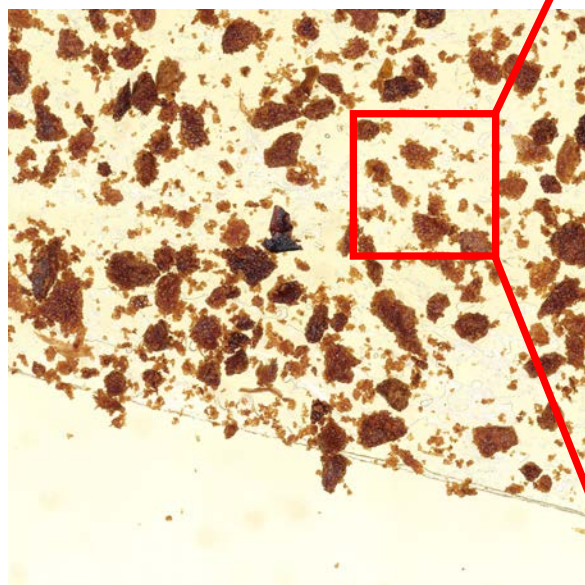
Water-Mill in England
(~1500 AD)

<https://www.youtube.com/watch?v=nY06Bw5zh-k>

10 kg/hour

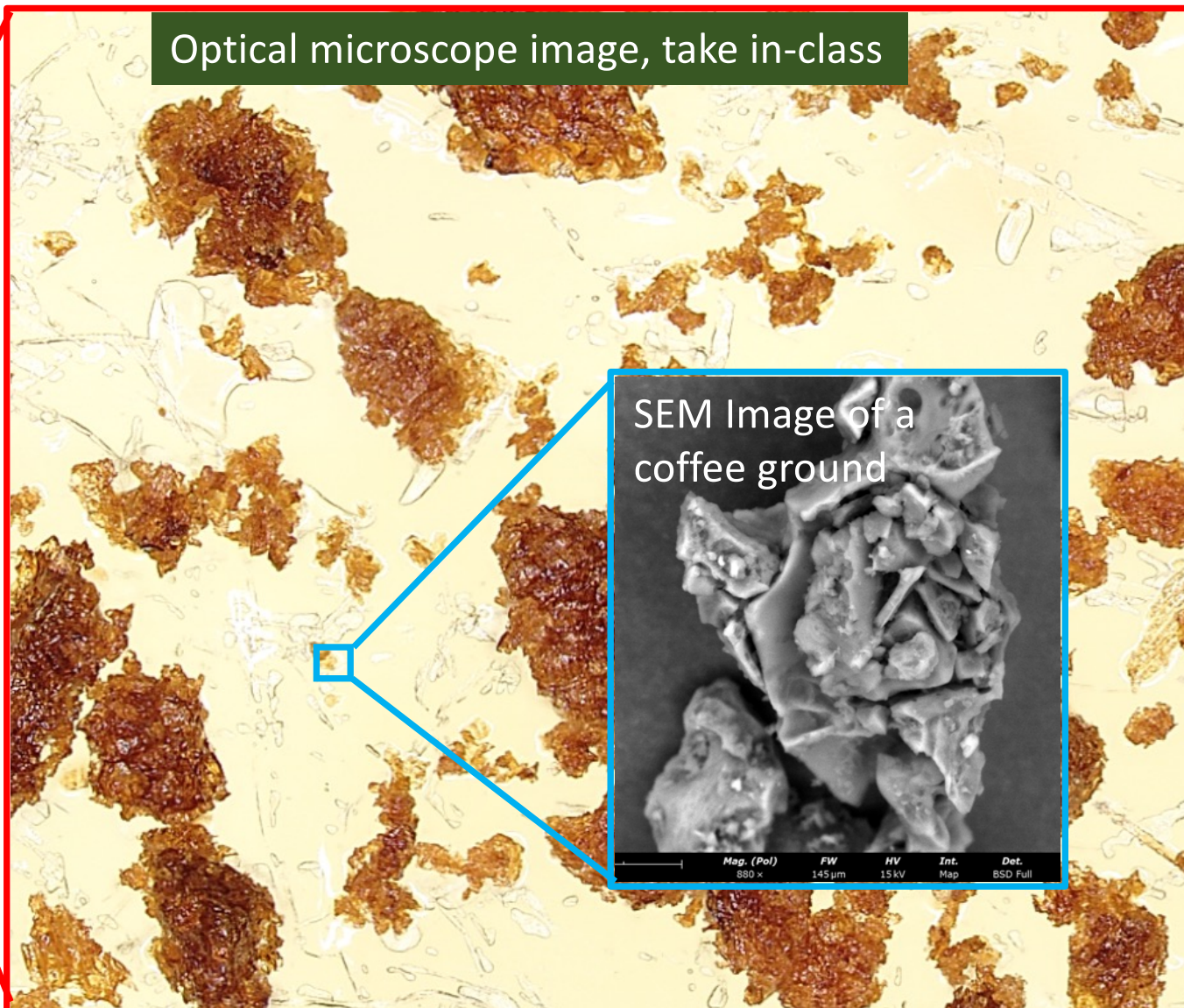


Seeing Coffee Grounds

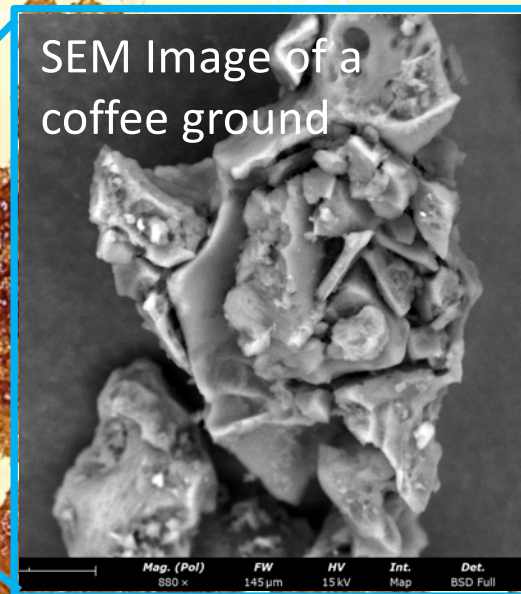


Effects of grind on clumping, particle size

Optical microscope image, take in-class



SEM Image of a coffee ground



Coffee Variables

- Bean selection
- Grind
- **Chemistry**
- Roast
- Brew/extraction
- Water, additives

