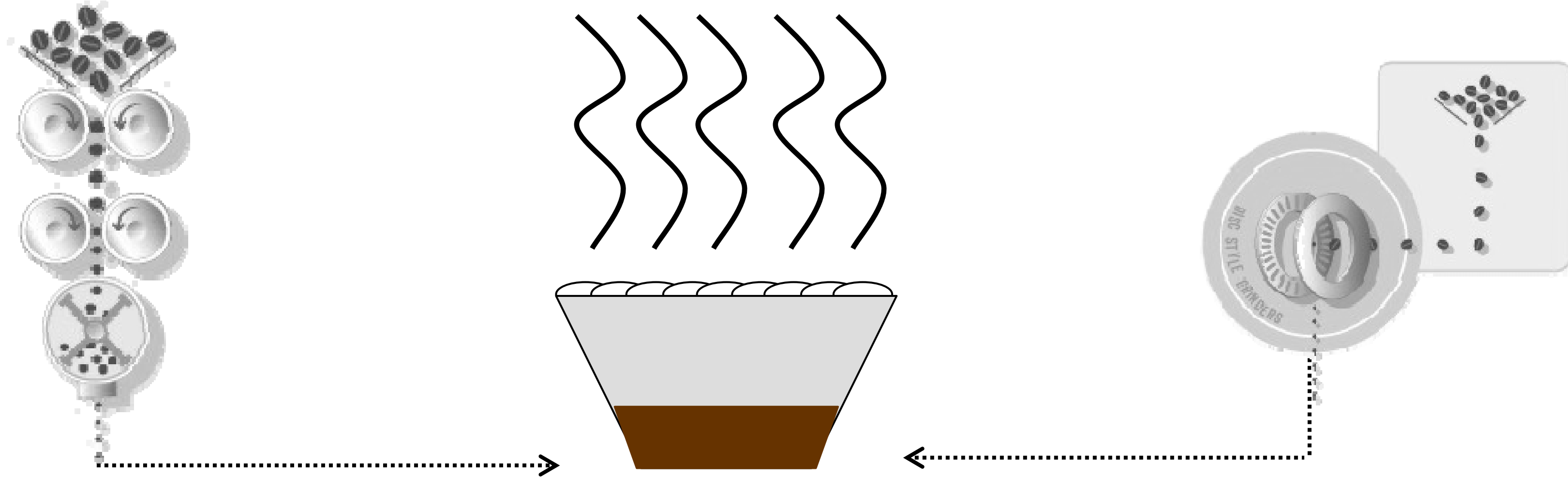
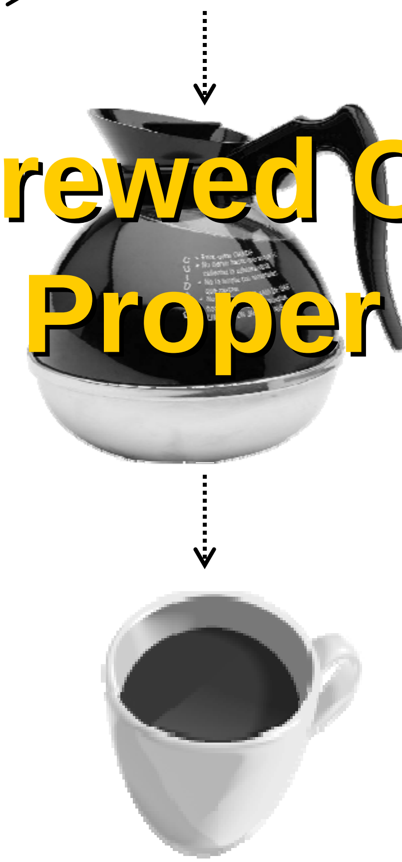


Optimizing Brewed Coffee Quality Through Proper Grinding



Daniel Ephraim

President

Modern Process Equipment

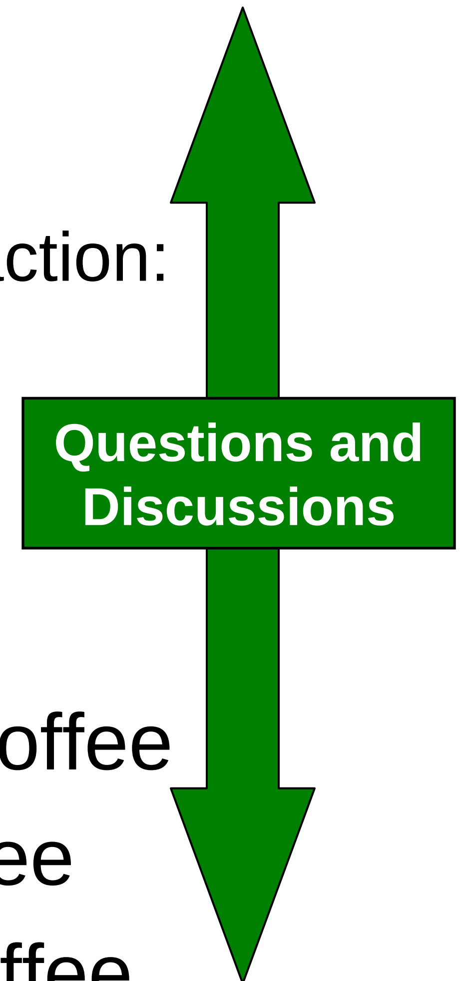
First and foremost …

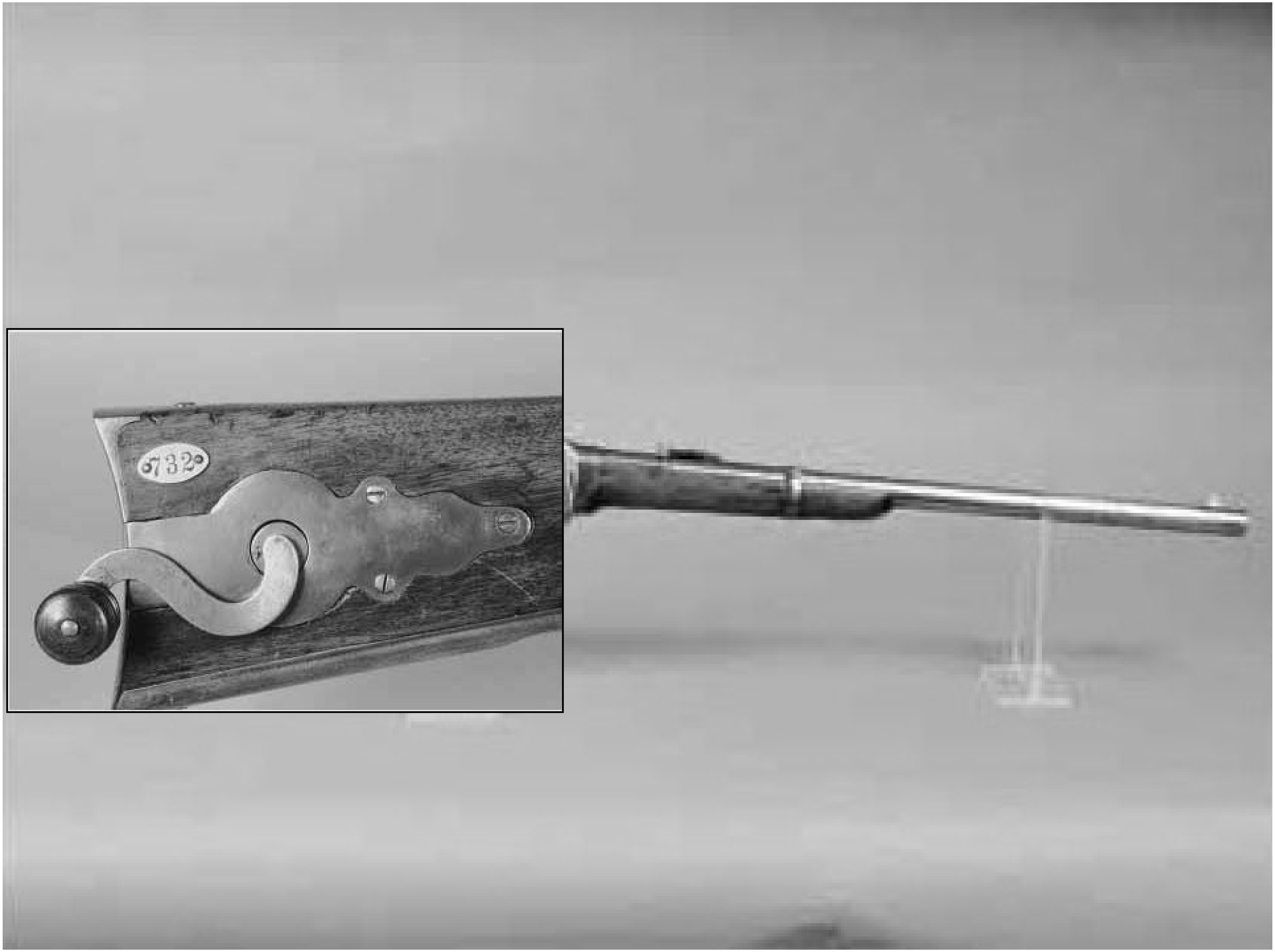
Is there a particular grinding problem or issue that you would like to see addressed today?

THERE'S NOTHING WORSE THAN SITTING THROUGH A PRESENTATION AND WALKING AWAY "EMPTY HANDED"!

Presentation Outline

- The Coffee Quality Cycle
- Brewing Theory:
  - – Key factors in Coffee Brewing or Extraction:
    - Particle size
    - Particle uniformity
    - Time
  - – The “Big Picture” in Coffee Brewing
- Effect of Temperature on Ground Coffee
- Analyzing and Testing Ground Coffee
- Grinding for Pods and Espresso Coffee




732

<u>Proper coffee grinding</u> is a most essential, and often neglected, part of the coffee quality process.

So let’s explore the process from the beginning with selected coffee quality tipping points …

Theoretical Coffee Quality = 100%

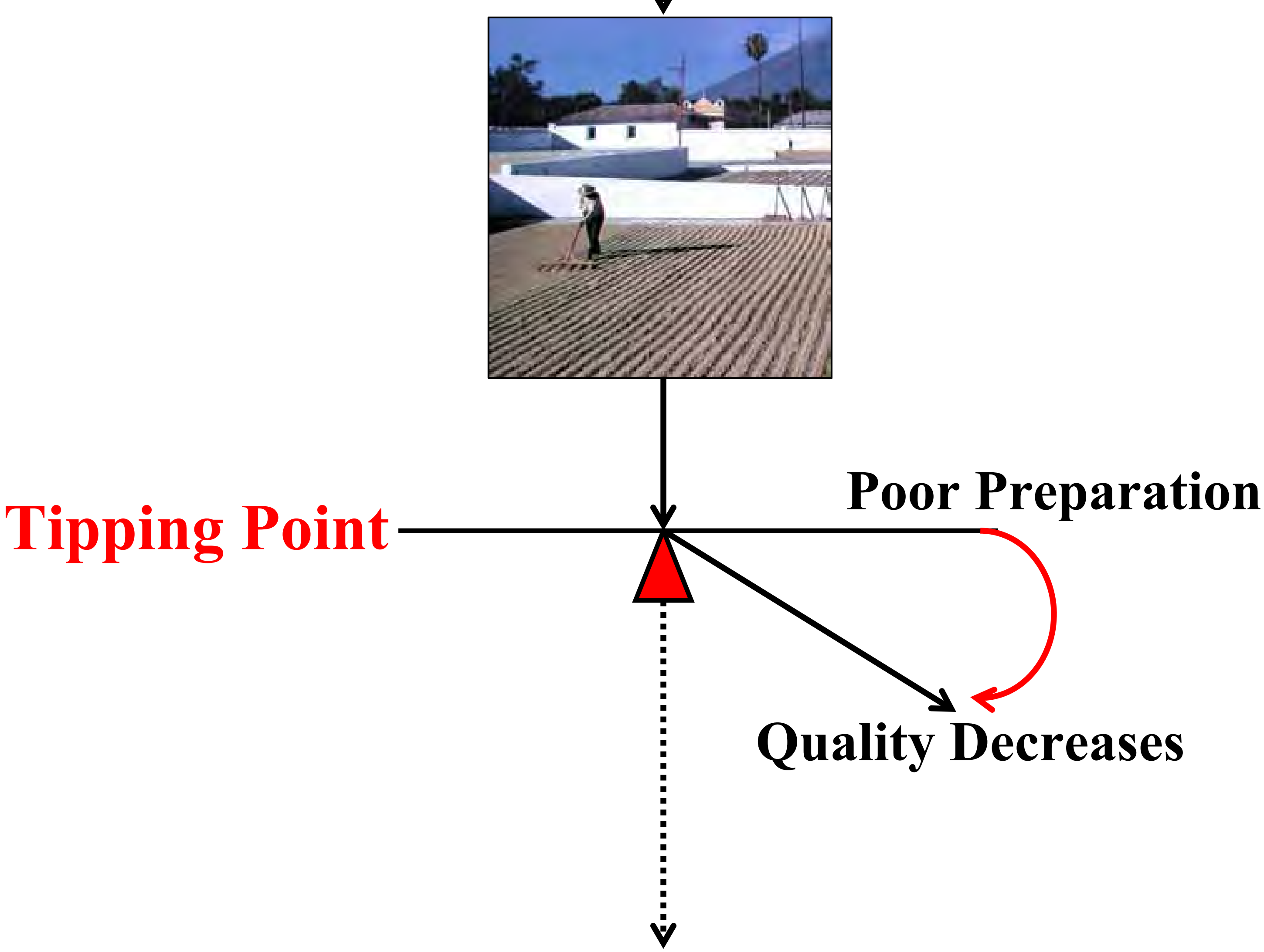
Maximum Possible Coffee Beverage Quality = 100%

Theoretical Coffee Quality = 100%

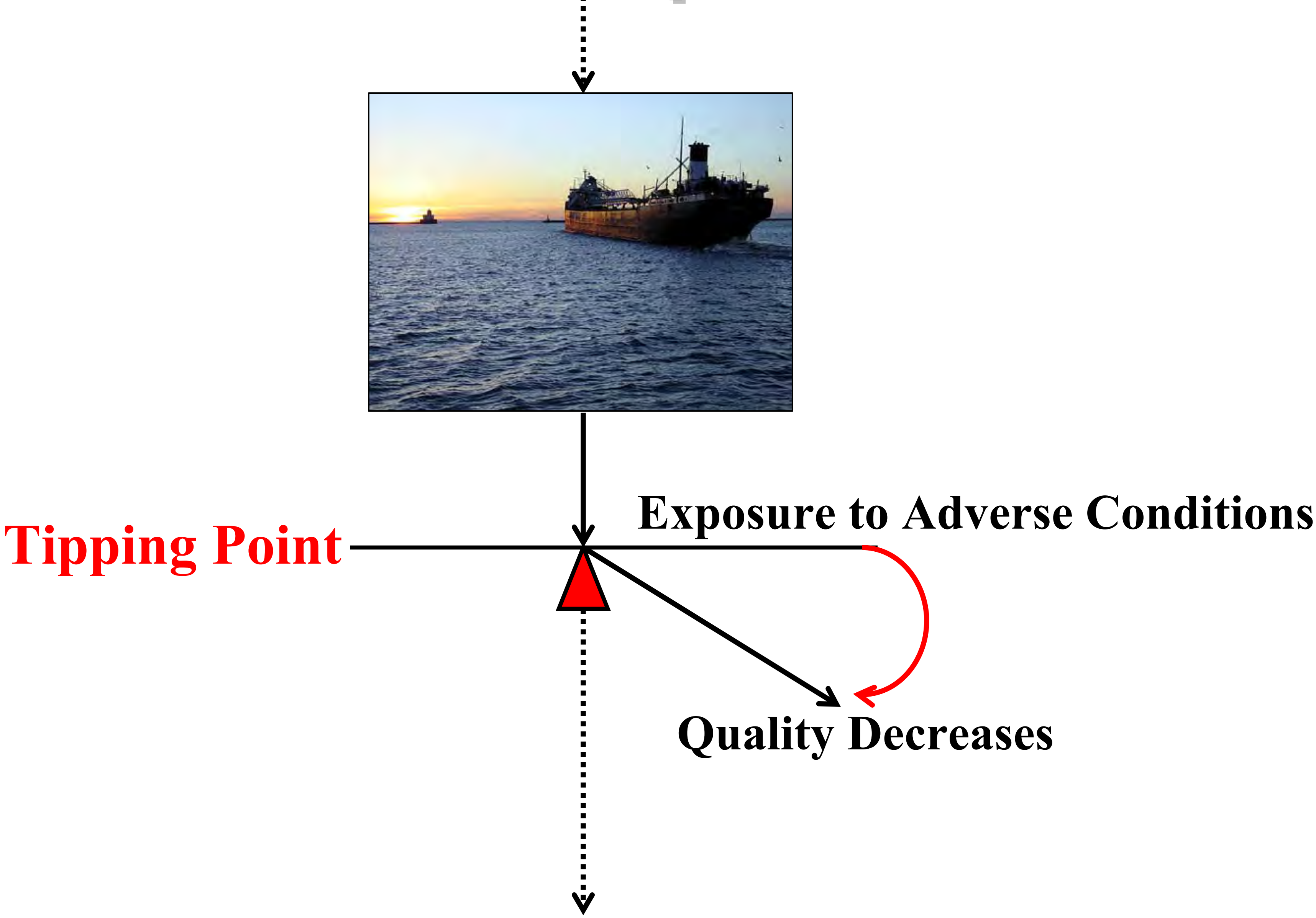
Maximum Possible Coffee Beverage Quality = 100%

We cannot improve on Mother Nature!