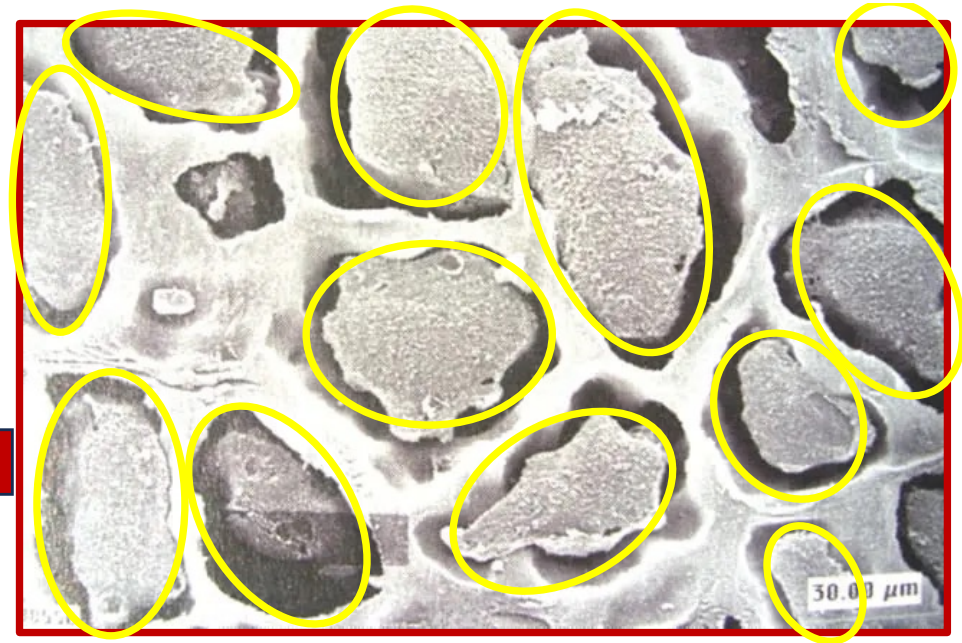


Coffee Chemistry

- caffeine stimulant
- chlorogenic acids acidity
- Trigonelline aroma,
 flavor
 (from roasting)
- melanoidins color, aroma, flavor



Breakerspace Tools
UV-Vis | FTIR | Raman



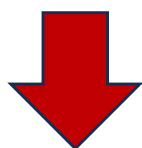
Spectroscopy: “Chemical Fingerprint”

- Relative concentrations of chemicals
- Effects of roasting conditions
- Effects of brewing conditions
- Origin of beans
- Presence of impurities



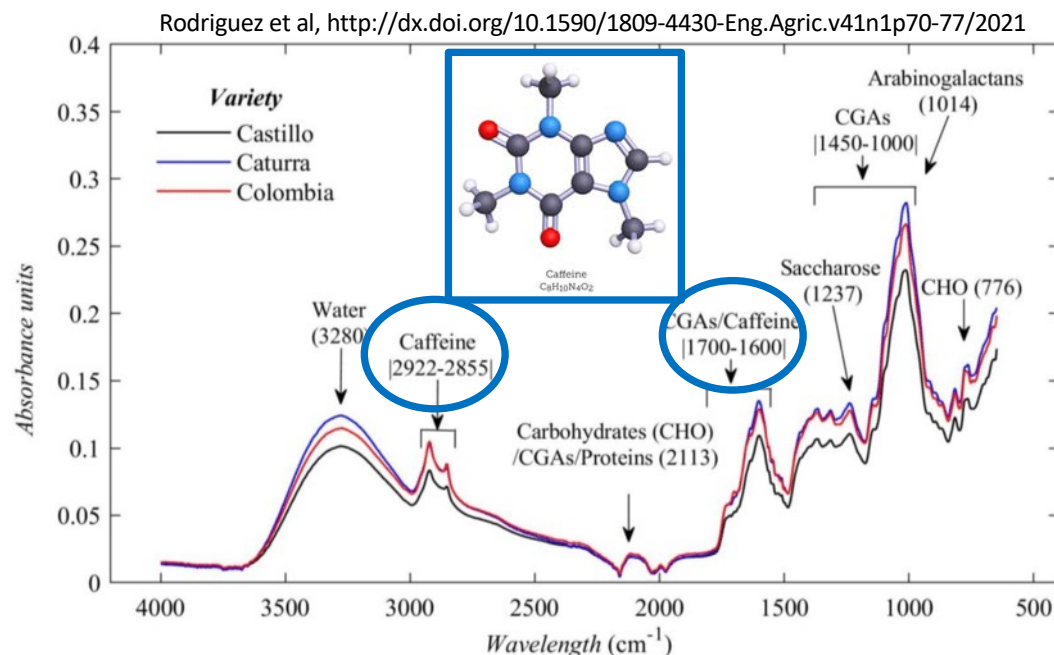
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Breakerspace Tools