Coffee Processing



Coffee Transportation



Coffee Roasting

Over/Under Roasted

Tipping Point

Quality Decreases

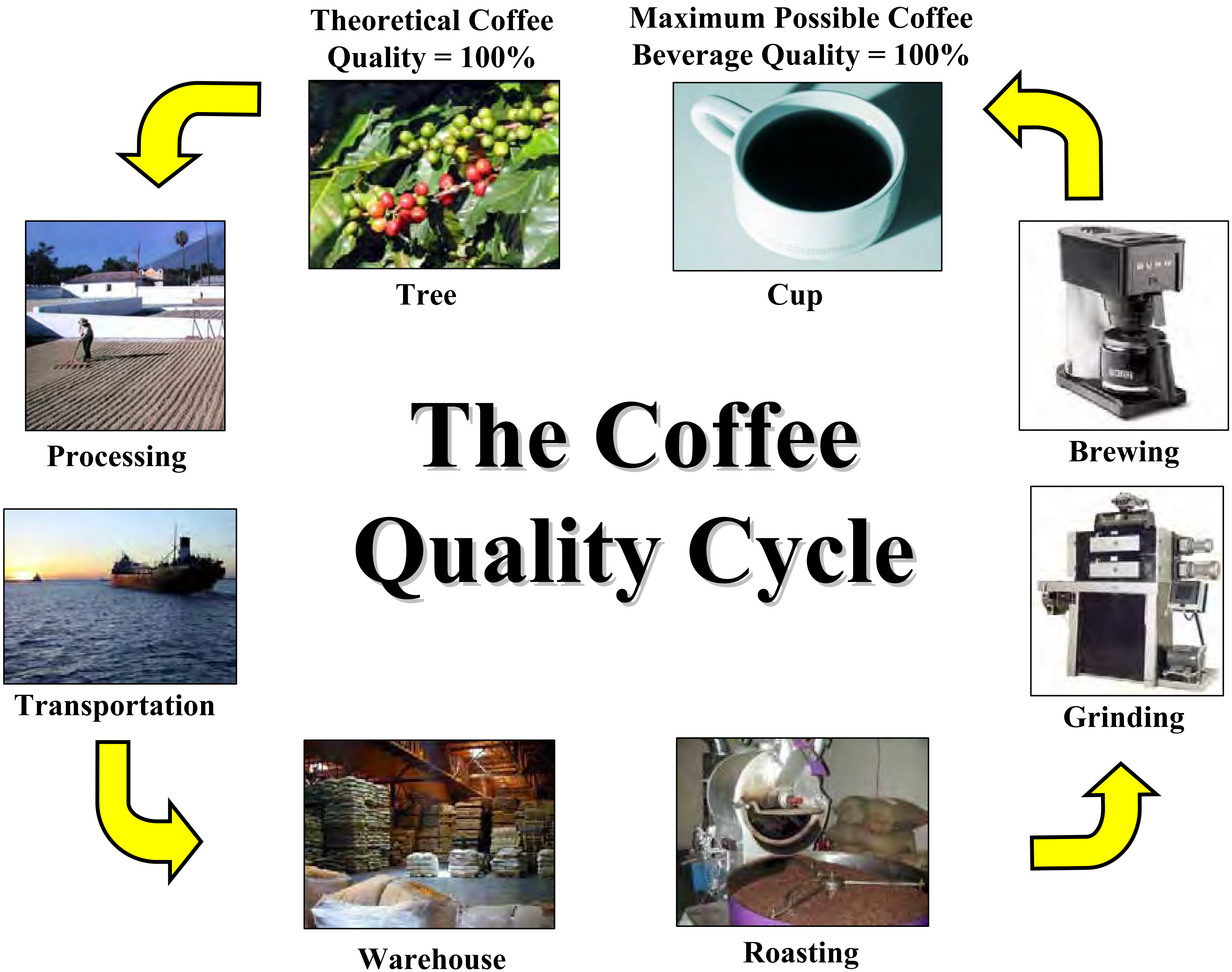
Coffee Grinding

Tipping Point

Improper Grind Size/ Poor Uniformity

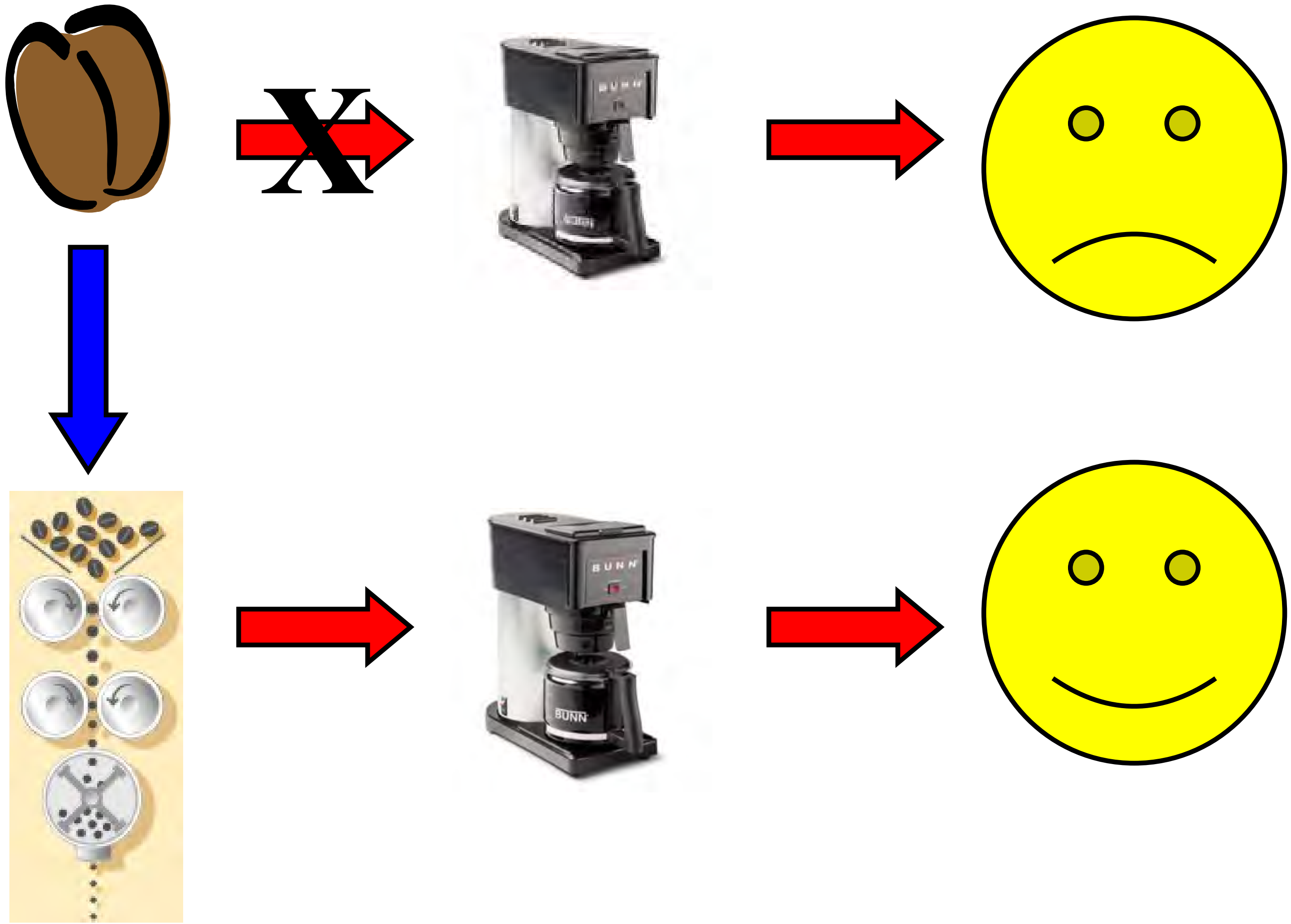
Quality decreases, <u>including the value of all processes up to this point</u>


Theoretical Coffee Quality = 100%
Maximum Possible Coffee Beverage Quality = 100%
Tree
Cup
Processing
The Coffee Quality Cycle
Brewing
Transportation
Grinding
Warehouse
Roasting

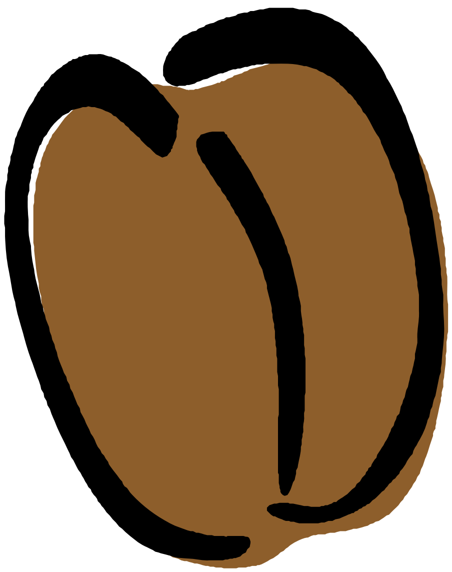
The great thing about cupping coffee is that it pretty well defines the quality of the bean.

<u>BUT</u>, the tough part is grinding the coffee to achieve the same quality of the bean to the brew.

We don't brew whole bean coffee!



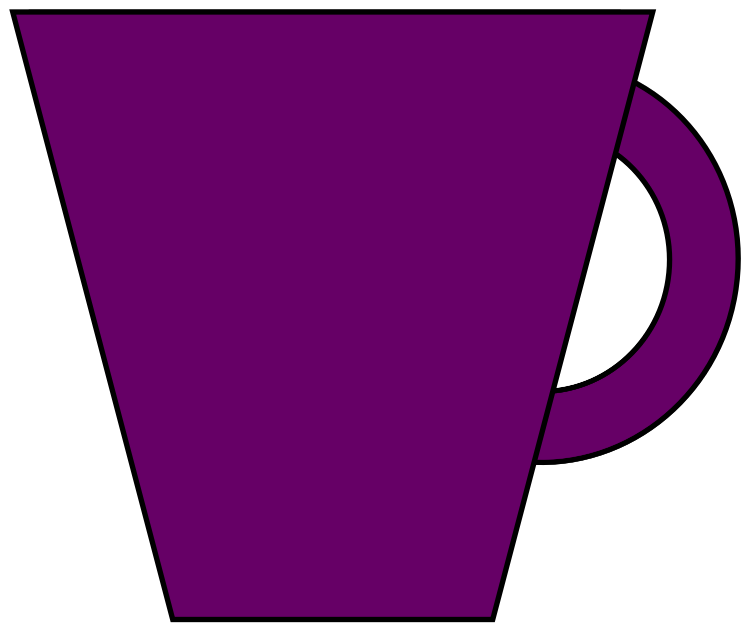
Proper Extraction and Strength



Coffee beans are composed of soluble solids, which must be extracted into the coffee brew.

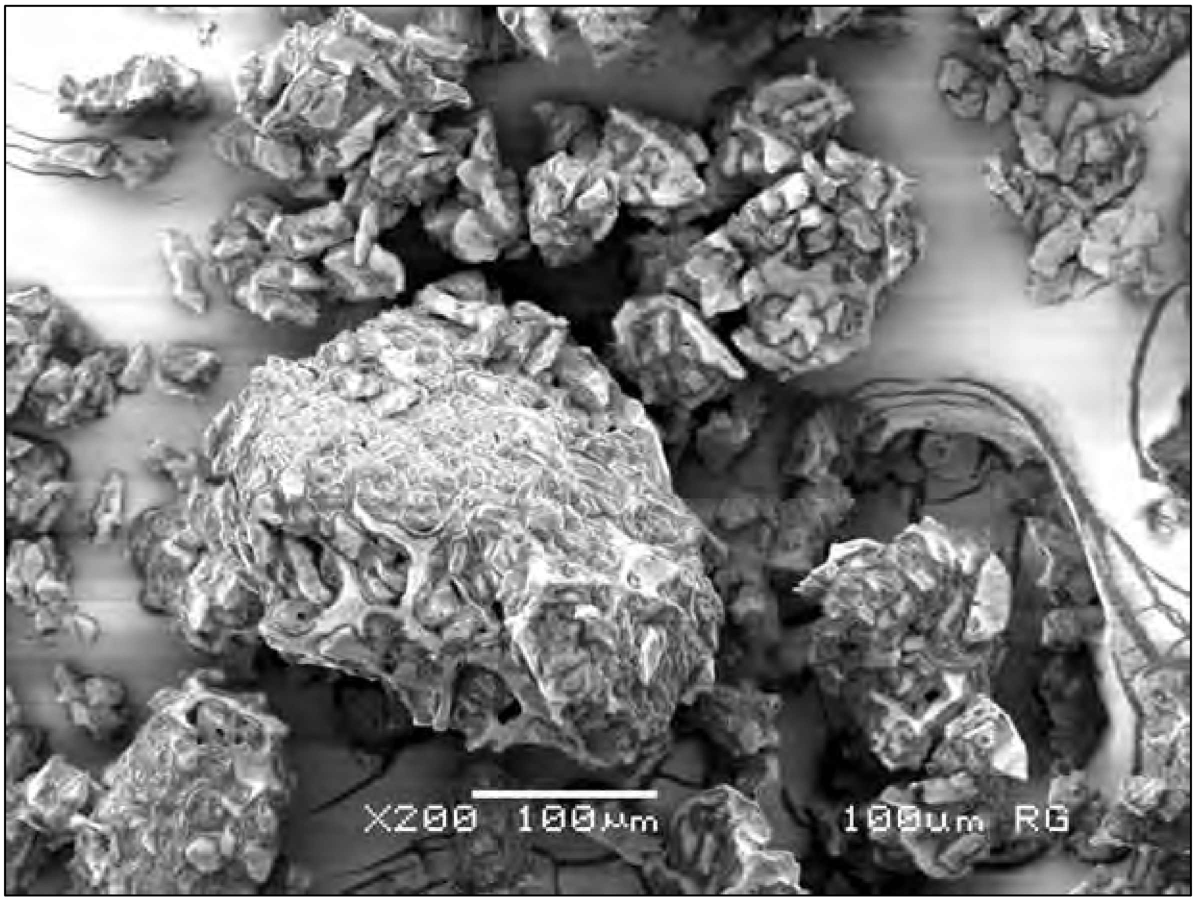
Proper Extraction and Strength

The amount of soluble solids extracted from the coffee bean into the brew must be the correct amount or percentage.

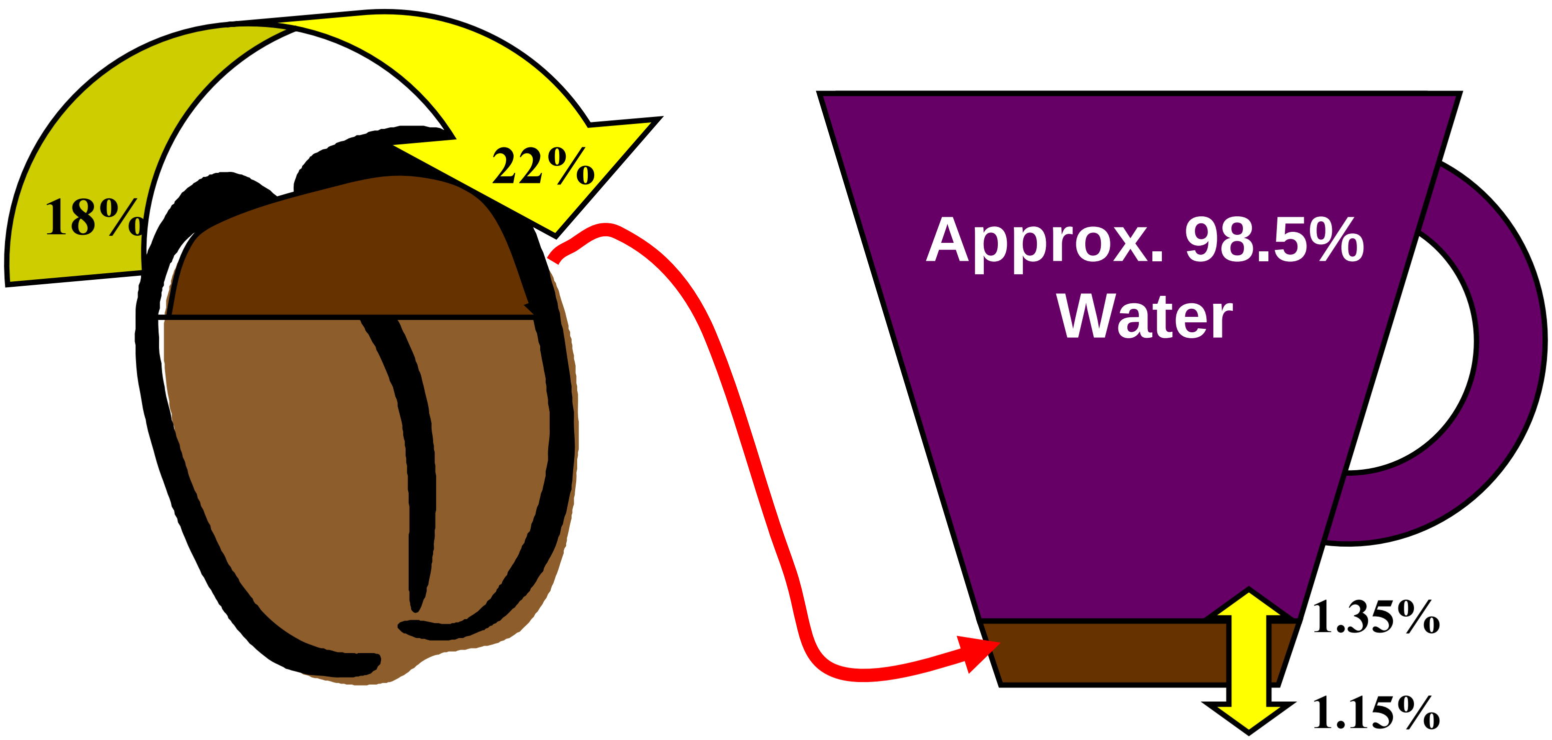


This is a much magnified view of a ground coffee particle using an electron microscope.

The cellular walls are about 30 microns in diameter, and the colloidal material fills the voids within the ground coffee and cellular structures. Part of this colloidal material is what we want to extract, but with a limit.



Proper Extraction and Strength

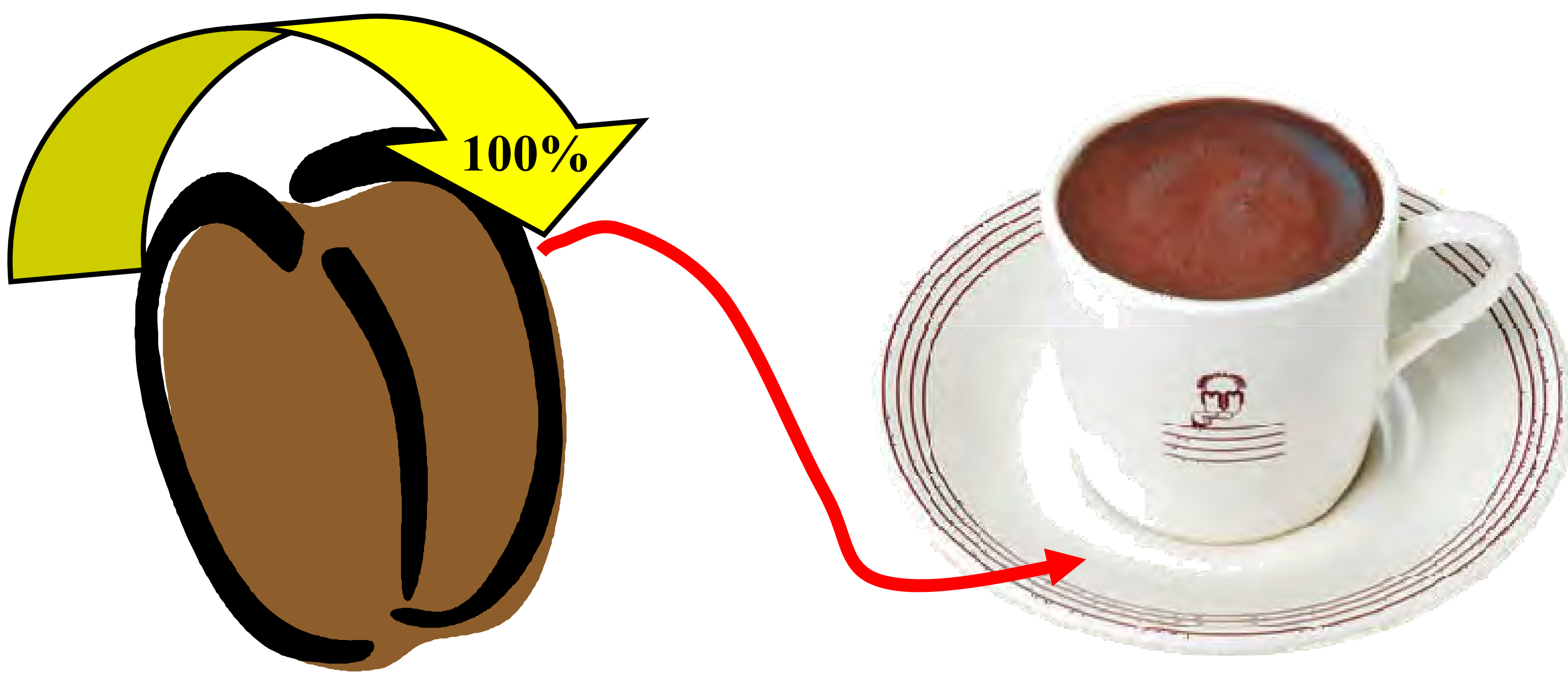


Ideal Extraction of the coffee particle's soluble solids is 18-22%

Ideal Brew Strength is 1.15-1.35% brewed solids

One Example of Overextraction is Turkish Coffee

… Where the entire bean is ground and <u>dissolved</u> into hot water.

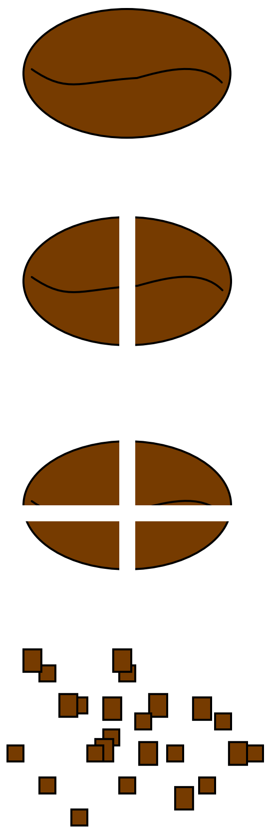


… Excess solids settle on the bottom of the cup, which is typically considered undrinkable.

The Center of the Universe for Coffee Grinding is EXTRACTION!
Specifically … PROPER EXTRACTION!

The key to PROPER EXTRACTION is creating, through GRINDING, the <u>IDEAL EXPOSED COFFEE SURFACE AREAS</u>

Effect of Grind Size on Surface Area



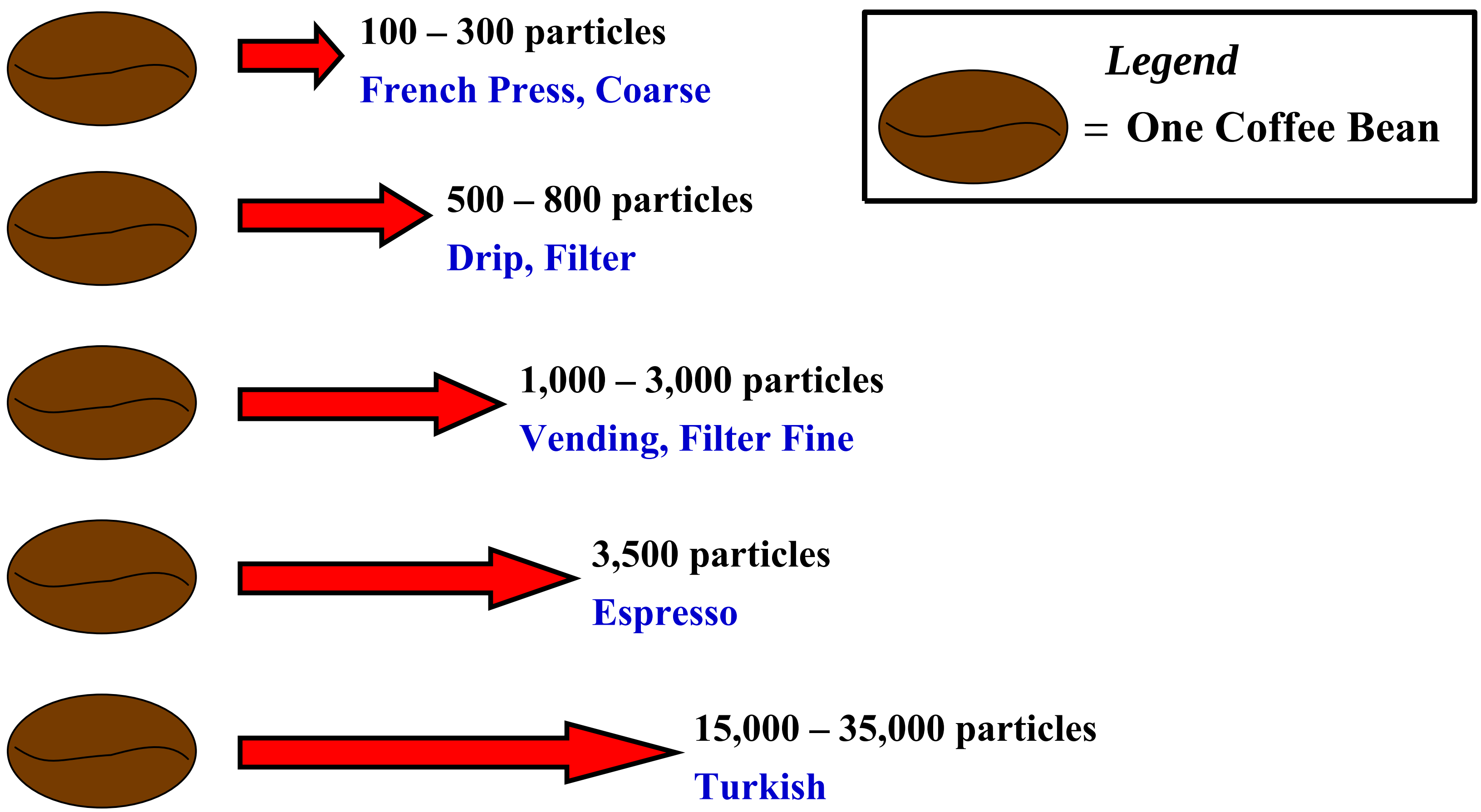
1 Bean = 3.4 cm^2

2 Particles = 4.4 cm^2

4 Particles = 5.4 cm^2

1000 Particles = 34 cm^2

Grind Comparison



Grind Sizes

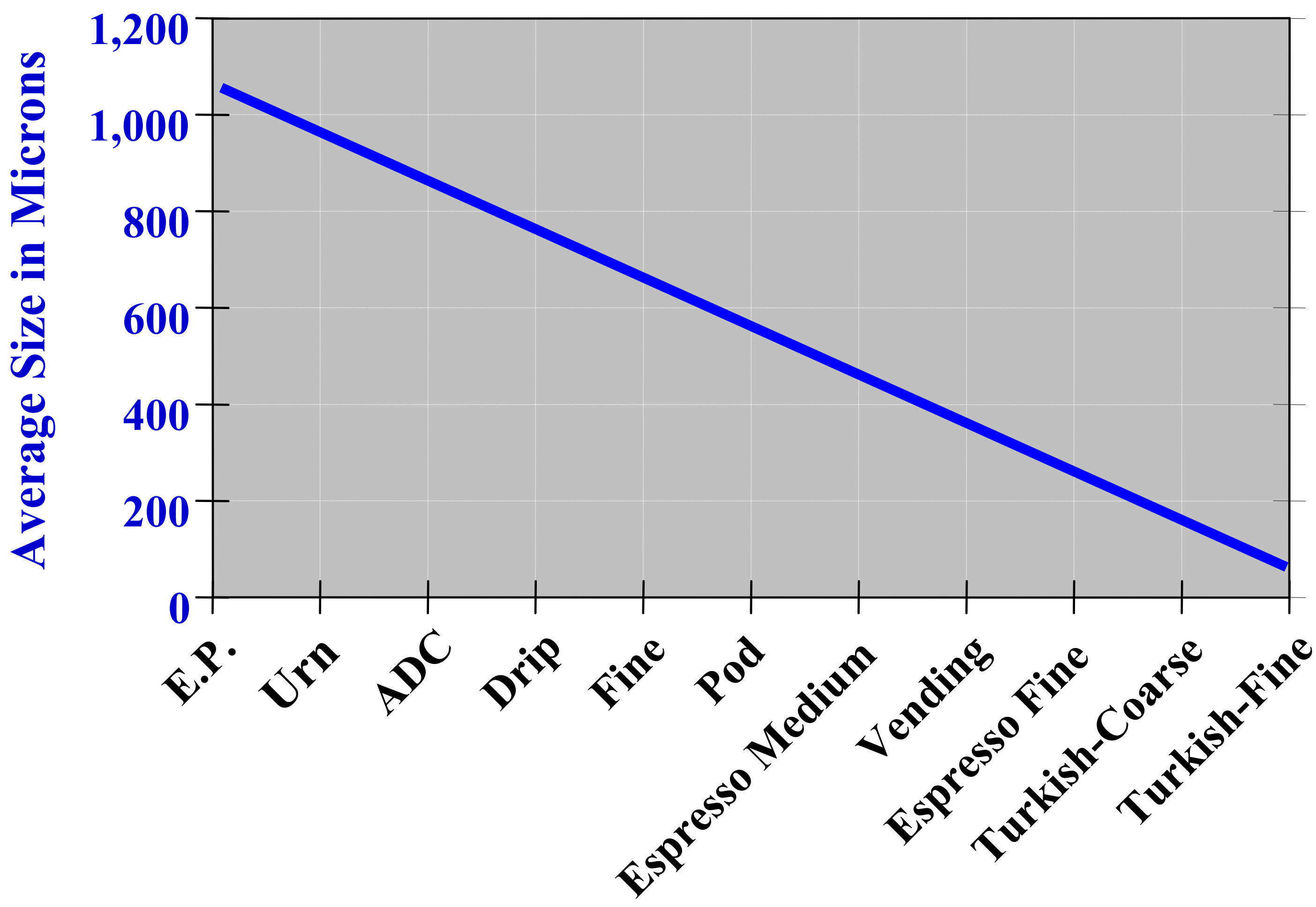
- Typically expressed in:
  - **Mesh**
  - **Microns (um)**

25,400 microns = 1 inch

or

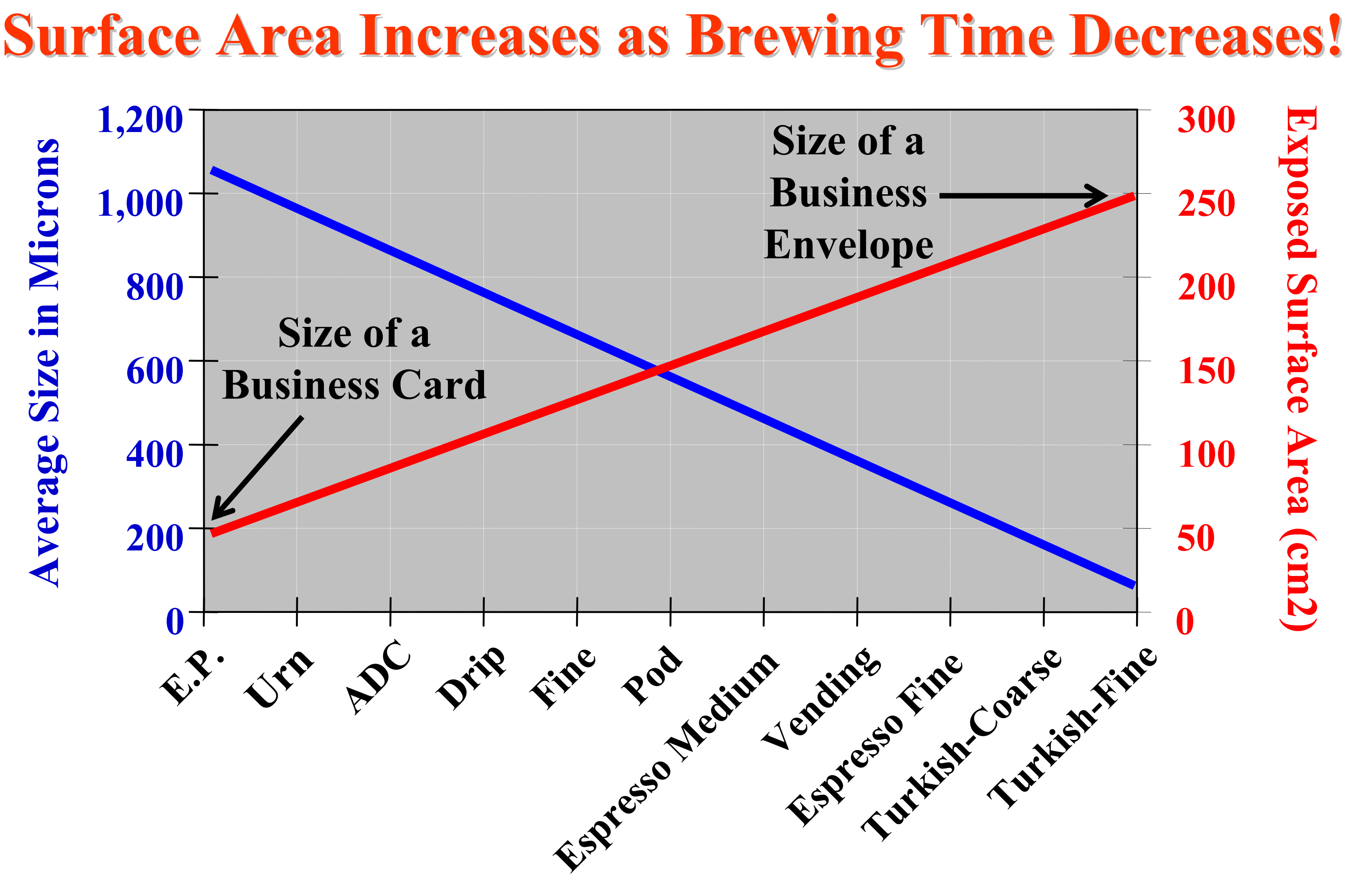
100 microns = 0.004 Inch = Thickness of One Hair!

Average Particle Size by Grind

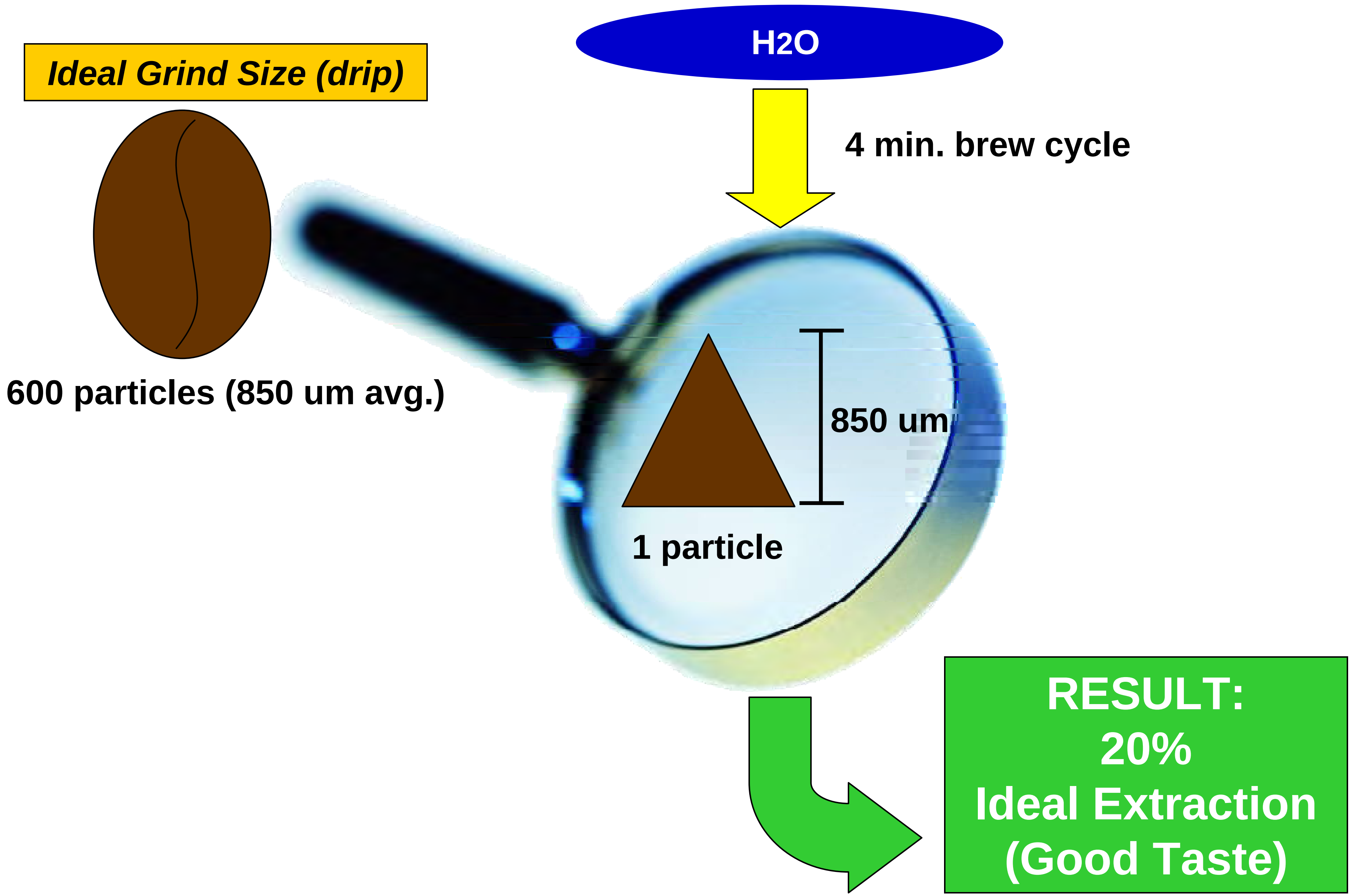


Average Size vs. Surface Area

(1 Bean = 3.4 cm^2 = Size of a Postage Stamp)

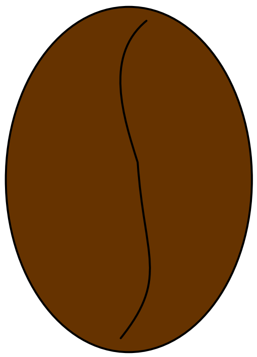


Micro Analysis of Extraction

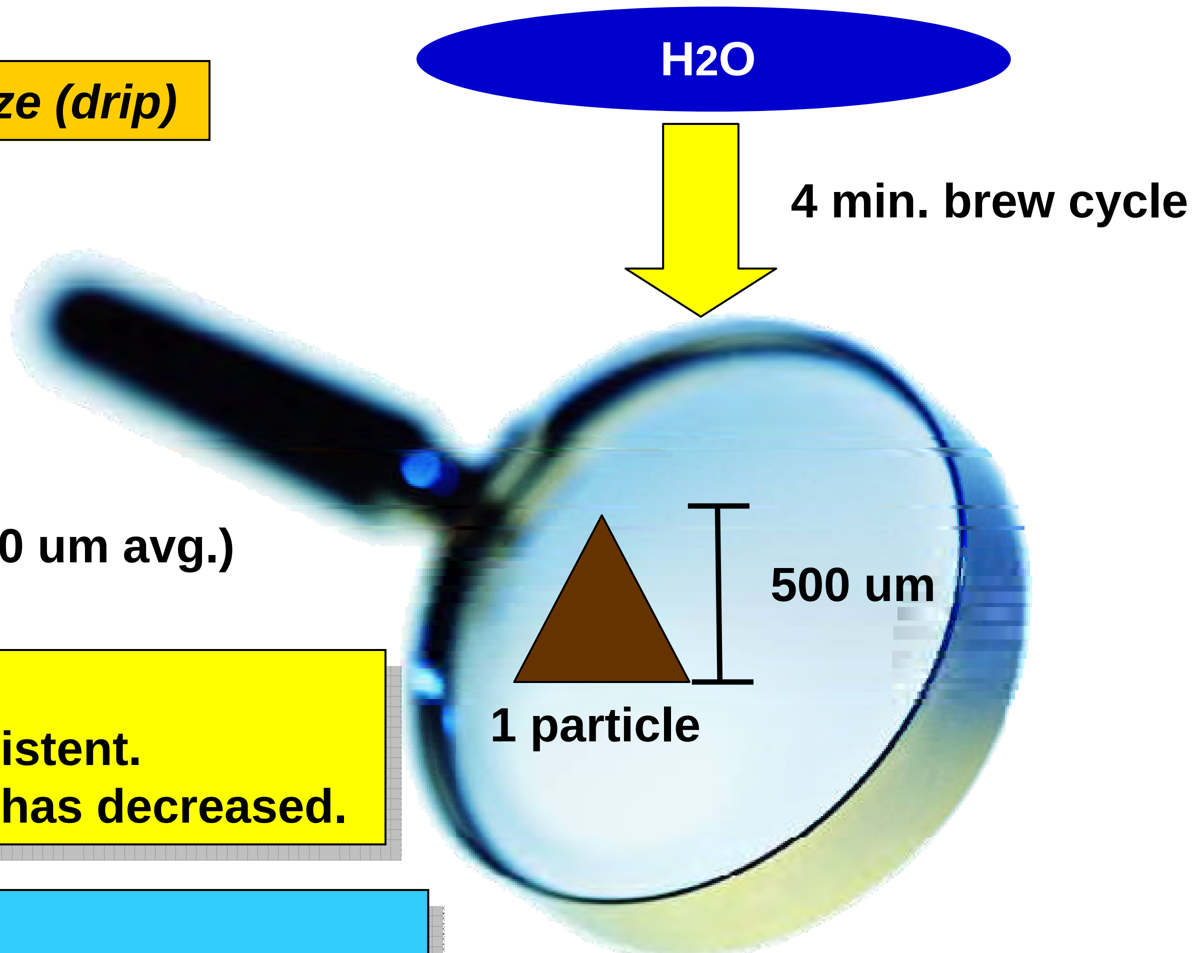


Micro Analysis of Extraction

Ideal Grind Size (drip)



600 particles (850 um avg.)