UV-Vis | FTIR | Raman

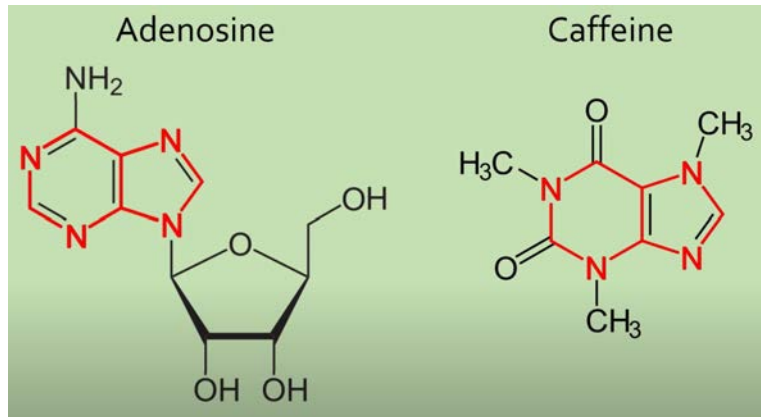


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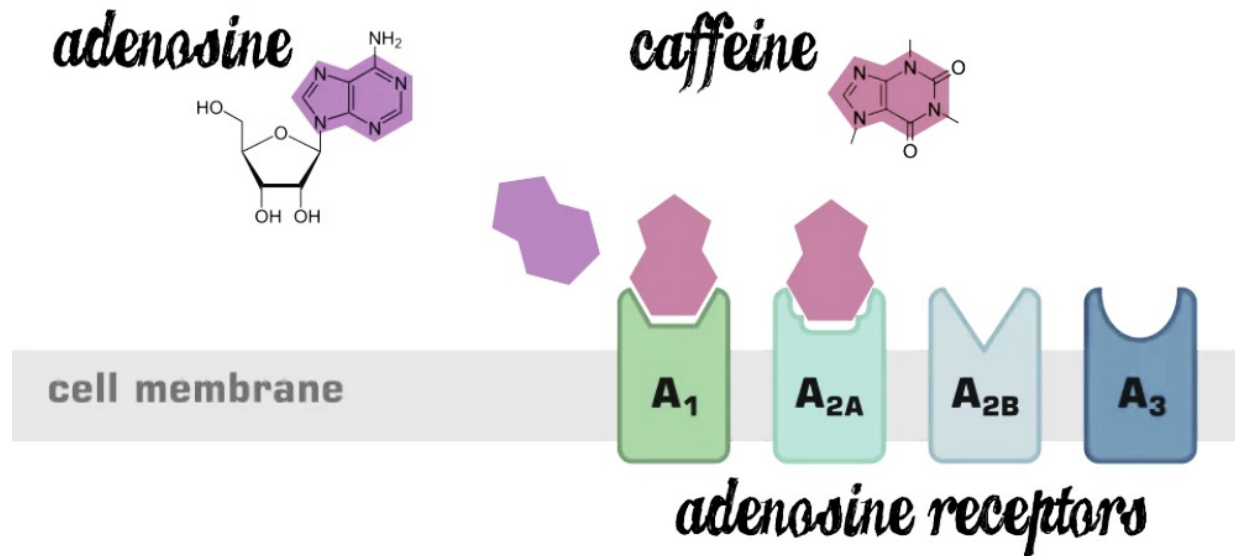


Caffeine most consumed psychoactive substance; bitter in flavor



Fantastic 6-minute video, worth watching: “How caffeine Addiction Changed History,” Michael Pollan, <https://www.youtube.com/watch?v=WD6cYabx0nk>

<https://www.youtube.com/watch?v=jOfquPE1cnU>

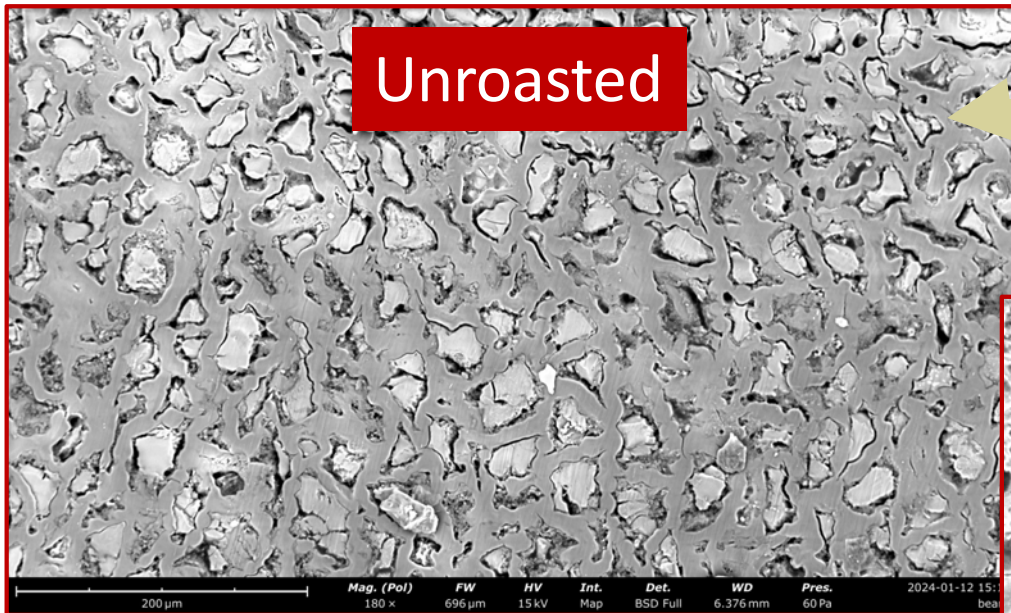
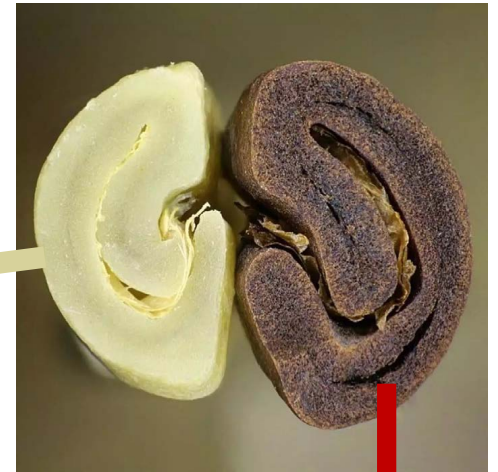


Coffee Variables

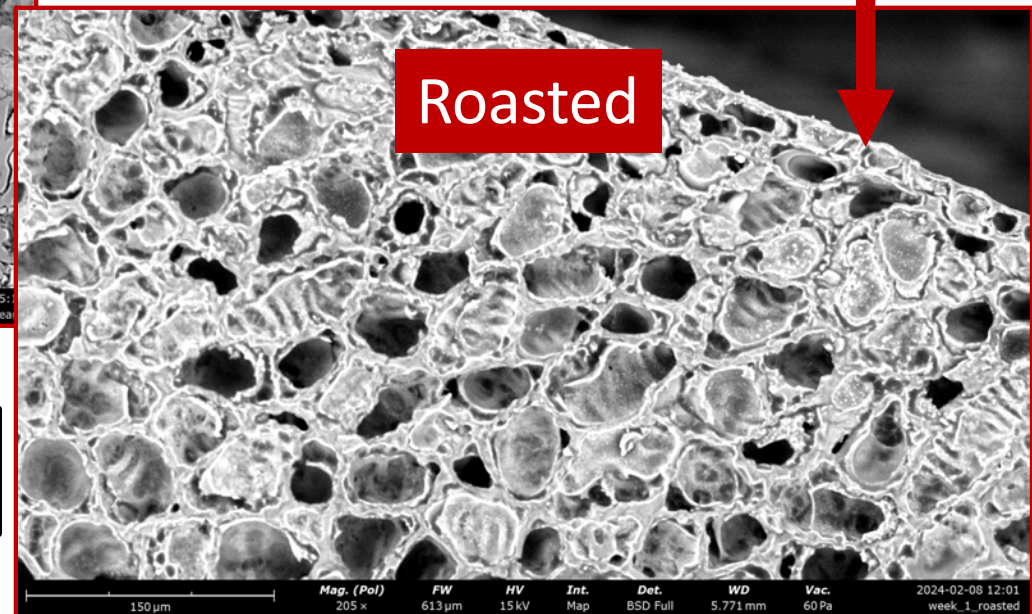
- Bean selection
- Grind
- Chemistry
- **Roast**
- Brew/extraction
- Water, additives