Factors:
1) Time is consistent.
2) Particle size has decreased.

Result:

Since the coffee particle is smaller than ideal, the surface area is greater and the extraction rate will be excessive.

RESULT:
30% Overextraction
(Poor/Bitter Taste)

Micro Analysis of Extraction

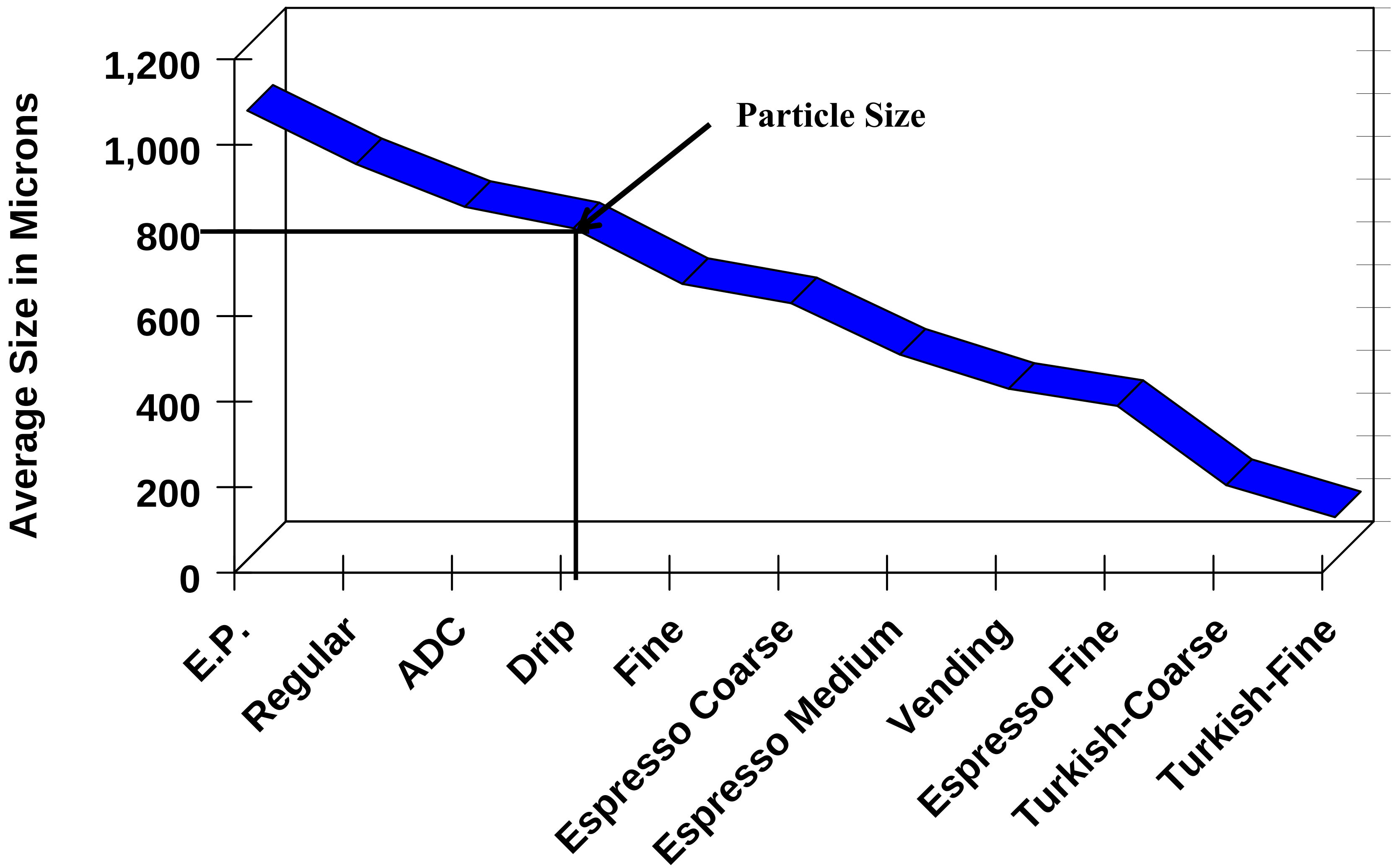
<u>Conclusion #1:</u>

Ideal extraction is a function of proper particle size for the brew time.