The effects of roasting up close

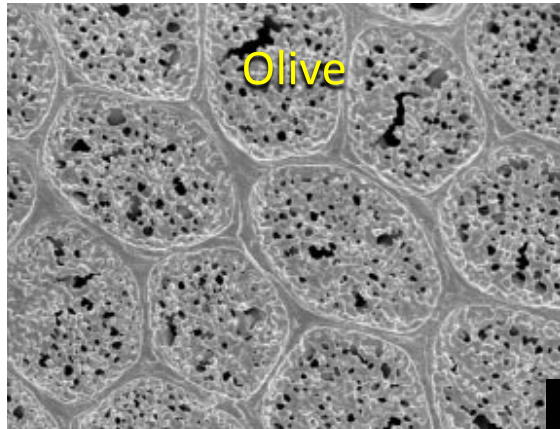


Scanning electron microscope
image, taken in class last spring

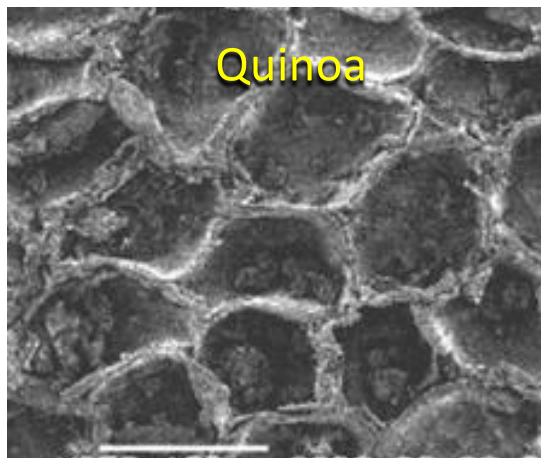
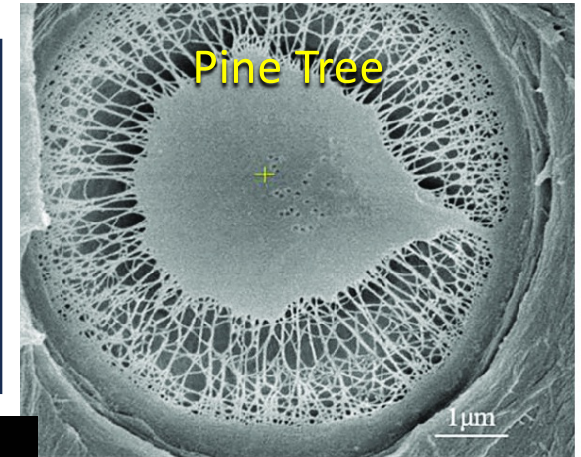




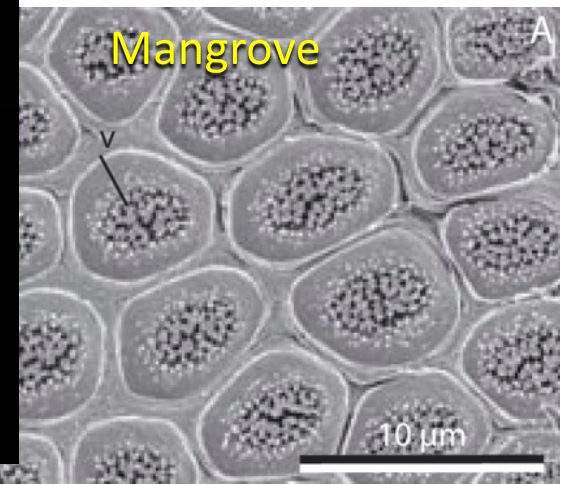
Coffee Structure is Uniquely Roastable



The wall materials in other seeds do not have the same combination of flexibility and stability as coffee seeds.