The Importance of Grind Uniformity

Typical Ground Coffee Particle Size

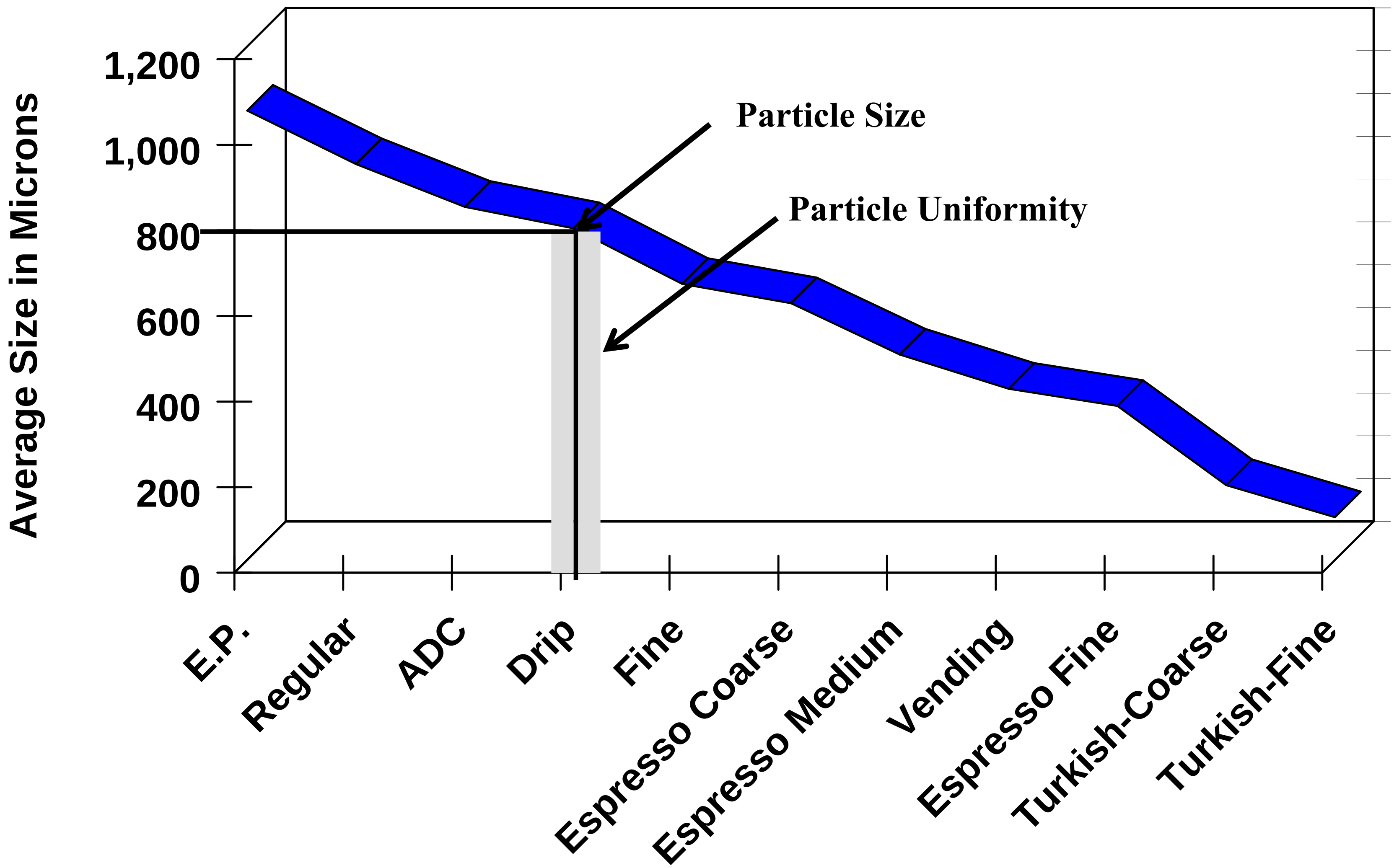
24,500 microns = 1 inch



The Importance of Grind Uniformity

Typical Ground Coffee Particle Size

24,500 microns = 1 inch

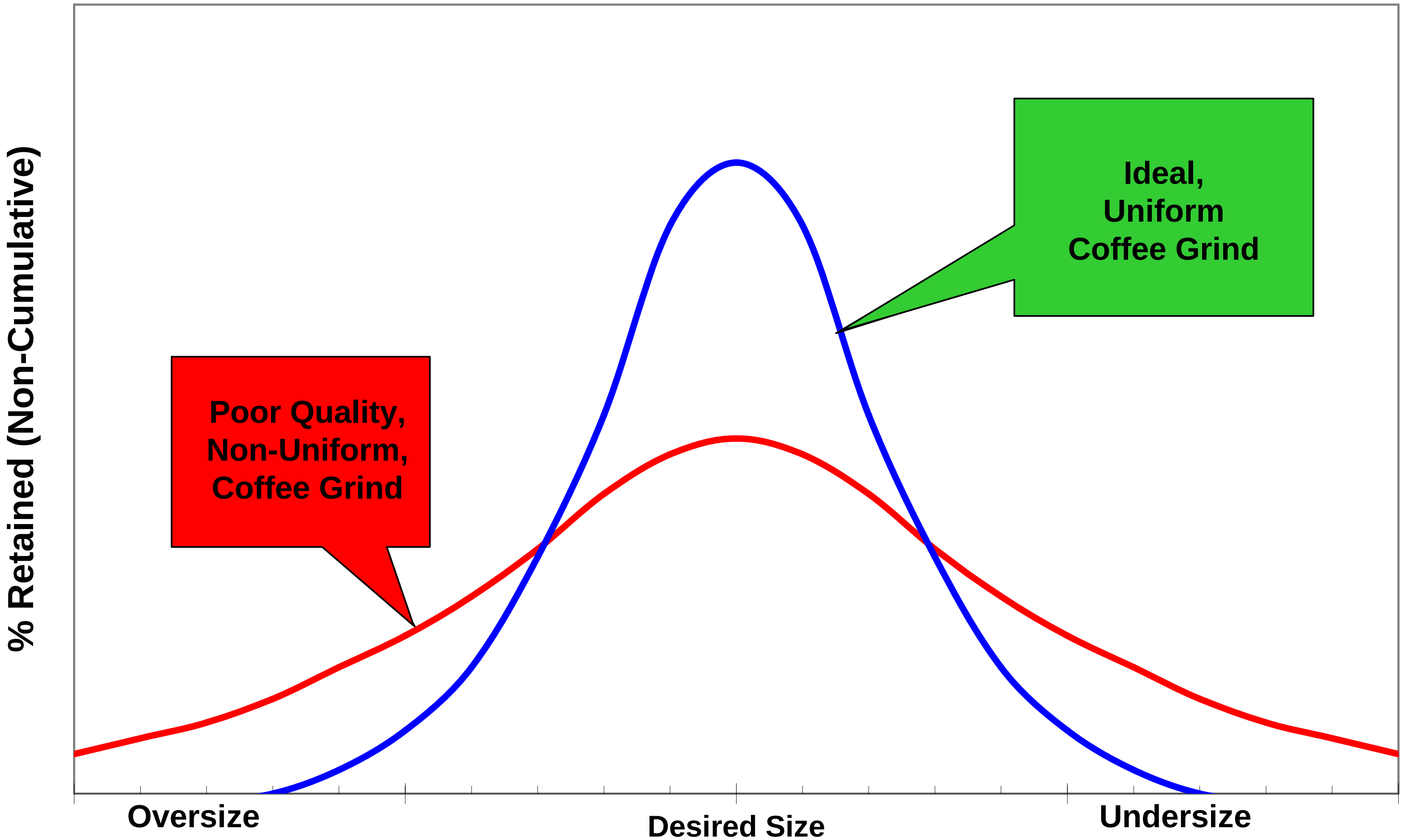


Grind Uniformity Comparison

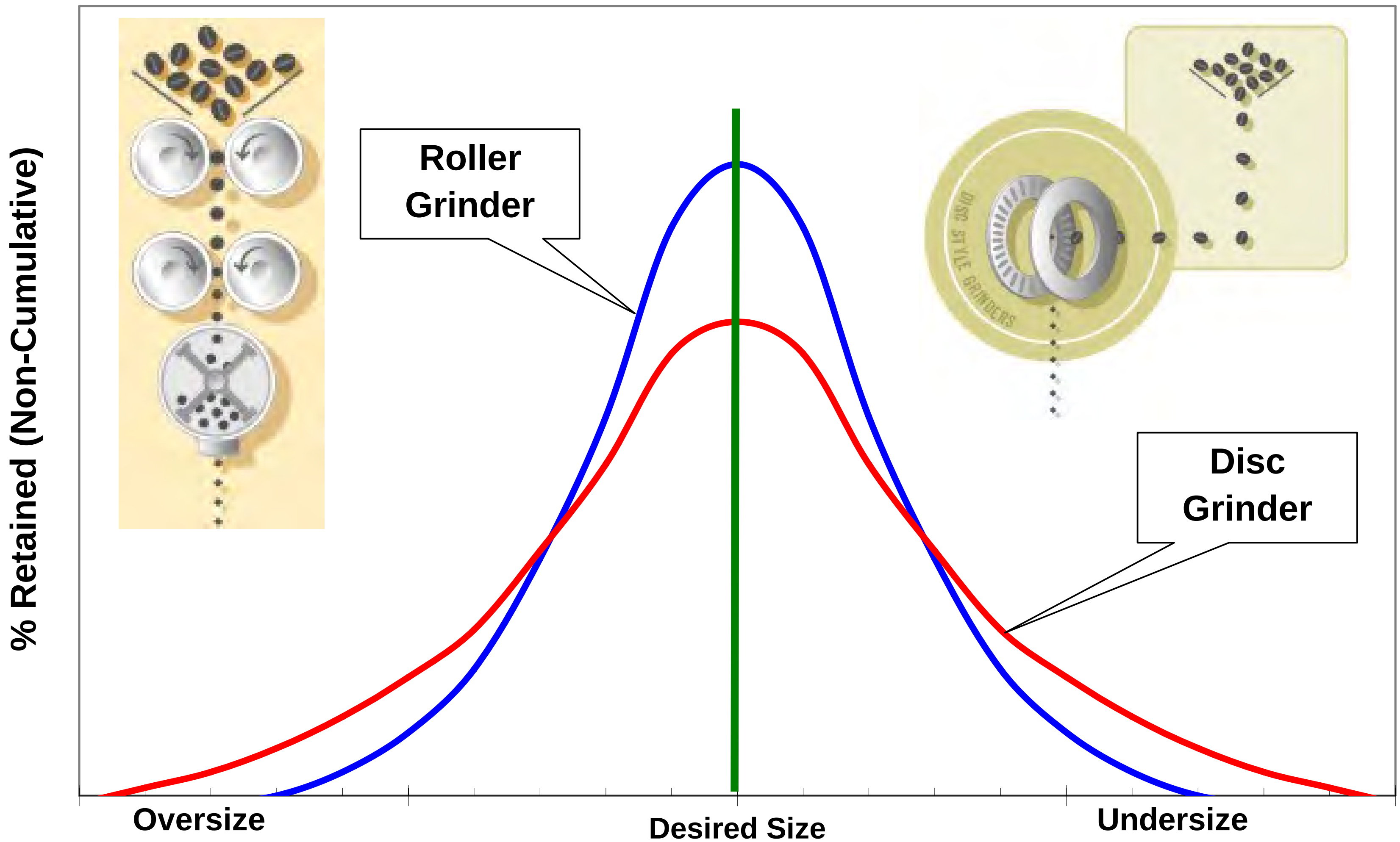
Non-Uniform Particle Size

Uniform Particle Size

Uniform vs. Non-Uniform Coffee Grind

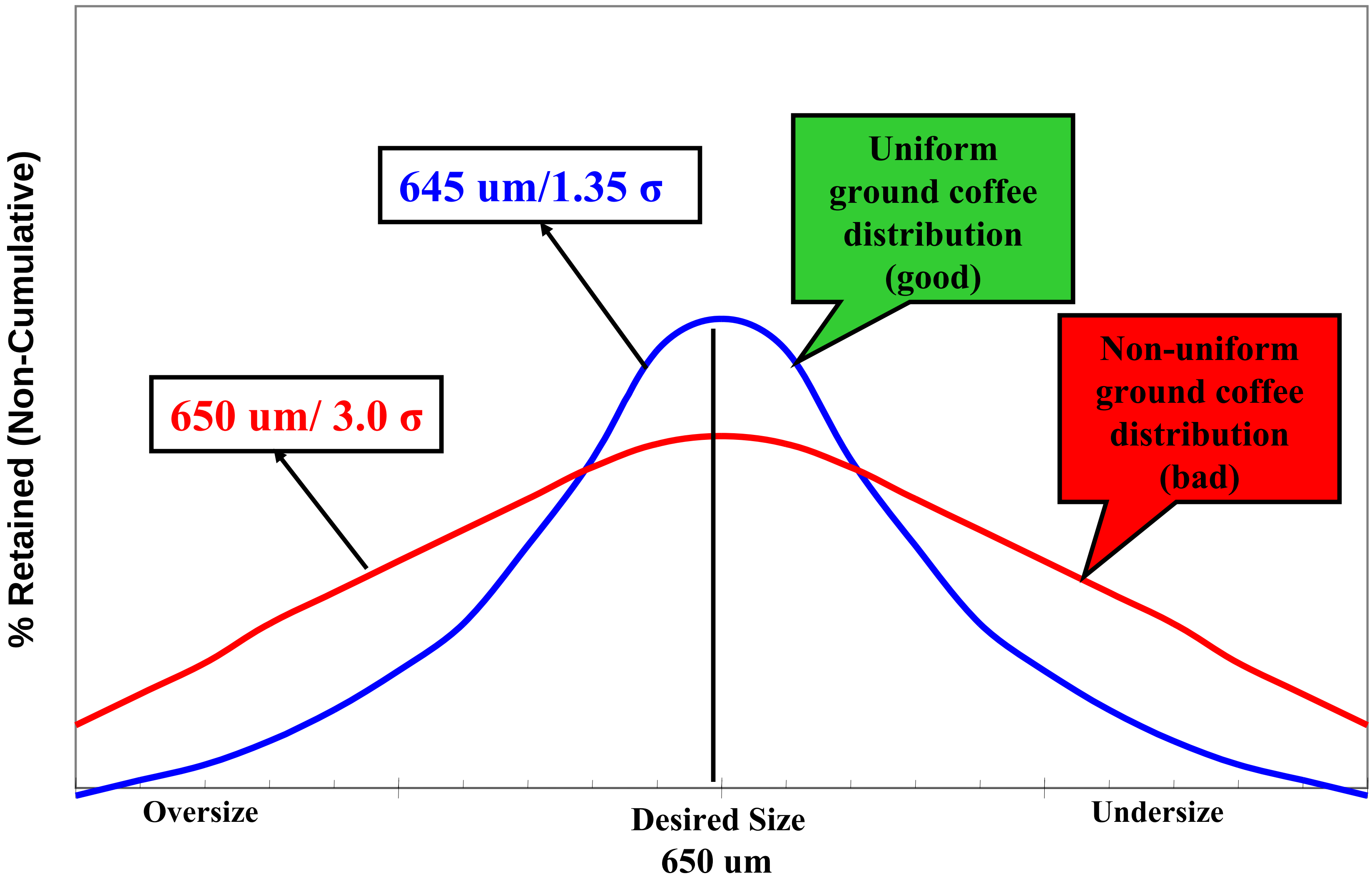


Roller vs. Disc Grinder

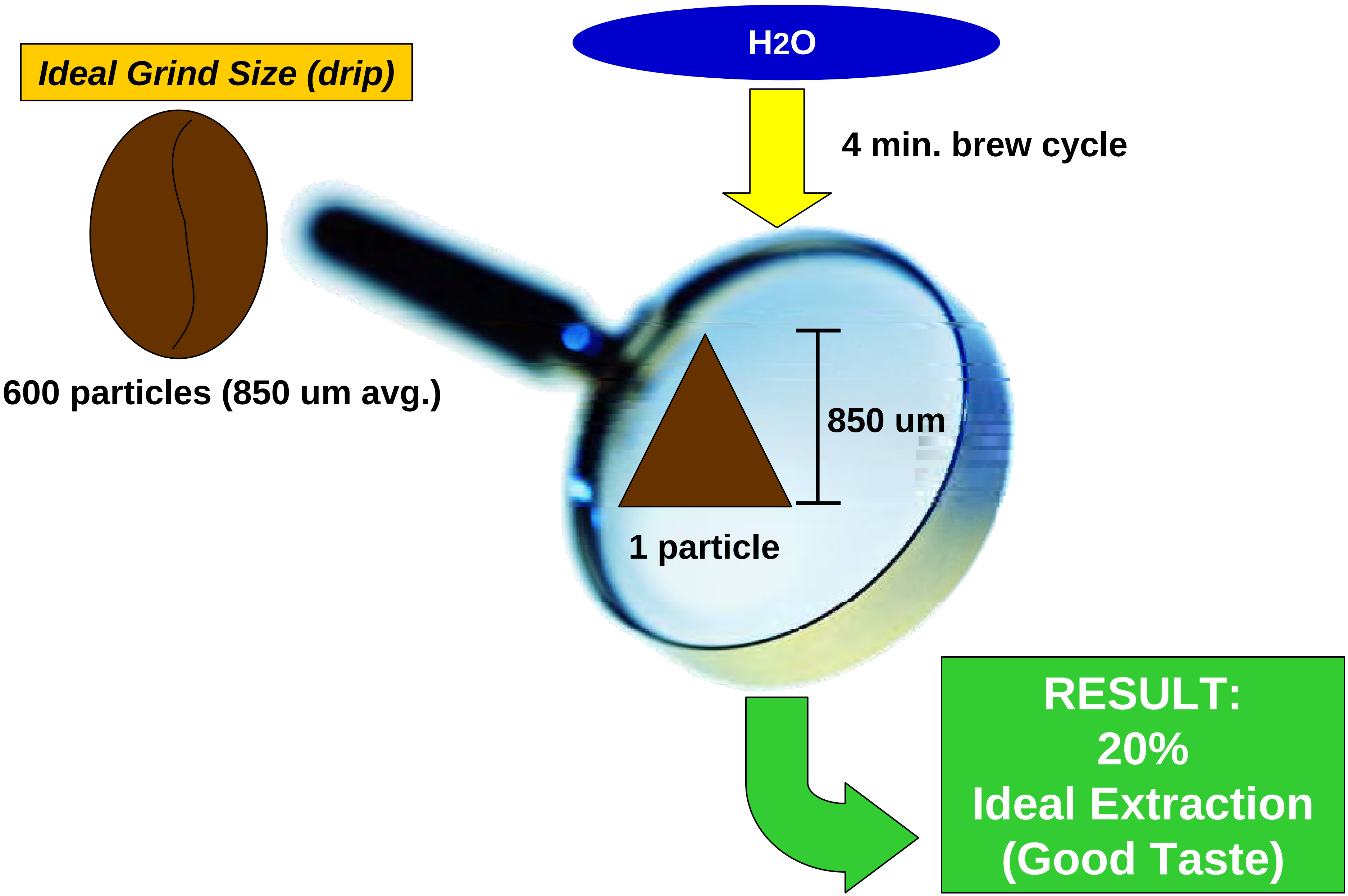


Impact of Improper Grinding Practice on Grind Quality

(Poor Methodology, Excessive Wear, etc.)

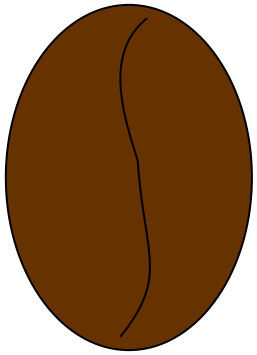


Micro Analysis of Extraction

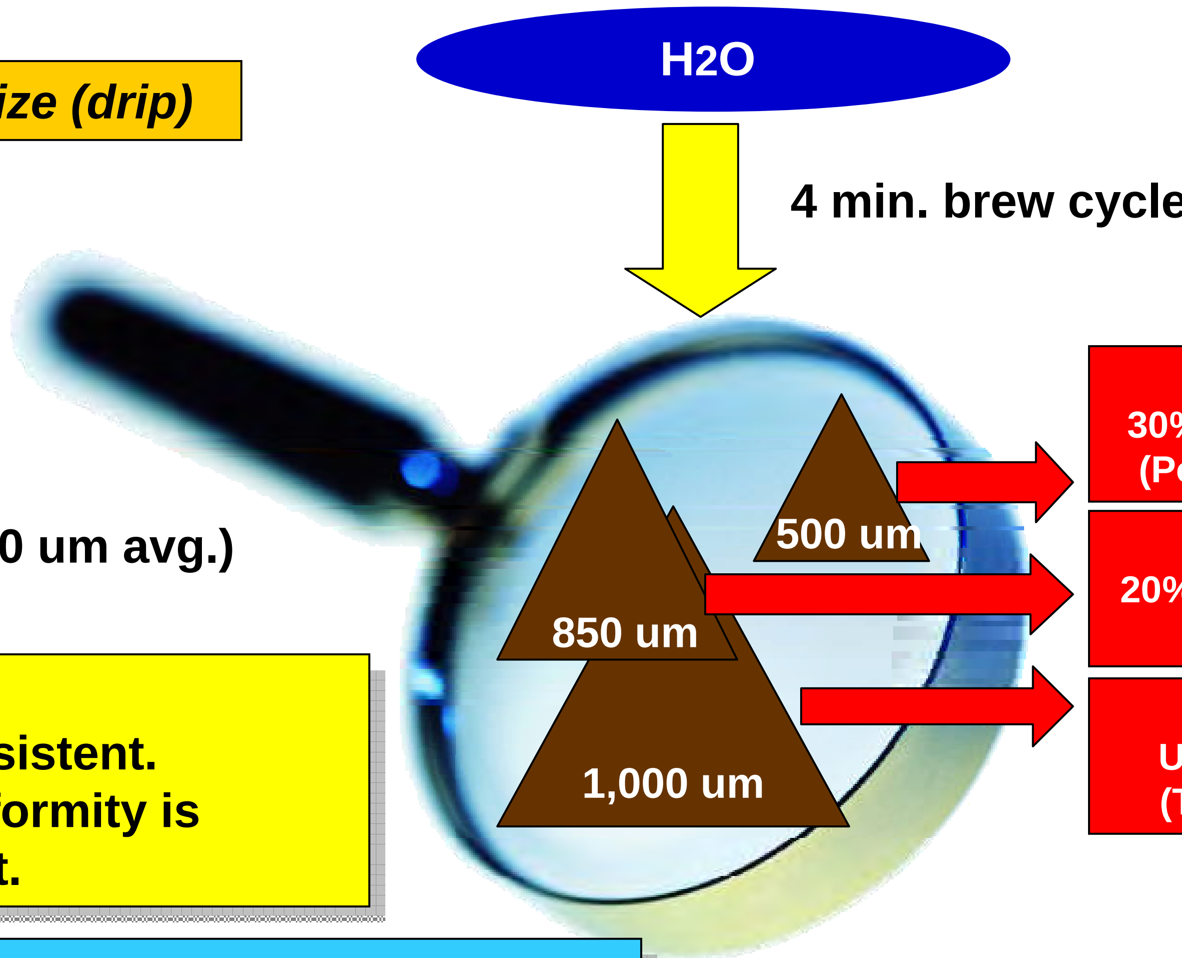


Micro Analysis of Extraction

Ideal Grind Size (drip)



600 particles (850 um avg.)



RESULT:
30% Overextraction
(Poor/Bitter Taste)

RESULT:
20% Ideal Extraction
(Good Taste)

RESULT:
Underextraction
(Tea-Like Taste)

Factors:
1) Time is consistent.
2) Particle uniformity is inconsistent.

Result:

Since some of the coffee particles are smaller and larger than ideal, the surface areas are greater and lesser and the extraction rates will be excessive or insufficient.

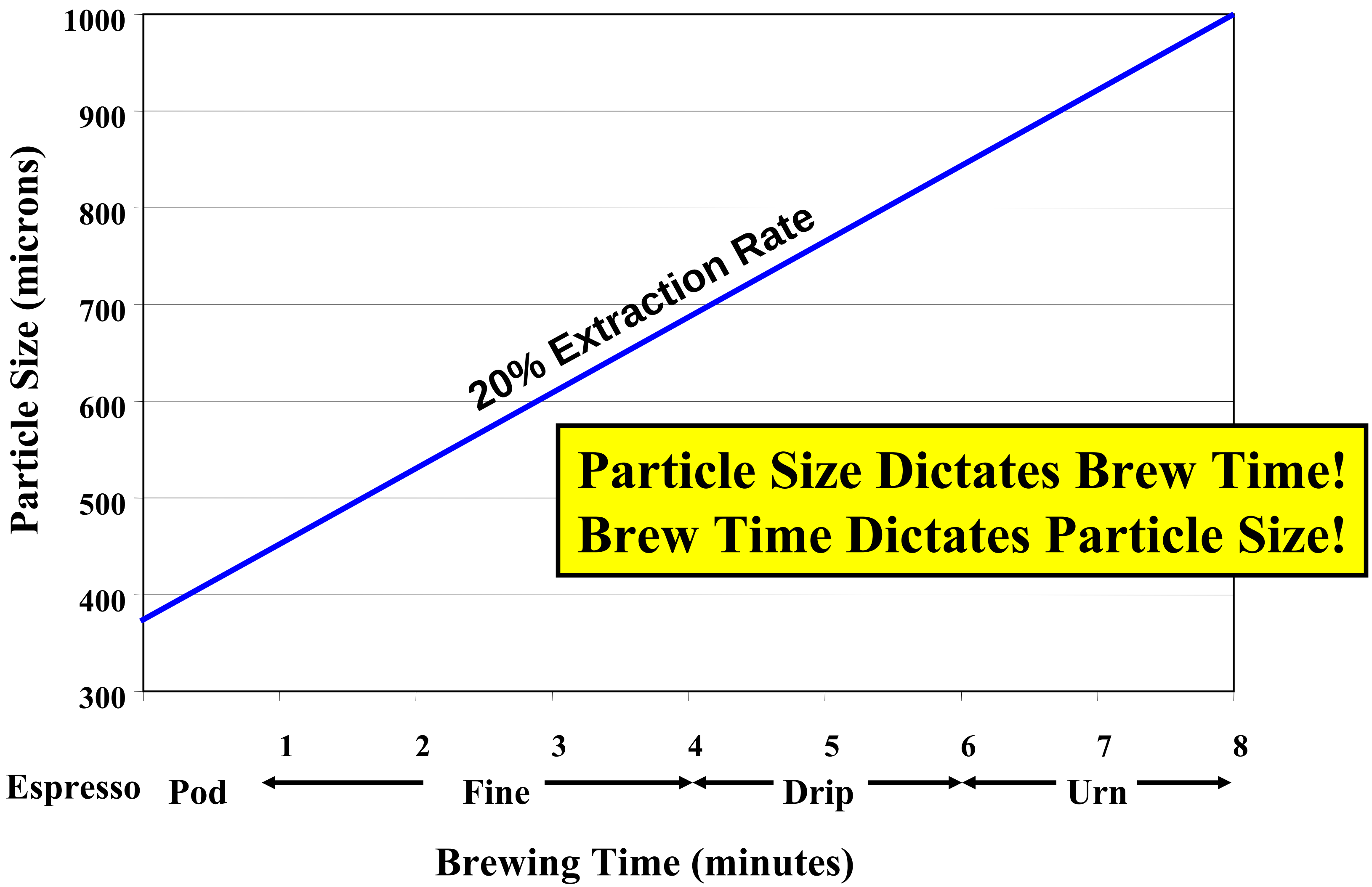
Micro Analysis of Extraction

<u>Conclusion #2:</u>

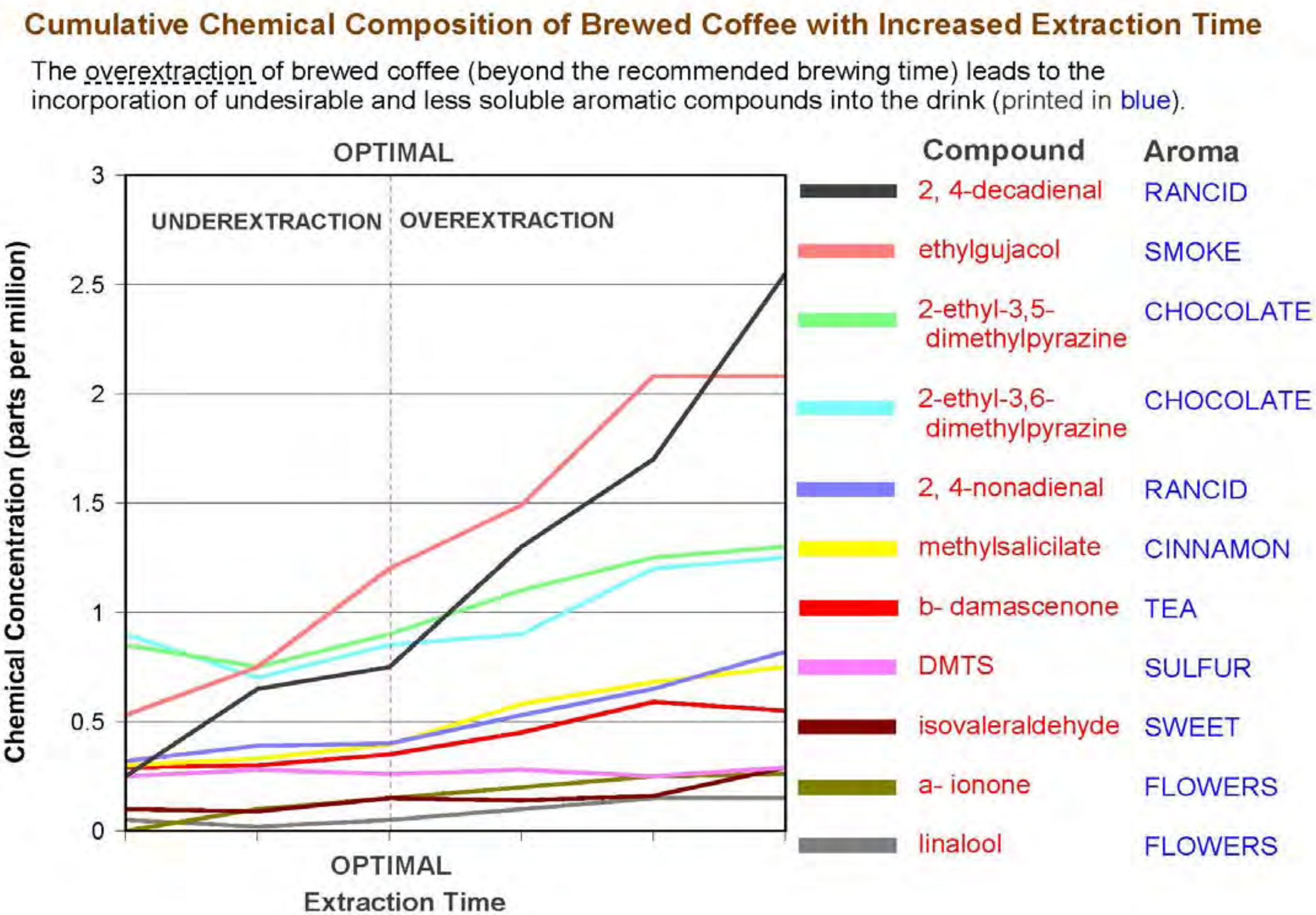
Ideal extraction is a function of proper particle size uniformity.

Optimal Brew Time vs. Particle Size

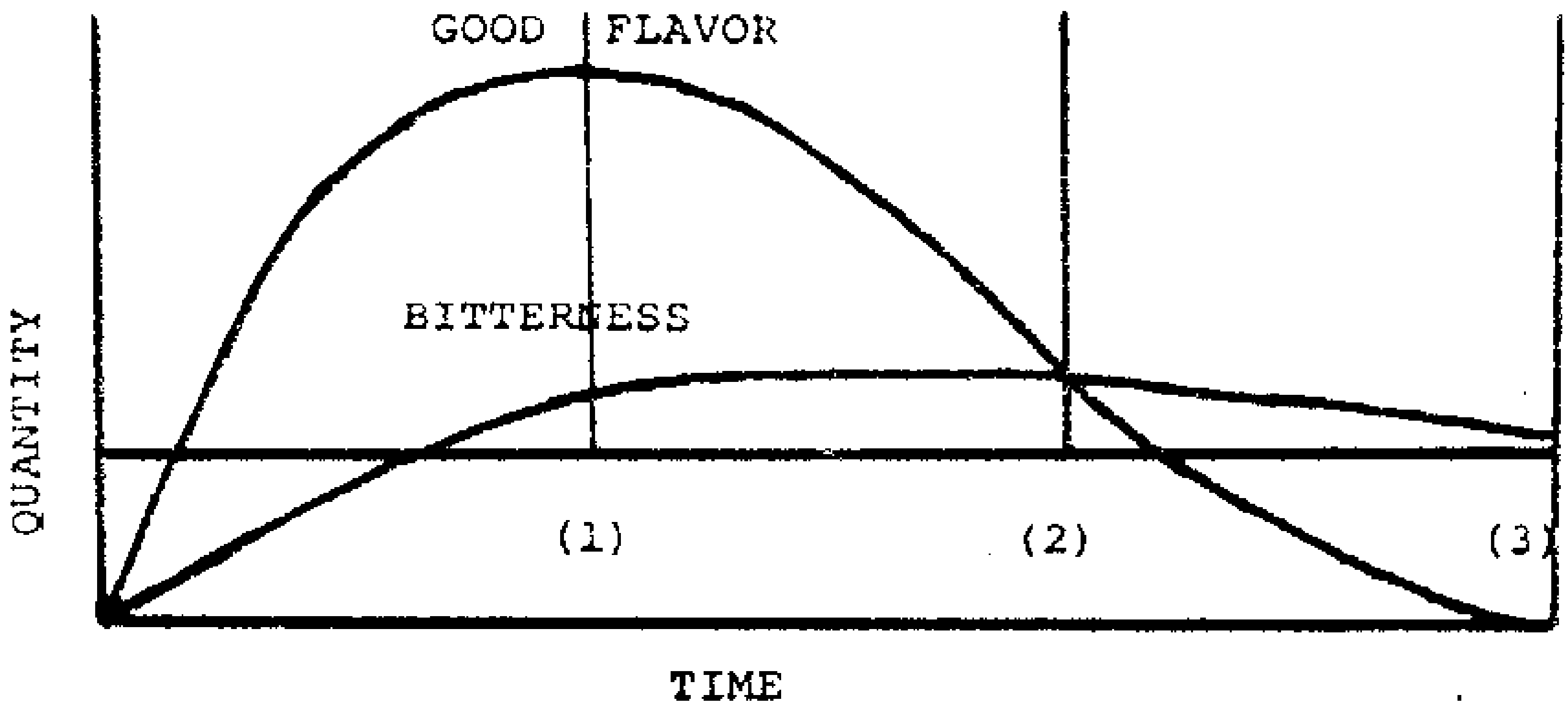
Brew Time vs. Particle Size to Achieve 20% Extraction Rate



Effect of Extraction Time on Taste

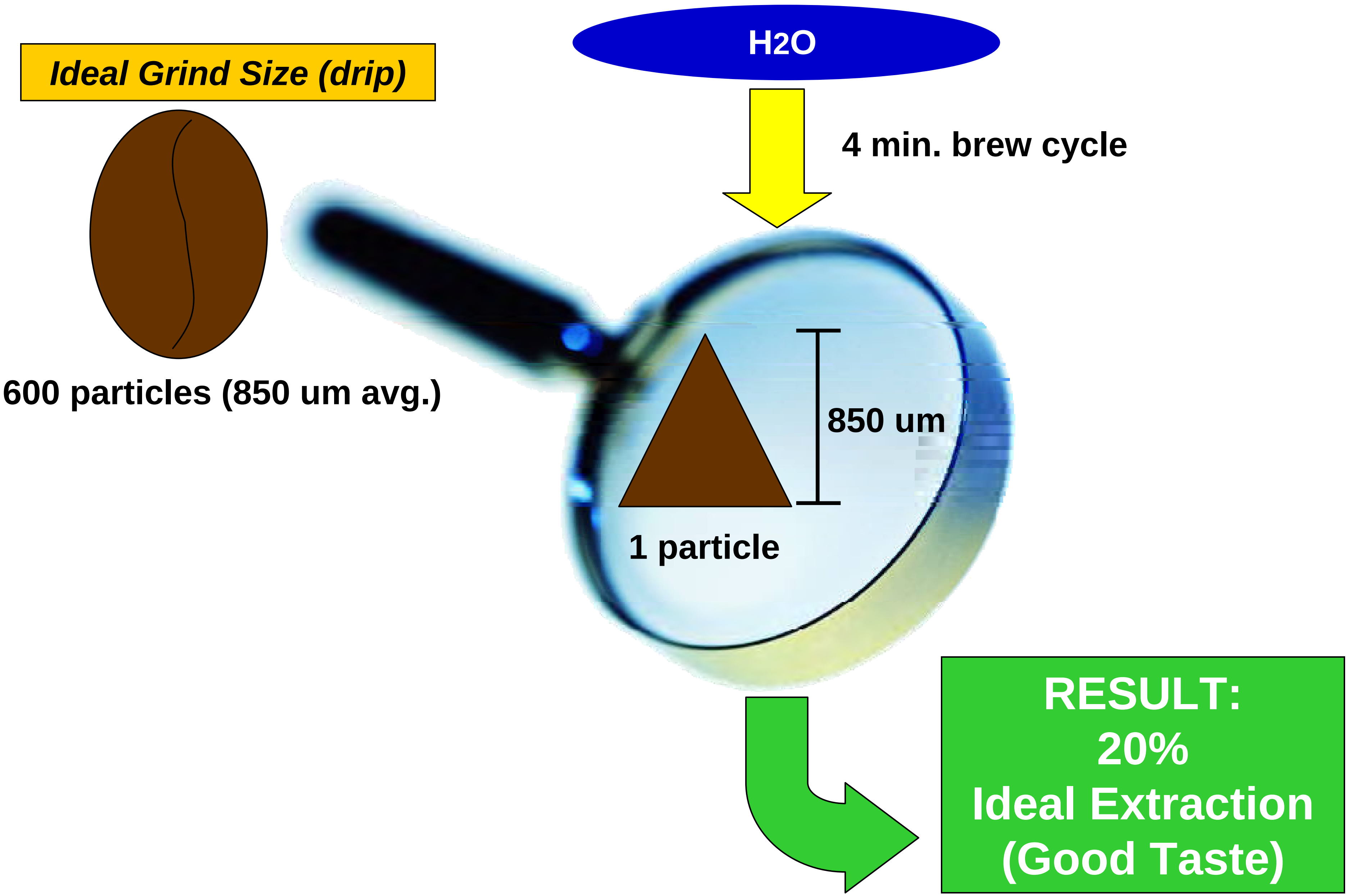


Effect of Cycle Time on Taste



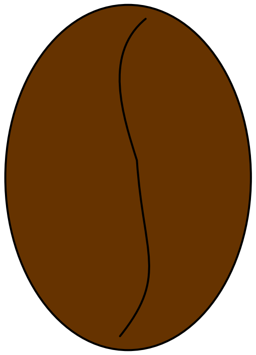
Courtesy of the Coffee Brewing Center

Micro Analysis of Extraction

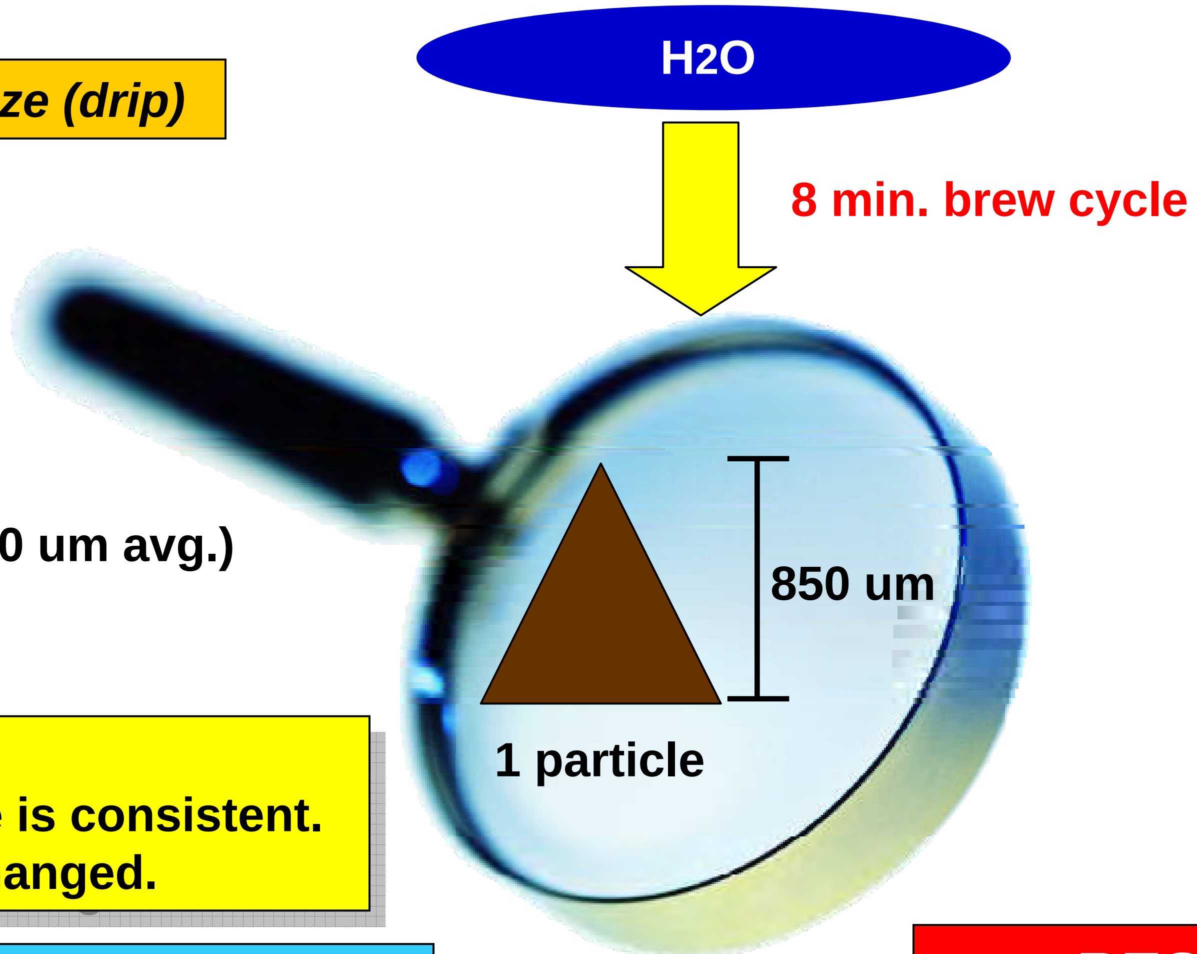


Micro Analysis of Extraction

Ideal Grind Size (drip)



600 particles (850 um avg.)



Factors:
1) Particle size is consistent.
2) Time has changed.

Result:

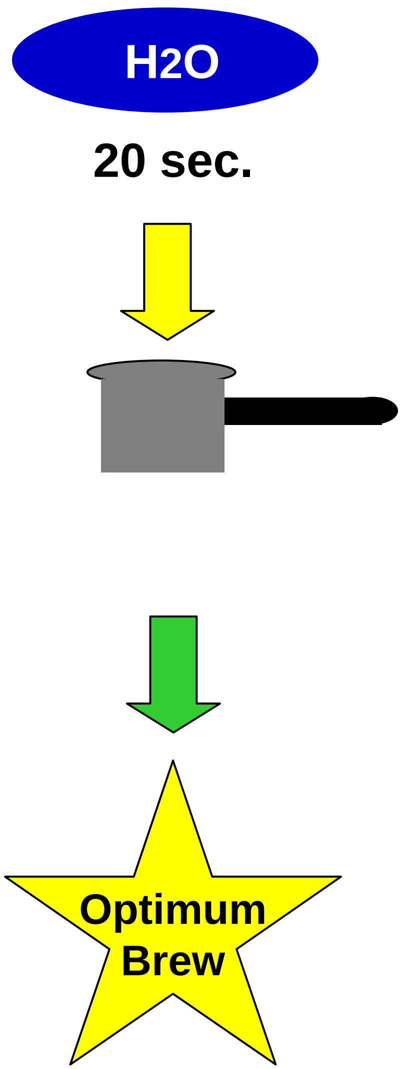
Since the brewing time is too long for the relative particle size, the extraction rate is excessive.

RESULT:
30-35%
Overextraction
(Poor/Bitter Taste)