example: popcorn





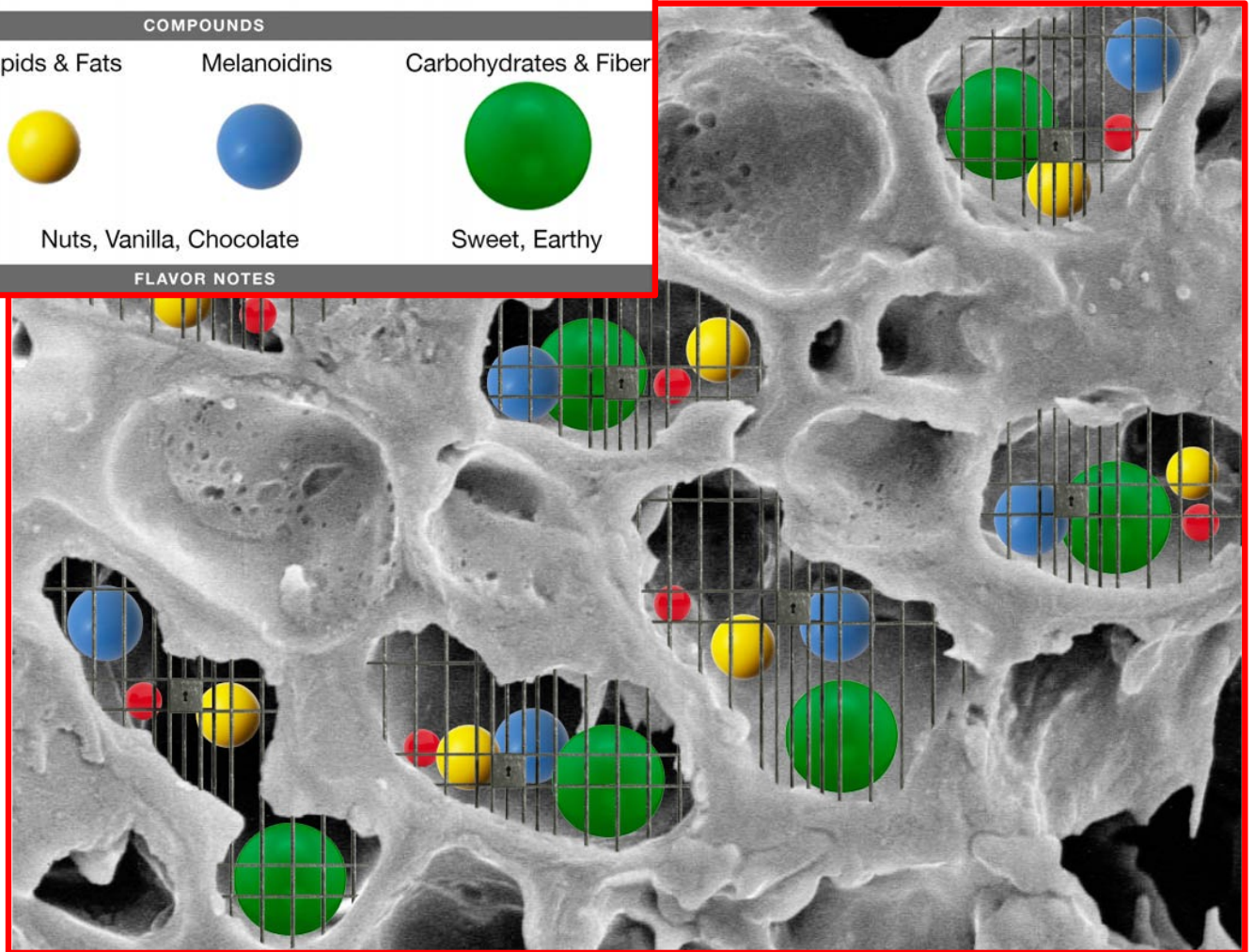
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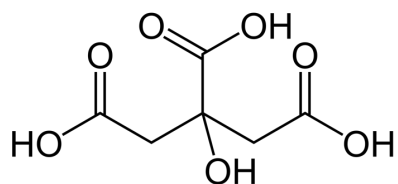
- Bean selection
- Grind
- Chemistry
- Roast
- **Brew/extraction**
- Water, additives



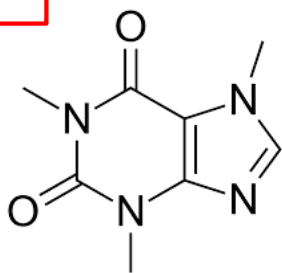
Coffee Solubles			
COMPOUNDS			
Acids & Caffeine	Lipids & Fats	Melanoidins	Carbohydrates & Fiber
			
Light & Fruity	Nuts, Vanilla, Chocolate		Sweet, Earthy
FLAVOR NOTES			

Extraction





Acids more soluble in water than caffeine



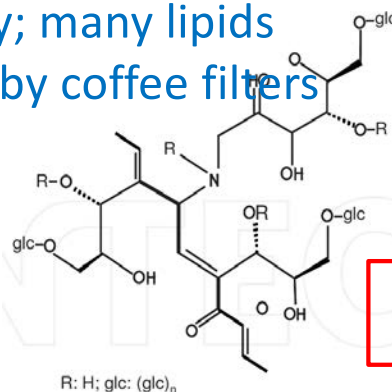
Caffeine

Coffee Solubles

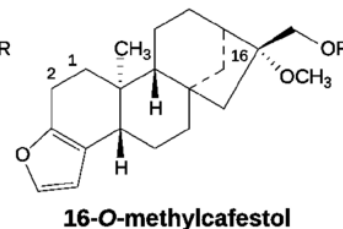
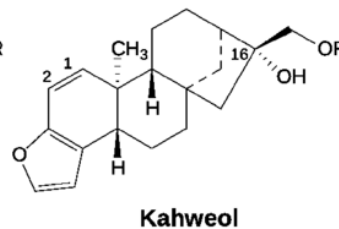
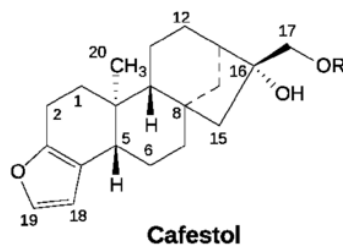
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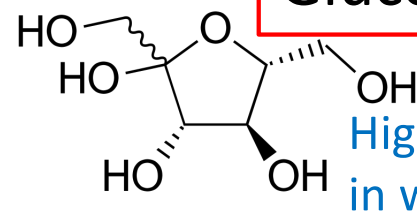
Wide range of solubility; many lipids blocked by coffee filters



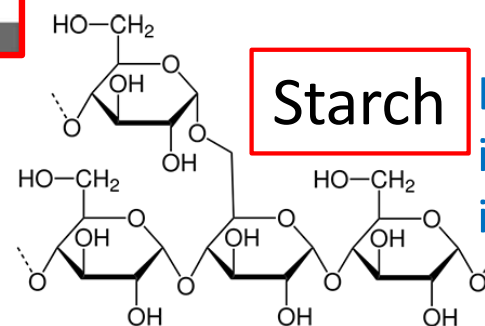
Melanoidin



Glucose



Starch

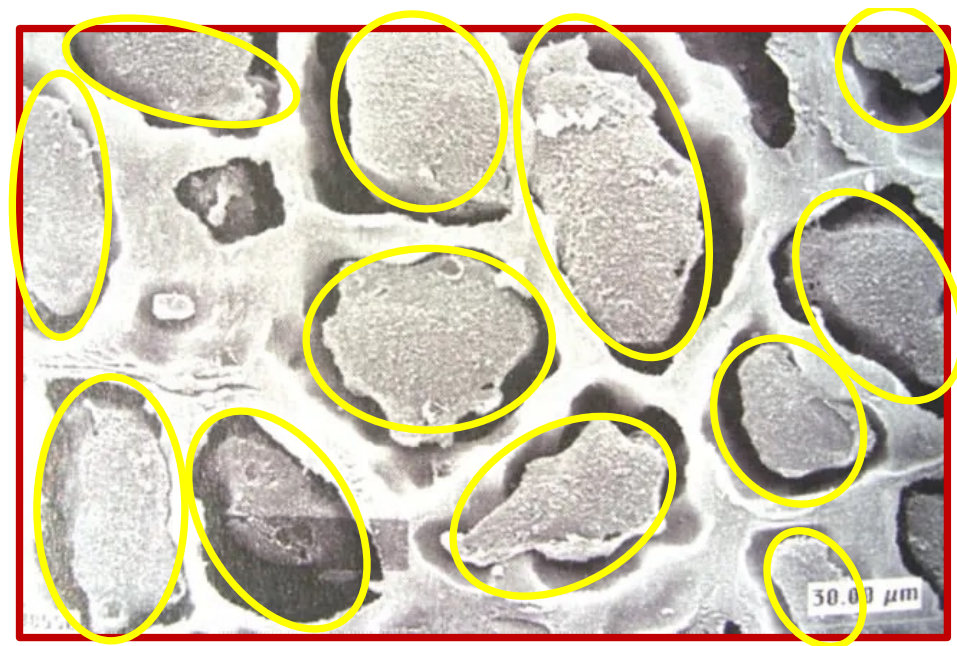


Less or insoluble in water

Lipids



Extraction



Some things that impact extraction:

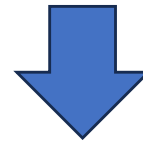
- Water temperature
- Brewing or steep time
- Ratio of ground coffee to water
- Level/uniformity of coffee grind
- Filter



Amalie did not like having those fines in her coffee



So she poked holes in the top of a brass pot and put her son's school blotting paper over it, using it as a filter.

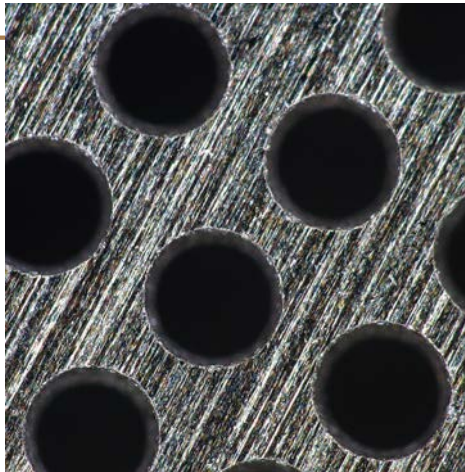


Amalie Auguste
Melitta Liebscher
(1873-1950)

- Patented the first ever paper filter in 1908
- Revolutionized coffee production, removed fines + oils
- Melitta Company has ~4000 employees, ~\$2B/year revenue



Seeing filters in the optical microscope



Images
taken in lab
last week



Coffee Variables

- Bean selection
- Grind
- Chemistry
- Roast
- Brew/extraction
- Water, **additives**



“Fixing” Coffee

Under-extracted, too acidic



See: “Why Does Salt Change the Taste of Everything?”

<https://www.youtube.com/watch?v=dWatMuHZIxE>

And: “Hacking Sour Espresso”

<https://www.youtube.com/watch?v=jtCbIbi2dHI>



Over-extracted, too bitter



“post-processing”
coffee works
for very
different
reasons!



Class Syllabus / Cadence / Grading

Lectures (Tuesdays):

- Introduction
- The Bean
- The Grind, Part 1
- Principles of Microscopy & Spectroscopy
- Developing Your Project Proposal
- Coffee Chemistry
- Roasting
- The Grind, Part 2
- Extraction
- Coffee as a material
- Final Presentations (last three lectures)

Different tastings paired with each lecture

Lab schedule:

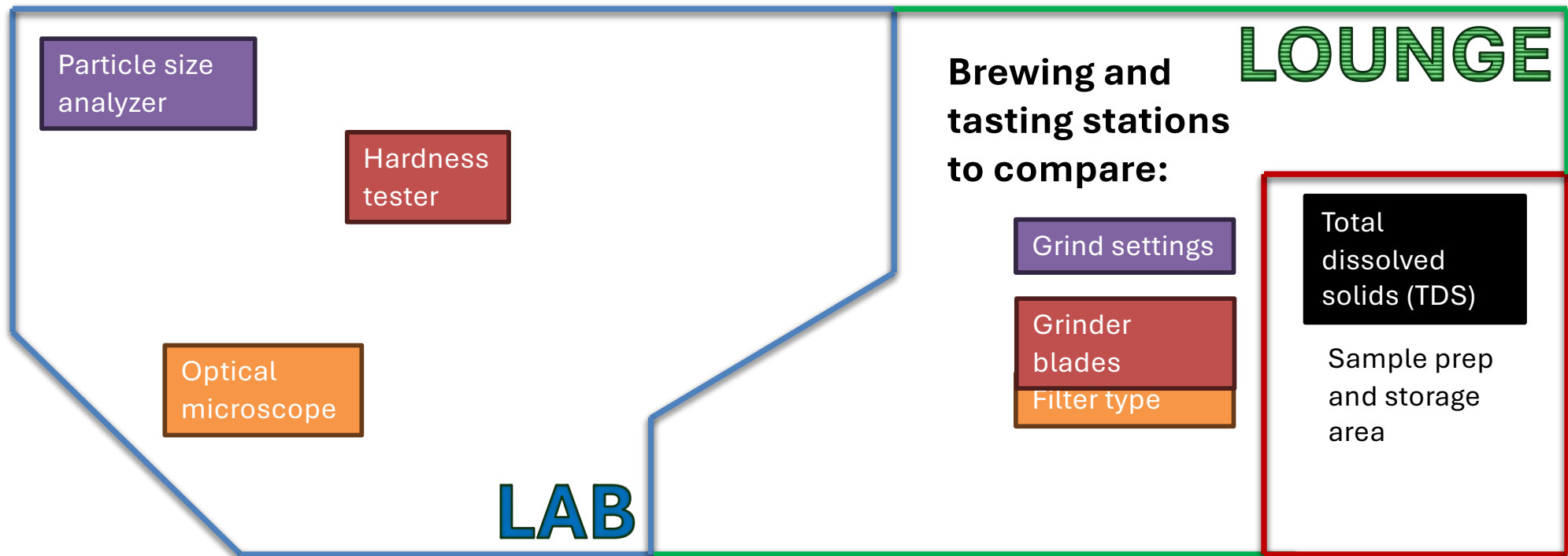
- Rotation 0 – Intro to the lab, espresso and first brewing
- Rotations Block 1 (3 weeks)
 - Grind settings, grinding burrs, filter types
 - Particle size analyzer, hardness tester, scanning electron microscope, optical microscope
- Rotations Block 2 (3 weeks)
 - Brewfest, water, roast
 - TDS, FTIR, UV-Vis/Fluorescence, scanning electron microscope, optical microscope
- Project work (6 weeks)