Macro Analysis of Extraction

Espresso Brewer

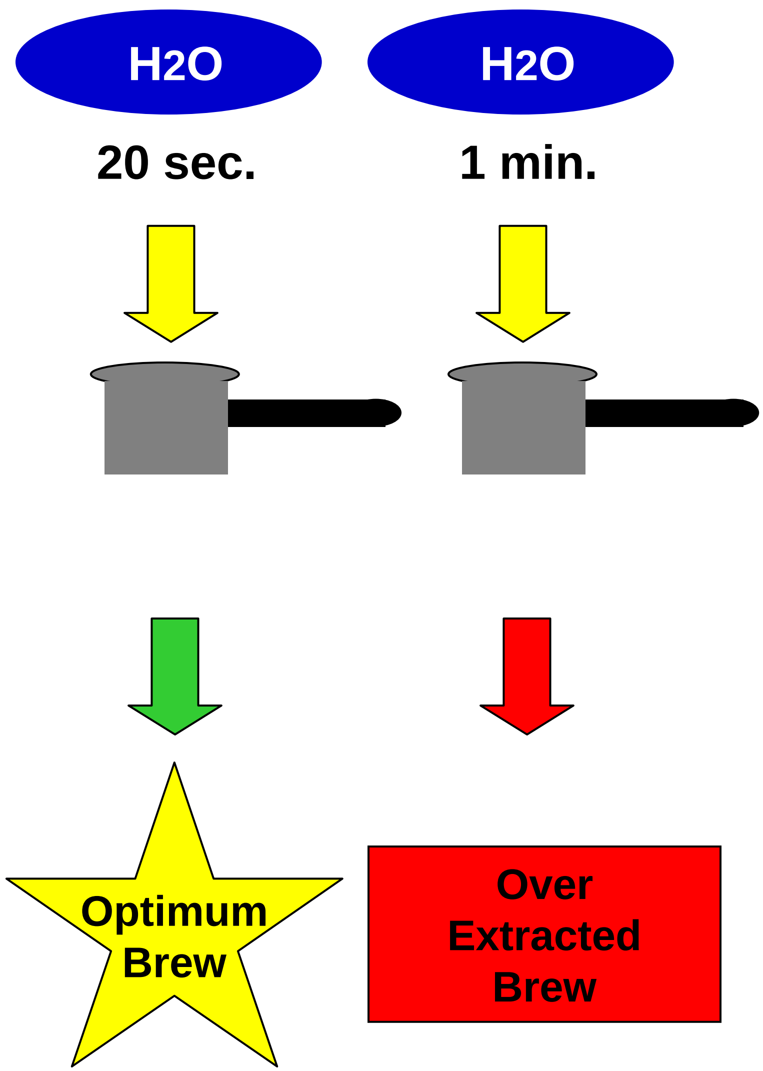
225 um grind



Macro Analysis of Extraction

Espresso Brewer

225 um grind



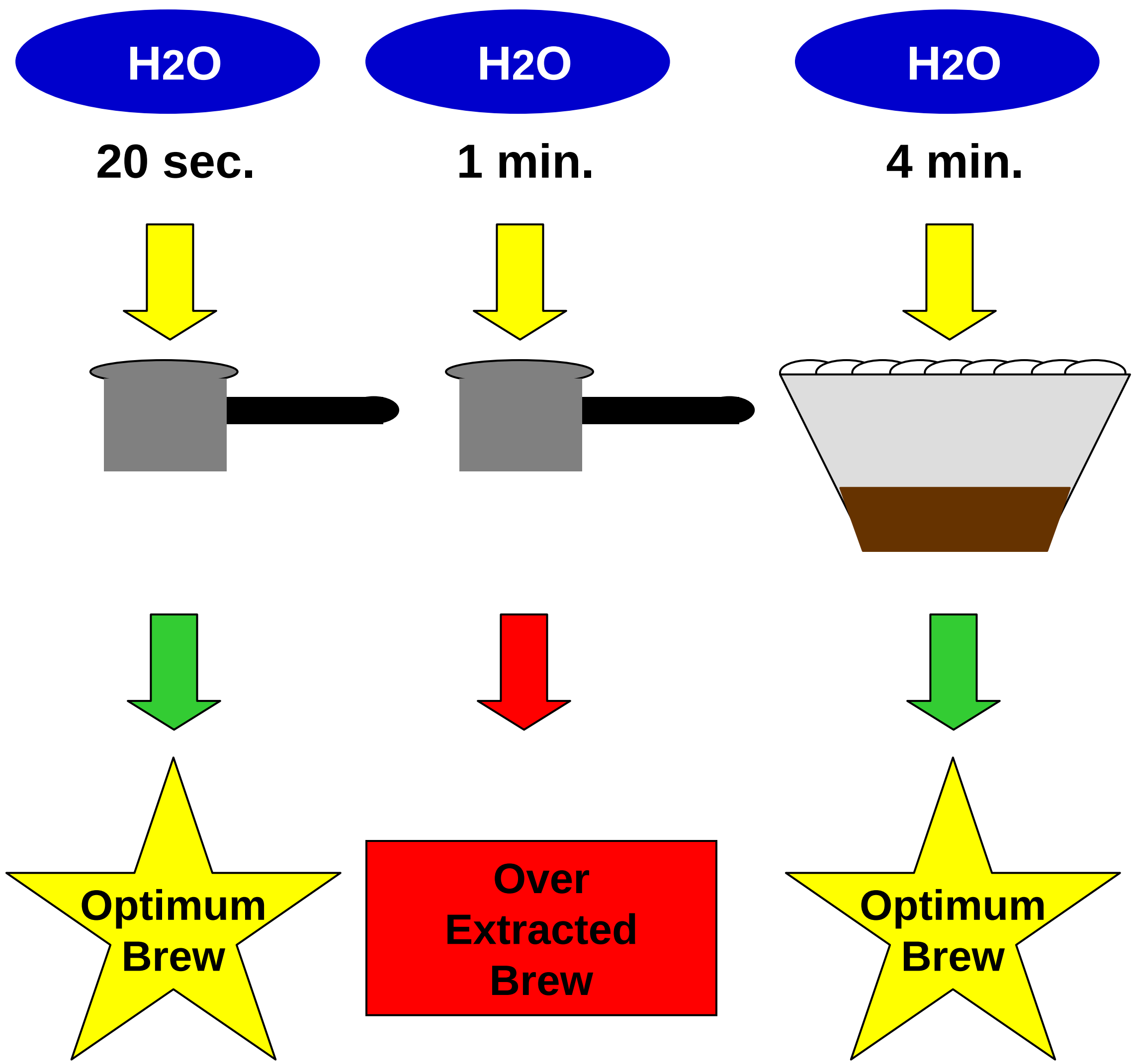
Macro Analysis of Extraction

Espresso Brewer

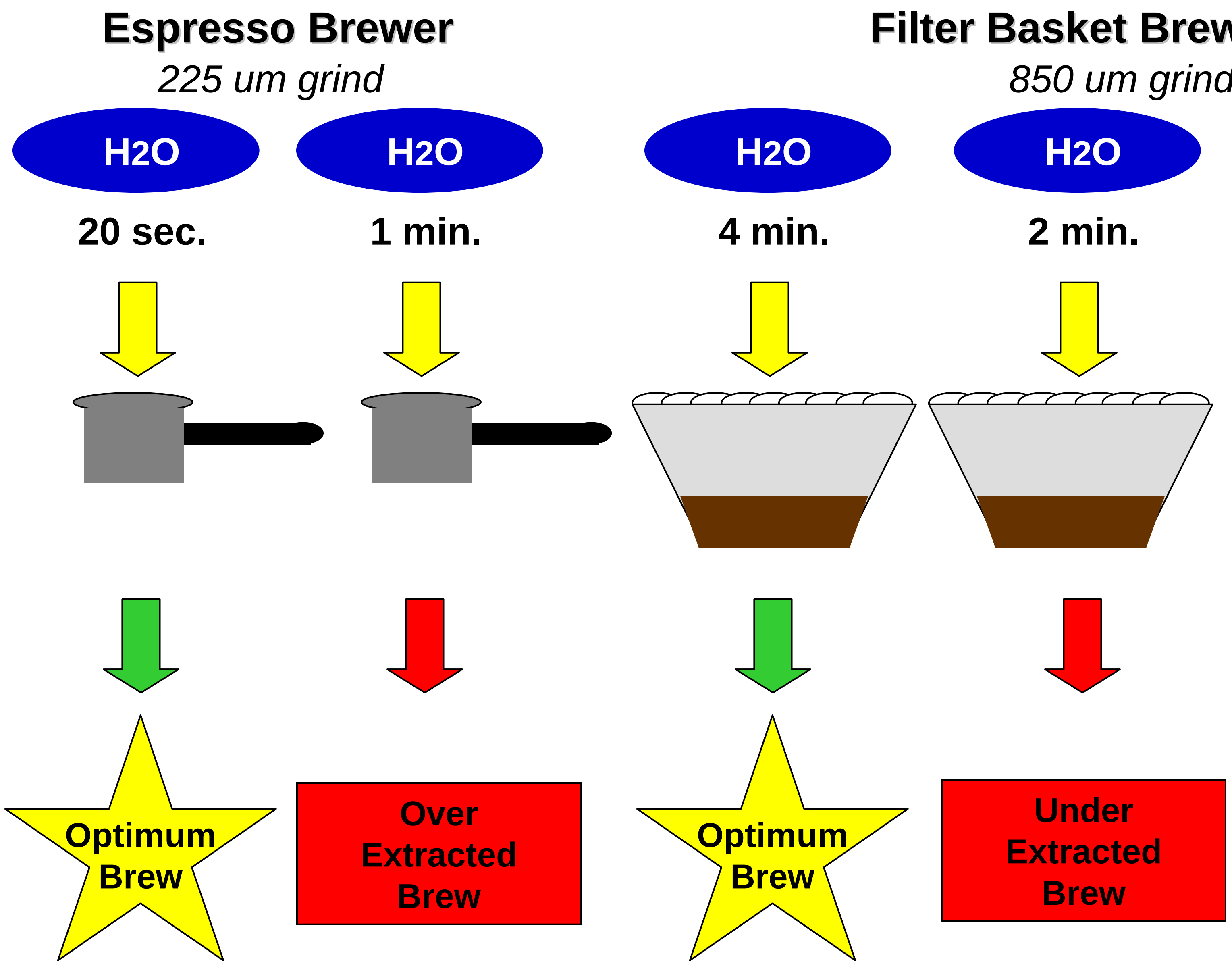
225 um grind

Filter Basket Brewer

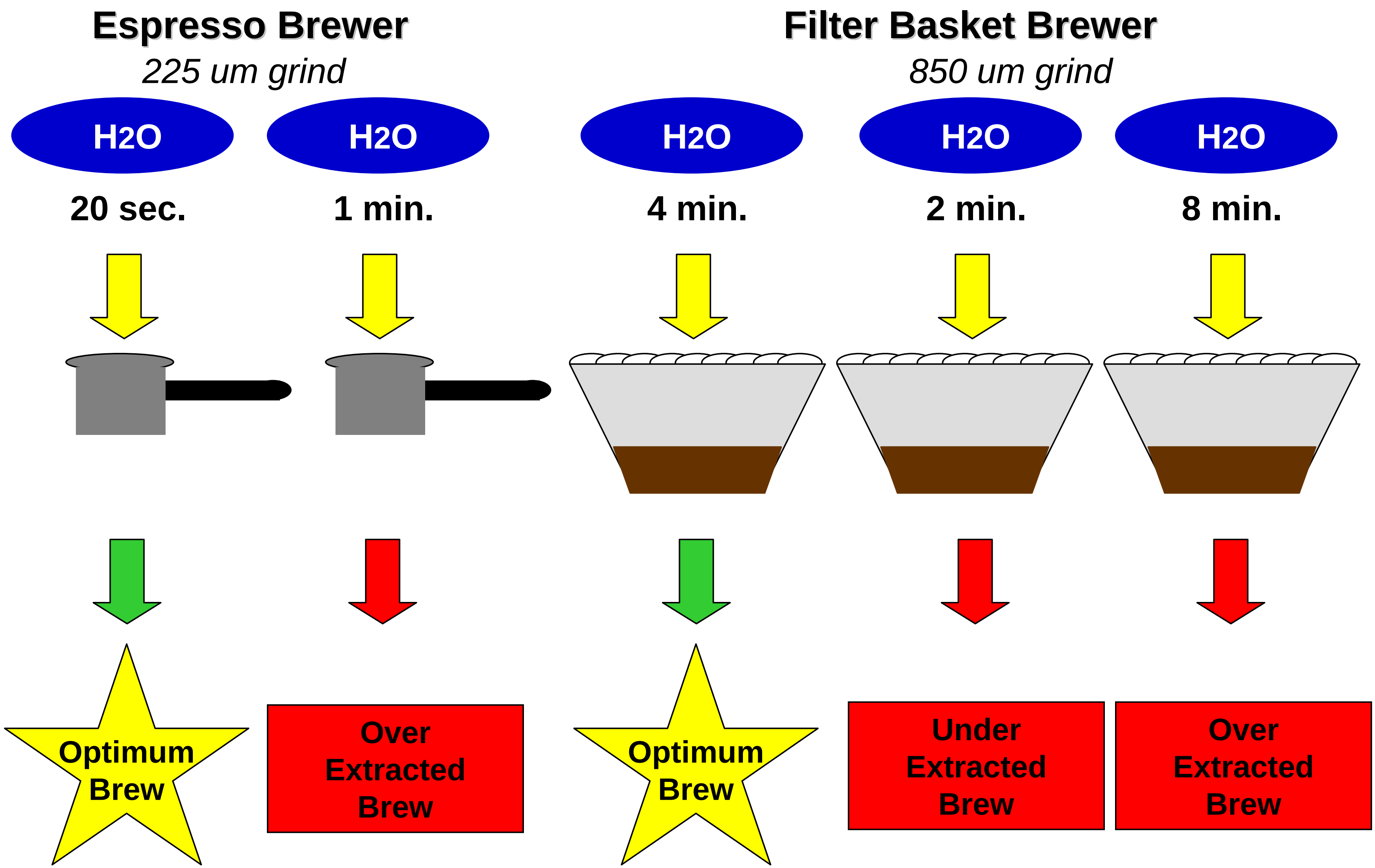
850 um grind



Macro Analysis of Extraction



Macro Analysis of Extraction

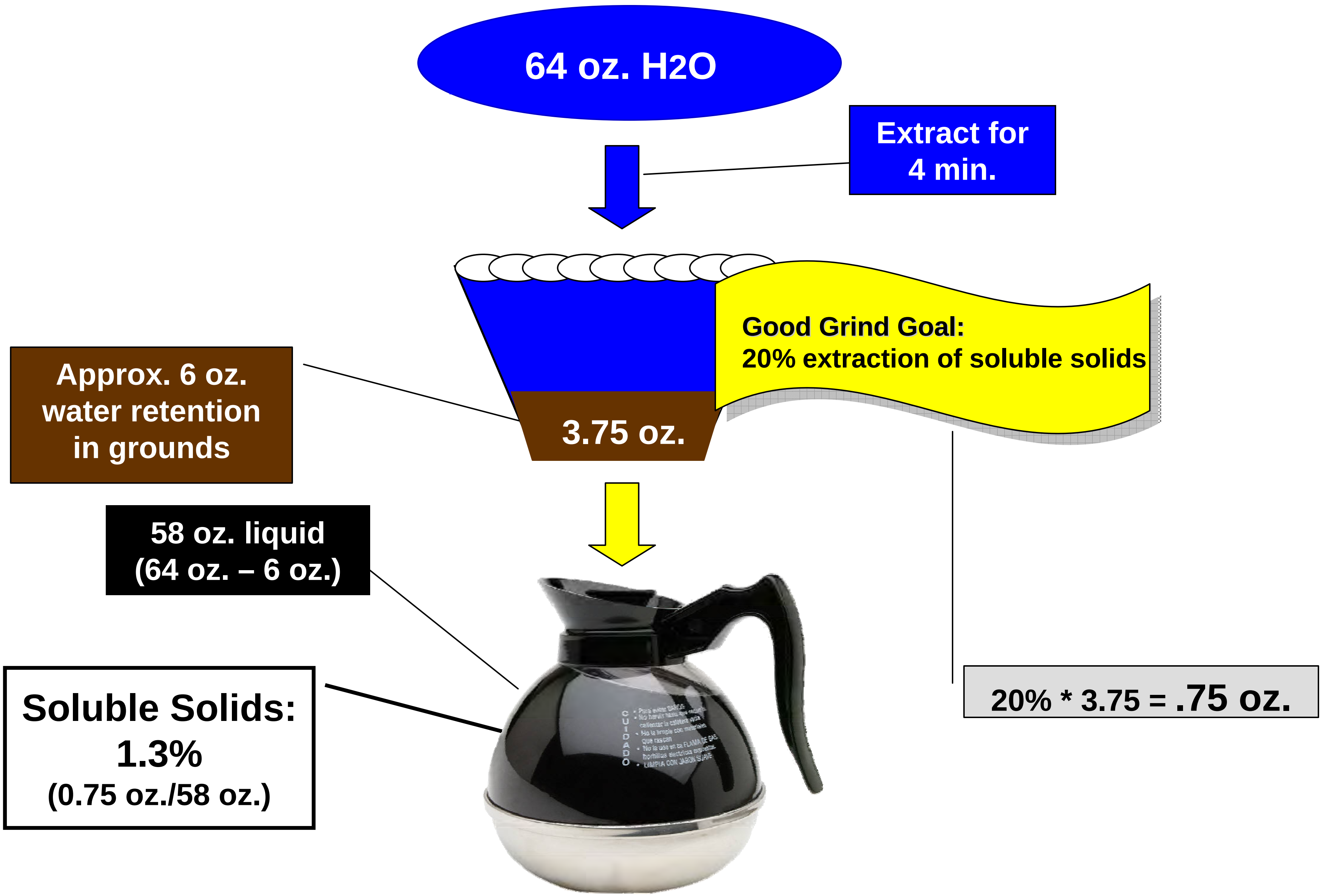


Micro Analysis of Extraction

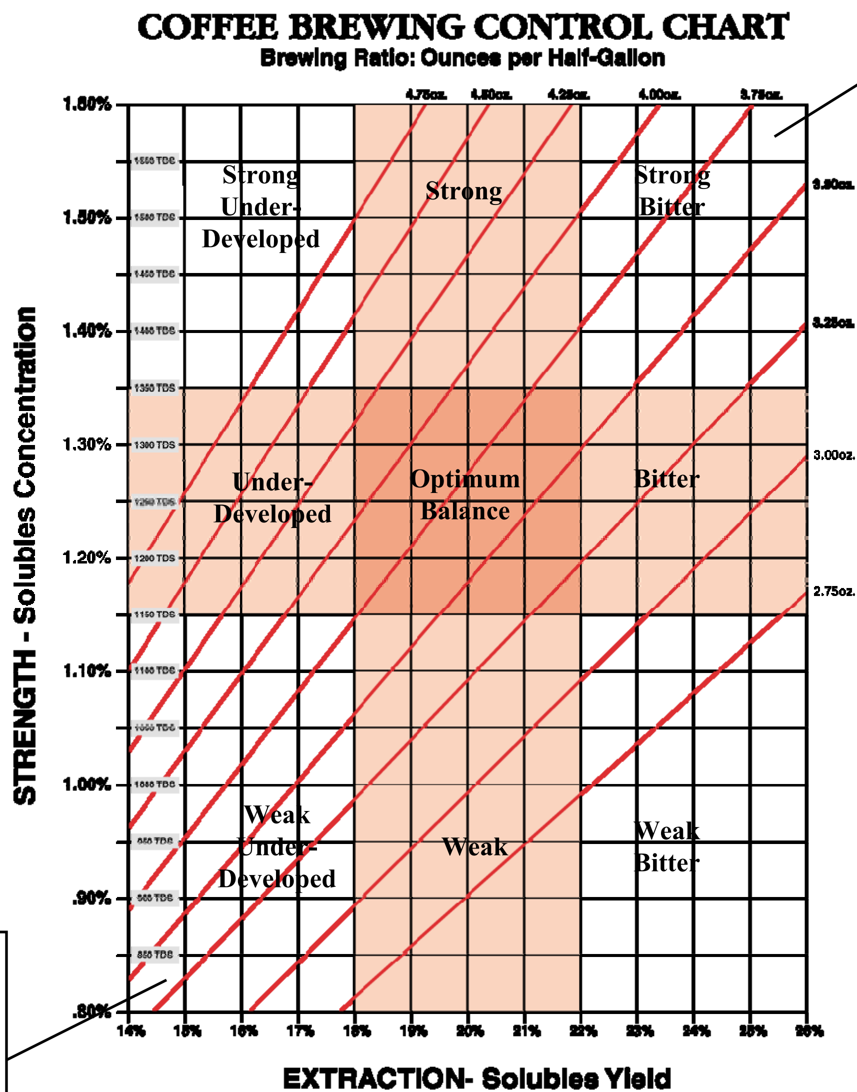
<u>Conclusion #3:</u>

Ideal extraction is a function of proper brew time for the method and grind.

Macro Grind Challenge



The “Gold Cup” Standard Calculation



Too Fine so Extraction Rate Too High

Too Coarse so Extraction Rate Too Low

How do we calculate brewed solids?

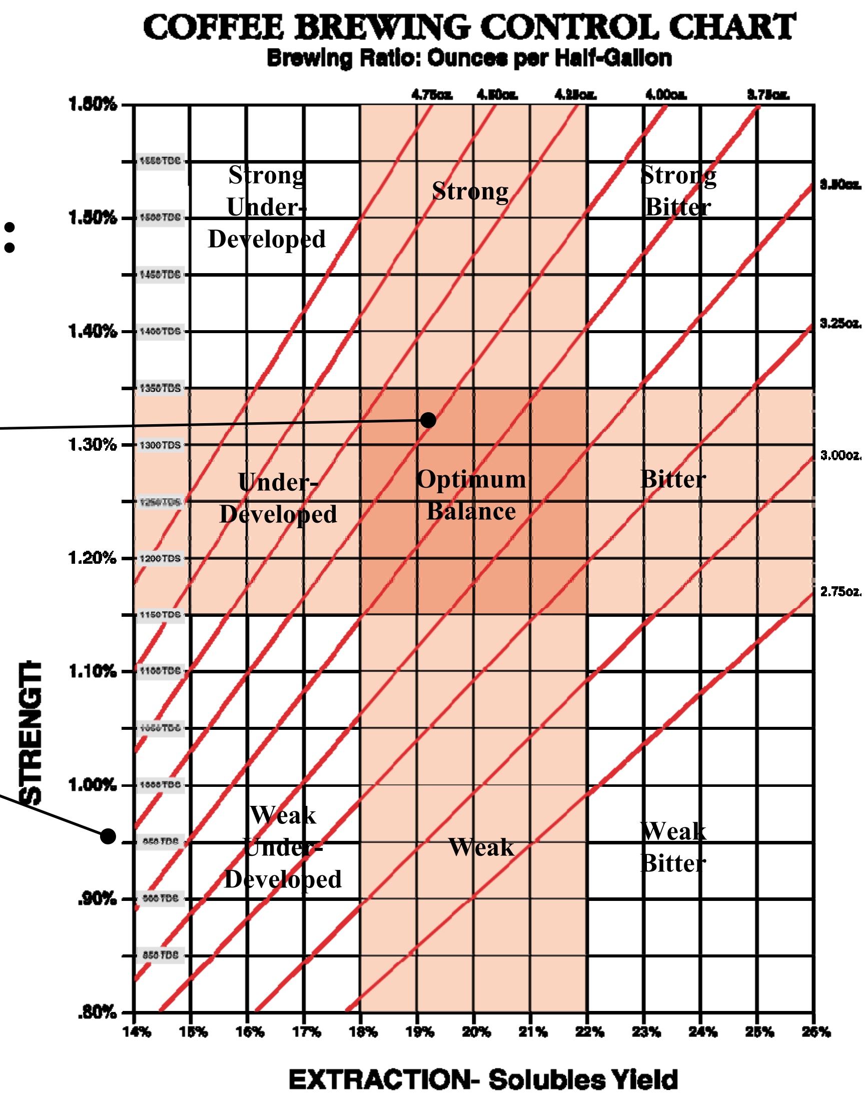
1. Use 64 oz. of water for brewing
2. Subtract water absorbed in coffee grounds (6 fl/oz.)
3. Use 3.75 oz. of ground coffee to extract 20% solids
4. Brew to “Gold Cup” Standard that will extract 20% of solids:
   20% x 3.75 oz. = 0.75 oz.
5. Calculate brewed solids as percentage of liquid:
   0.75 oz./58 oz. = 1.3%

Evaluation of the <u>same grind</u> (average particle size) but <u>different uniformities</u>

Particle Size/Particle Uniformity:

645 um/1.35 σ *(Good Quality Grind)*

650 um/ 3.0 σ *(Poor Quality Grind)*



The Key Principals of Coffee Extraction

- The rate of soluble solids extraction from a coffee particle is directly related to the amount of exposed surface area to the hot water.

- The time that the hot water will be exposed to the coffee particle must be directly proportional to the exposed surface area, or particle size, of the ground coffee.

- **If particle size, uniformity and brewing time are matched correctly, with all other factors being equal, a 20% extraction rate can be achieved.**

Ideal Matrix of Grind vs. Time

Brew Times	Grind: Coarse	Grind: Optimal	Grind: Fine
Excessive	Strong Under-Developed	Strong	Strong Bitter
Optimal	Under-Developed	Optimum Balance	Bitter
Too Short	Weak Under-Developed	Weak	Weak Bitter

Brewed Coffee Taste Profiles

Ideal Matrix of Grind vs. Time

Grind

Brew Times	Coarse	Optimal	Fine
Excessive	Strong Under-Developed	Strong	Strong Bitter
Optimal	Under-Developed	Optimum Balance	Bitter
Too Short	Weak Under-Developed	Weak	Weak Bitter

Brewed Coffee Taste Profiles

Most Common Problems

Heat vs. Grinding

Goal:
We only want to roast coffee once, and that is in the roaster!

= **OK!**

Challenge:
Maintain low temperatures during grinding.

= **NOT OK!**

Chemical Composition of Coffee
Volatiles and Aromatics

5

Aldehydes

Propanal	276
n-Butanal	133
Isobutanal	134
Isopentanal	43
2-Methylbutanal	43
n-Hexanal	below 30
2-Methylbut-2-enal	below 30
Benzaldehyde	below 20
O-Tolualdehyde	below 20
Salicylaldehyde	below 20
Phenylacetaldehyde	below 20
3-Methyl-2-butenal	25

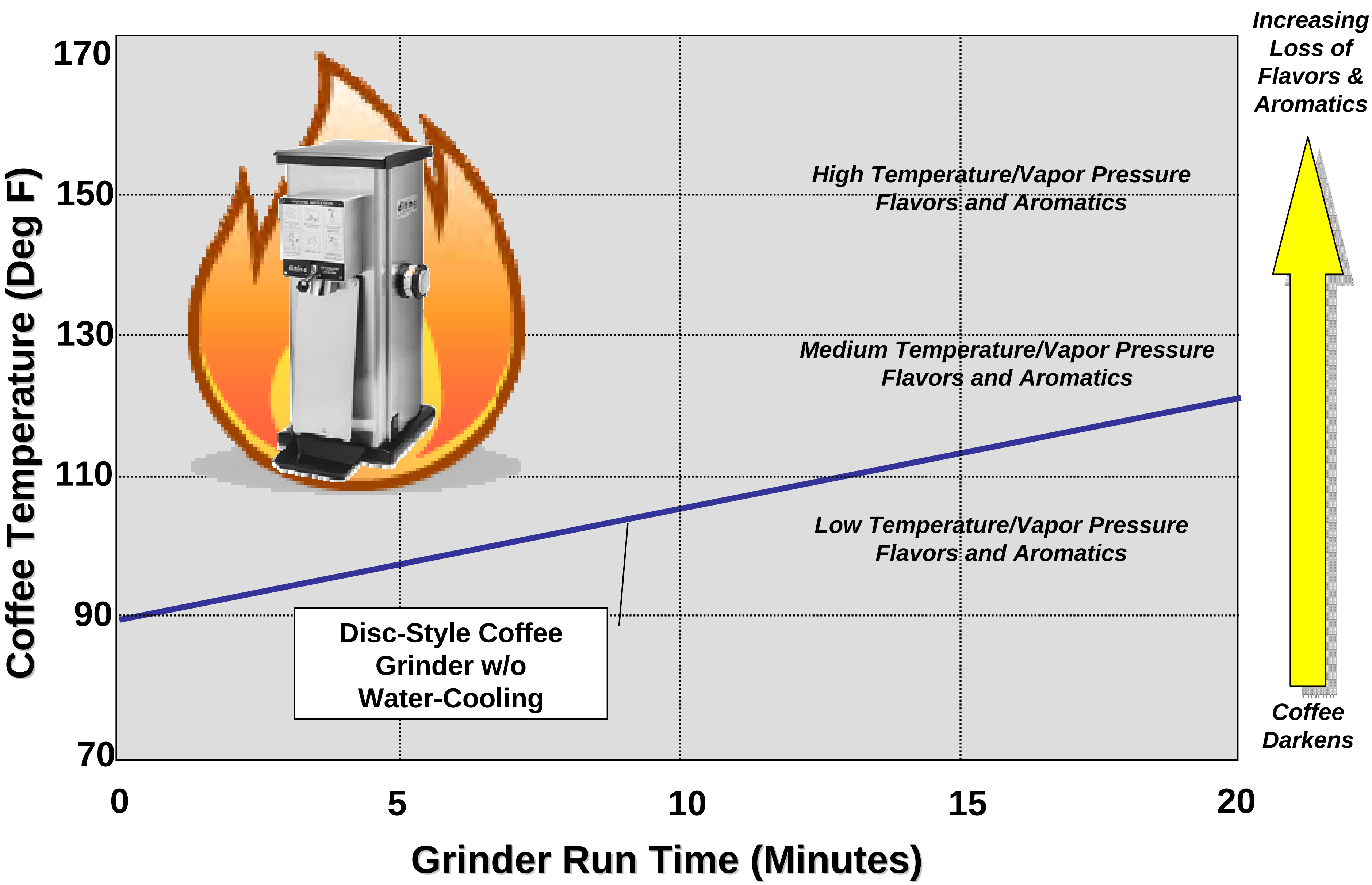
Substances with vapor pressures below 500 mm. Hg. at 20° C.