Lab Block 1 (weeks 1-3)

Break up into 6 groups (2-4 students each)

Each group will spend 25 mins each on a given lab/taste pairing

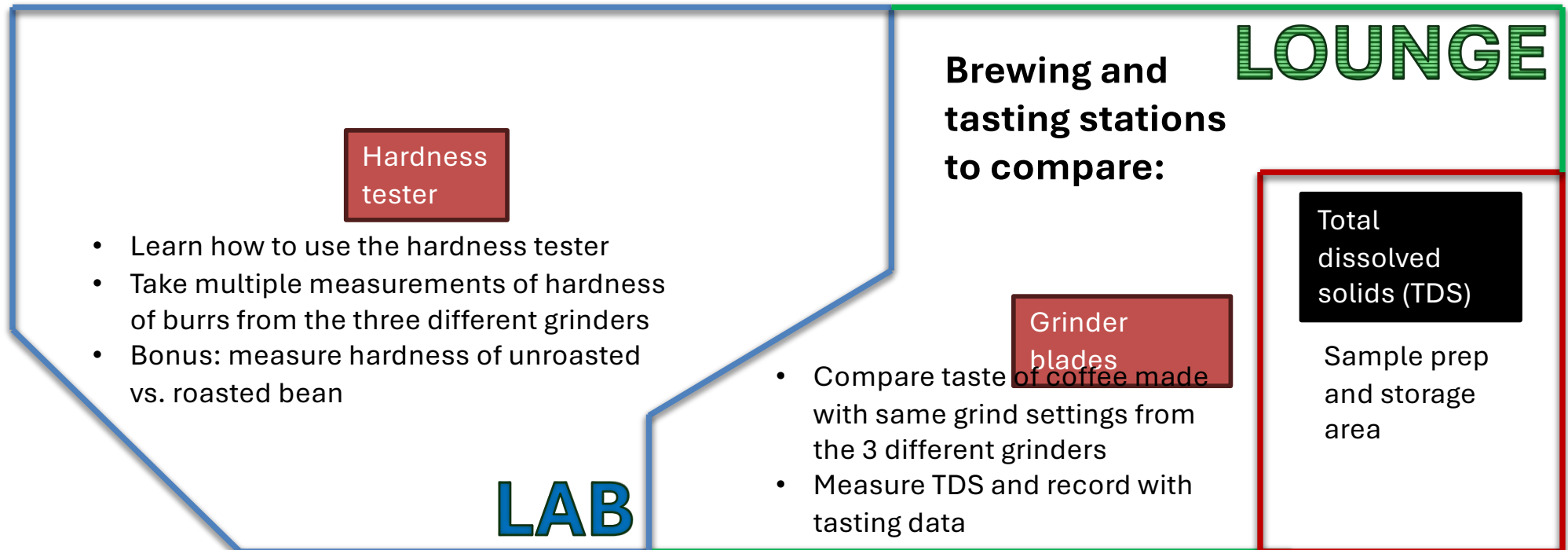




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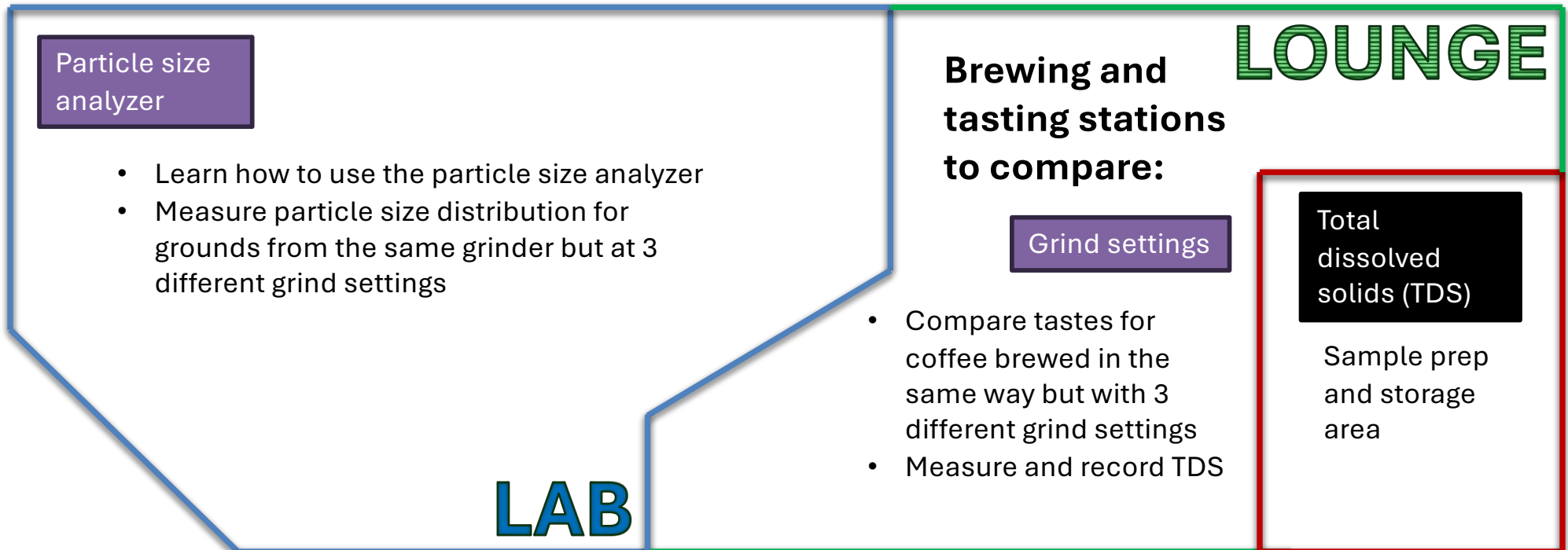




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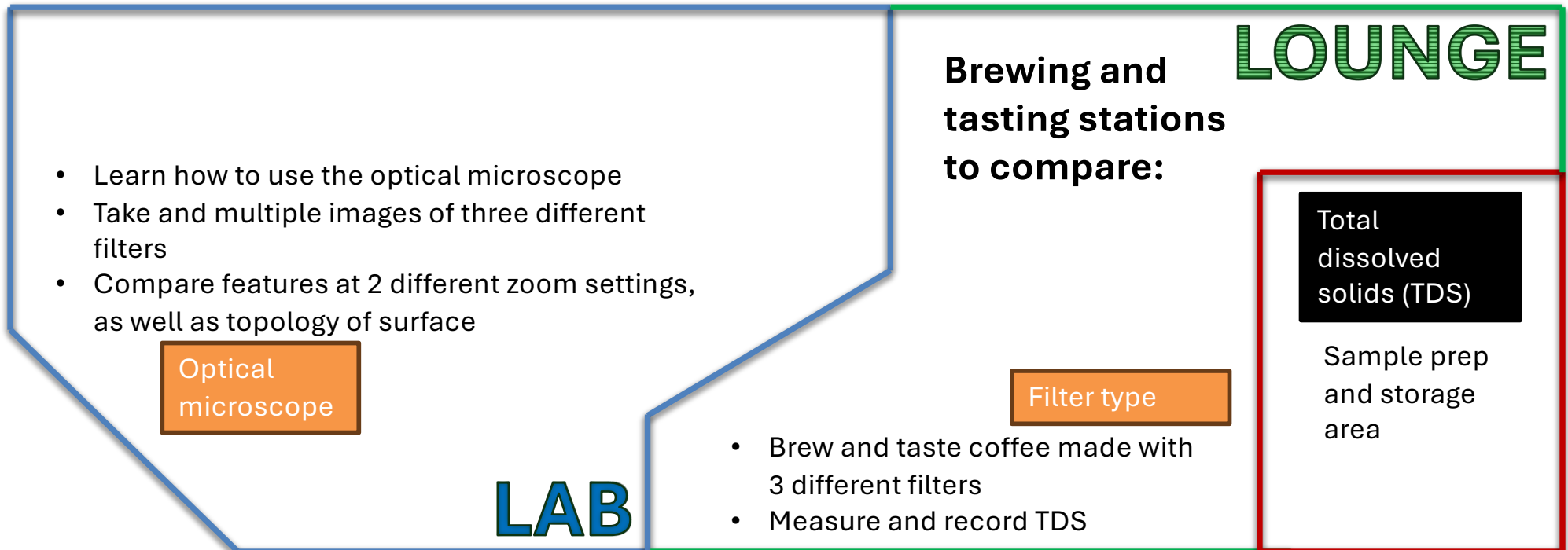




Lab Block 1 (weeks 1-3)

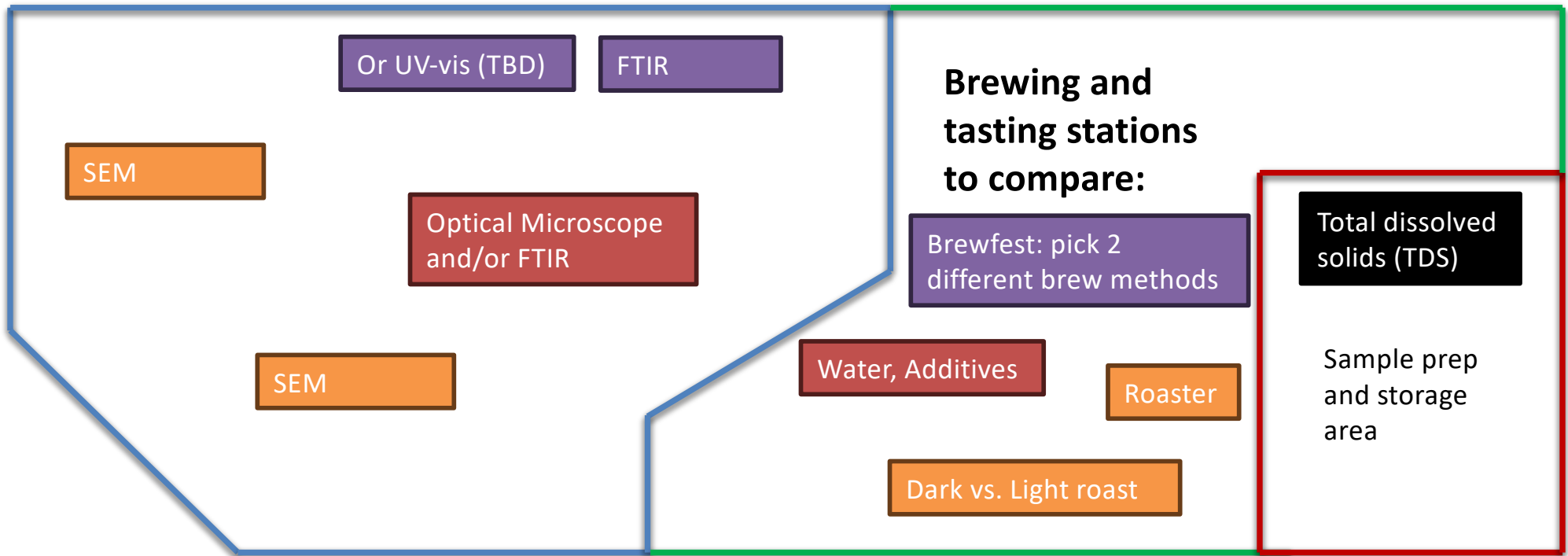
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Lab Block 2 (weeks 4-6)



Class Projects (Spring 2024)

- **Coffee Additives**
- **Analyzing Coffee with flavor notes**
- **Effects of Extraction Temperature**
- **Coffee Grind Size Analysis**
- **Chocolate Flavor Notes in Coffee: A Myth of Marketing?**
- **What happens when you microwave coffee?**
- **Roasting levels: a journey through aromatic bliss**
- **Freezing coffee**
- **Caffeine content vs. grind size**
- **Effect of SWP Decaffeination on Coffee Beans**
- **The impact of water hardness on extraction**

A scanning electron micrograph (SEM) showing a dark, textured surface covered with numerous small, irregular, light-colored particles or fragments. The particles vary in size and shape, some appearing as small clusters and others as individual flakes. The background is a dark, uniform gray. Overlaid on the image is the text "Thank you!" in a bright yellow, sans-serif font, centered horizontally in the upper half of the image.

Thank you!

also please reach out any time – jcg@mit.edu
let me know if you're on campus, I know a place we can get a coffee

Mag. (Pol)

FW

HV

Int.

Det.

WD

Pres.

2023-12-13 12:13