Esters and Lactones

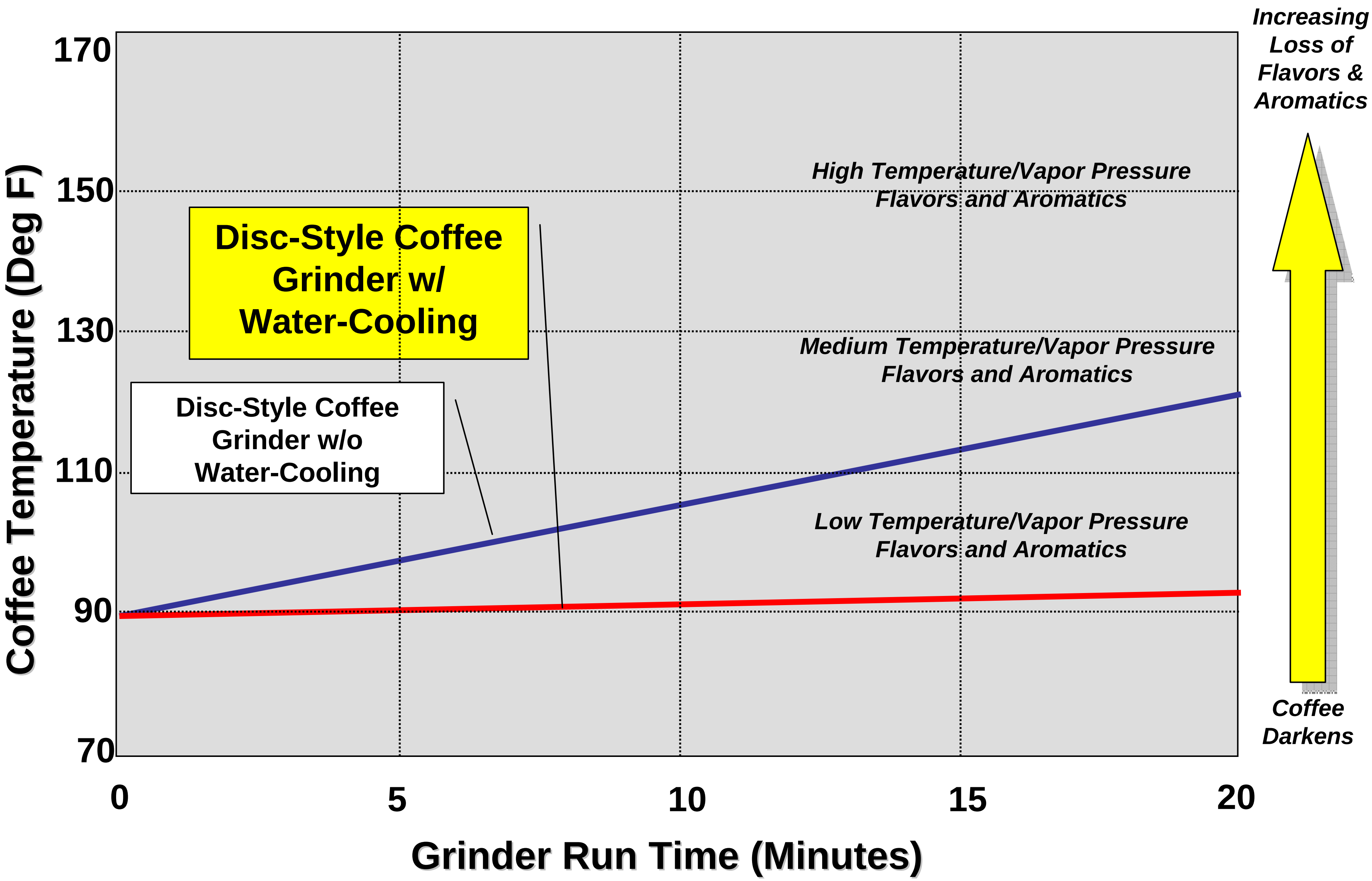
- Methyl formate
- Methyl acetate
- Methyl palmitate
- Methyl benzoate
- Benzyl formate
- γ-Butyrolactone
- Crotonolactone
- Acetol acetate
- Butan-2-one-1-yl acetate
- Methyl nicotinate
- Isopropyl formate
- Isoamyl acetate
- Methyl phenylacetate

Phenols

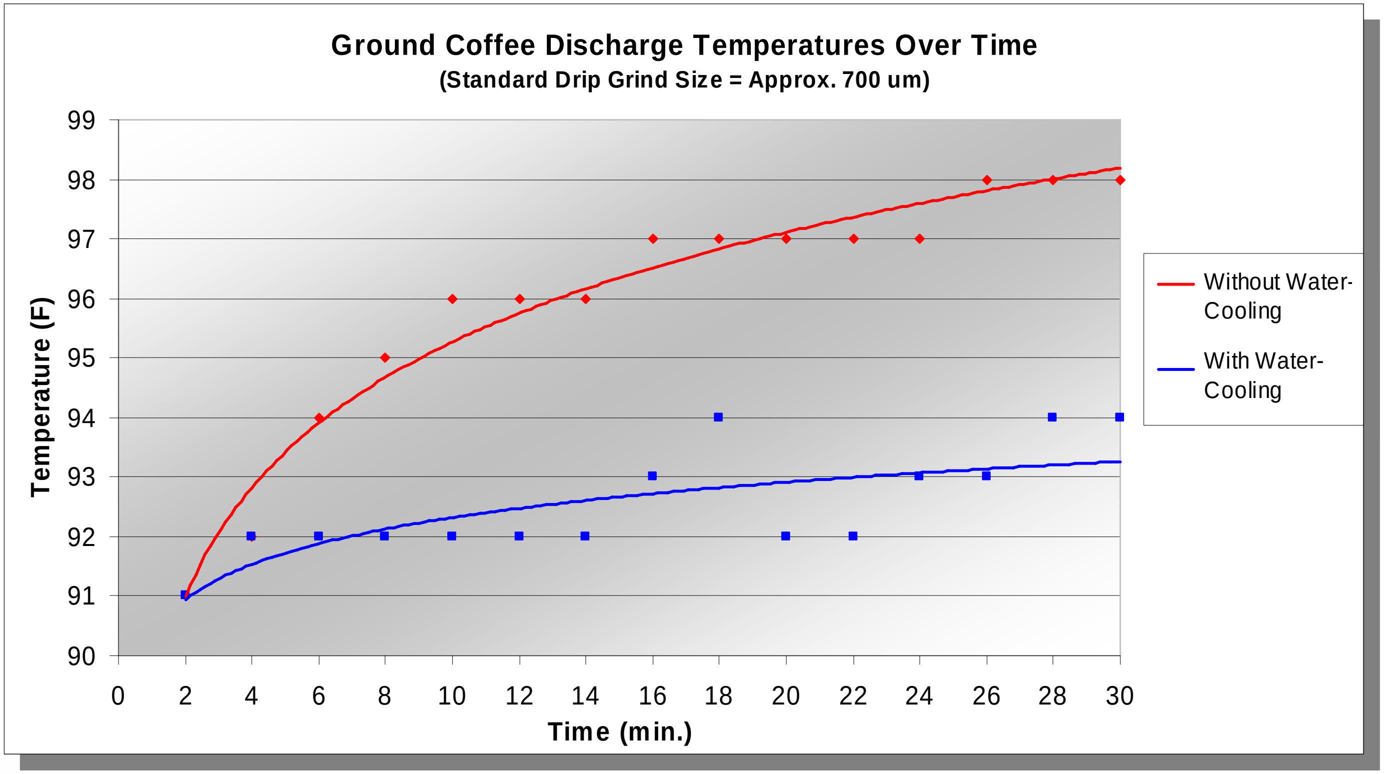
Temperature Rise During Grinding



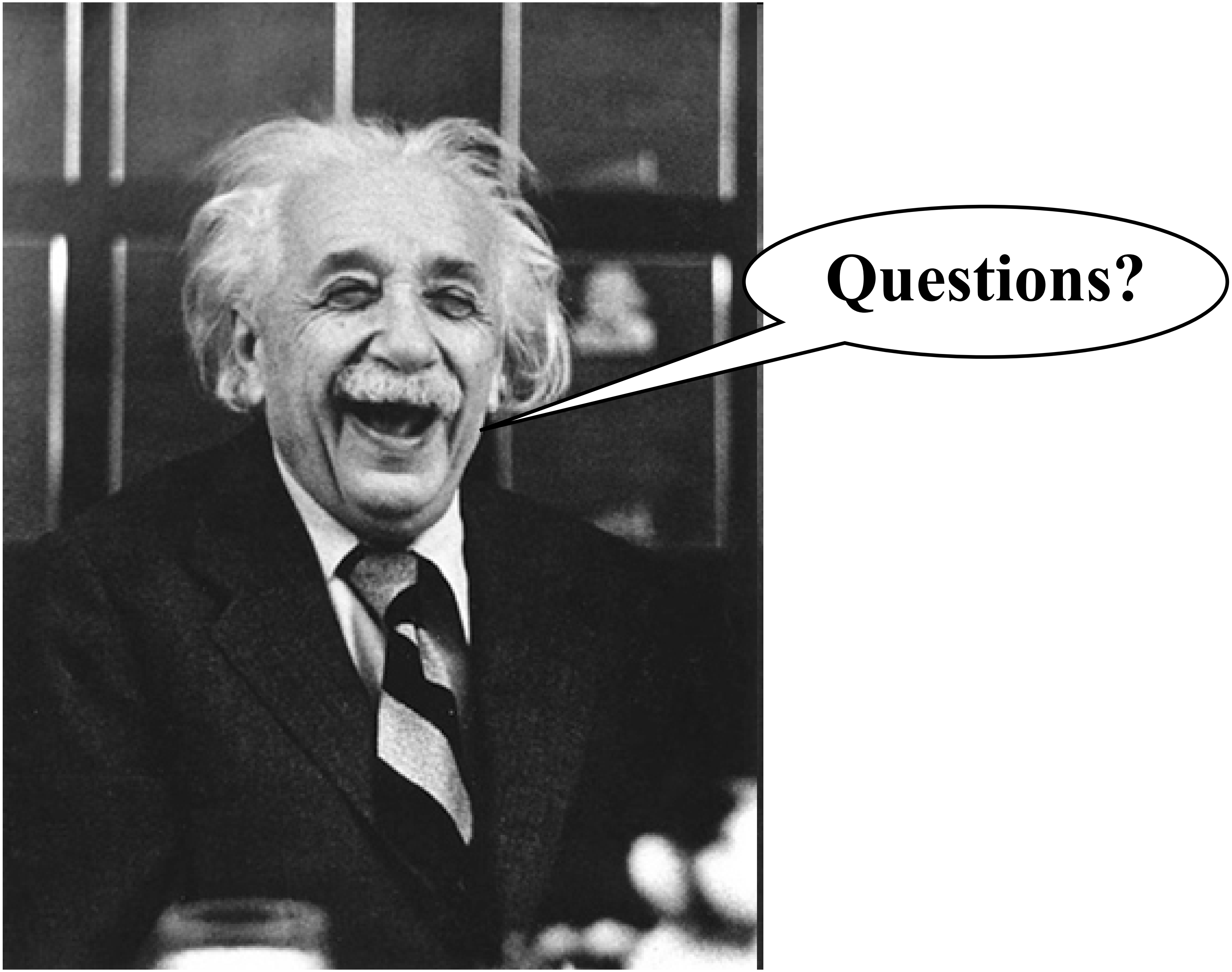
Temperature Rise During Grinding



One Example of the Results from a Water-Cooled Disc-Style Grinder



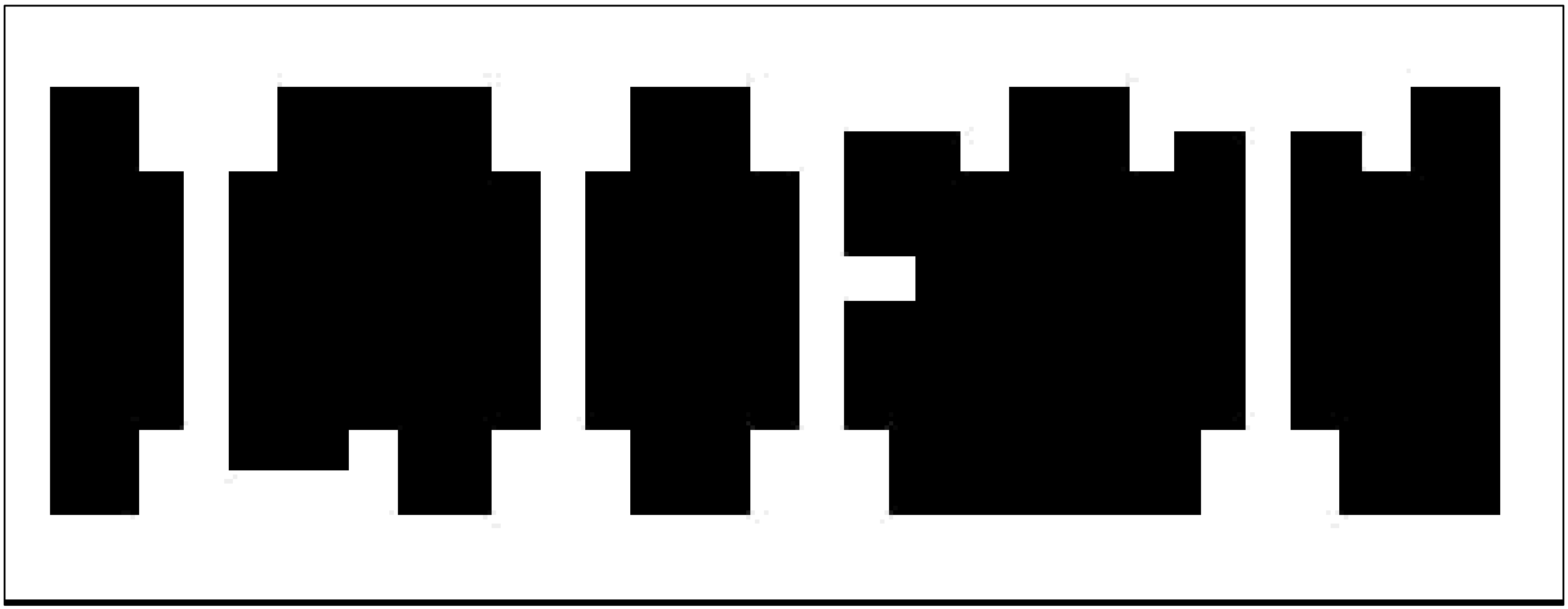
Model GPX.WCI (Water-Cooling Integrated)
Disc-Style Coffee Grinder


Questions?

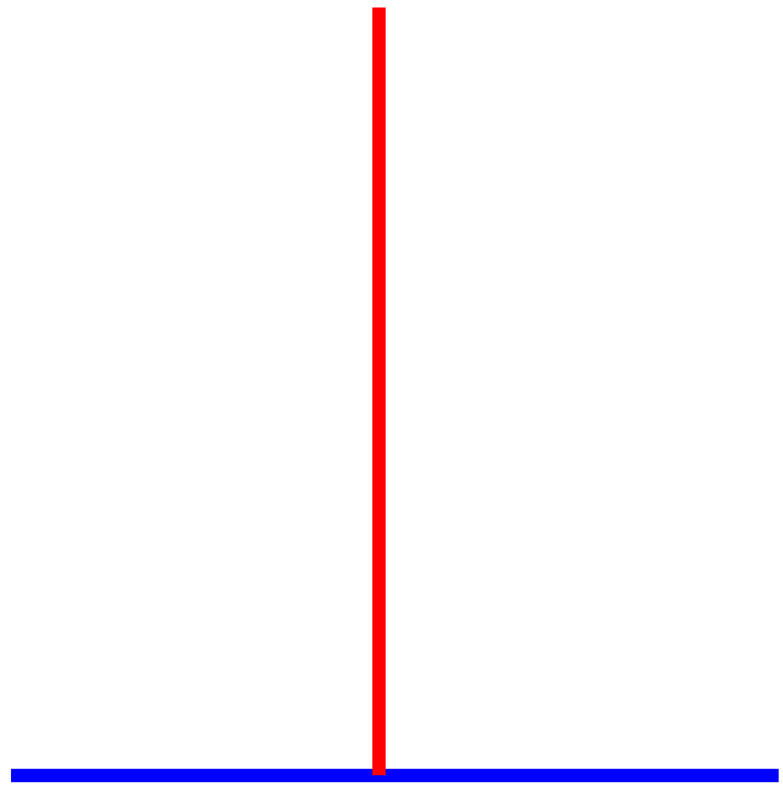
Is Evaluating Ground Coffee "By Eye" Reliable?

What do you see?

What do you see?



Which Line is Longer?



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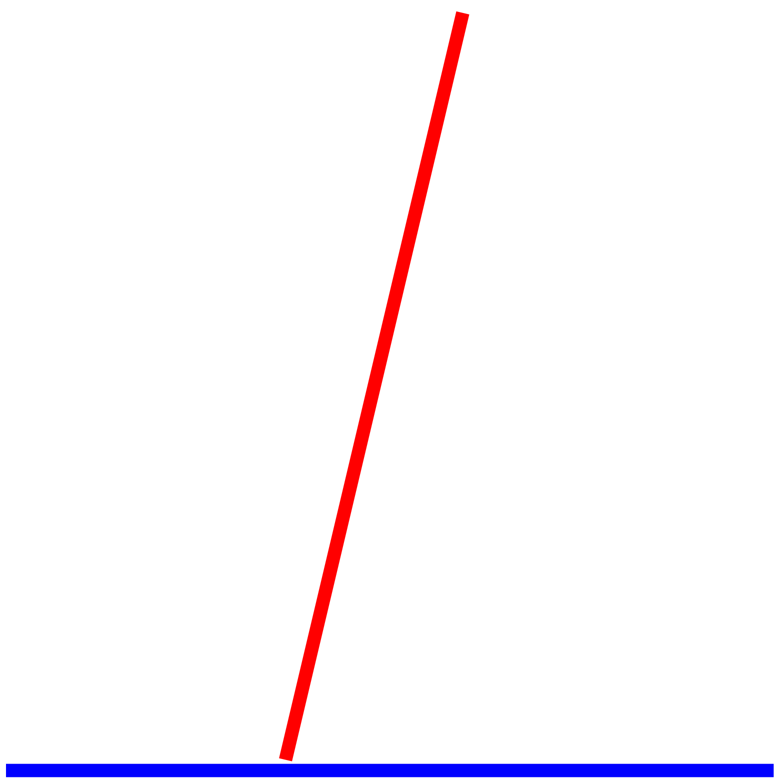

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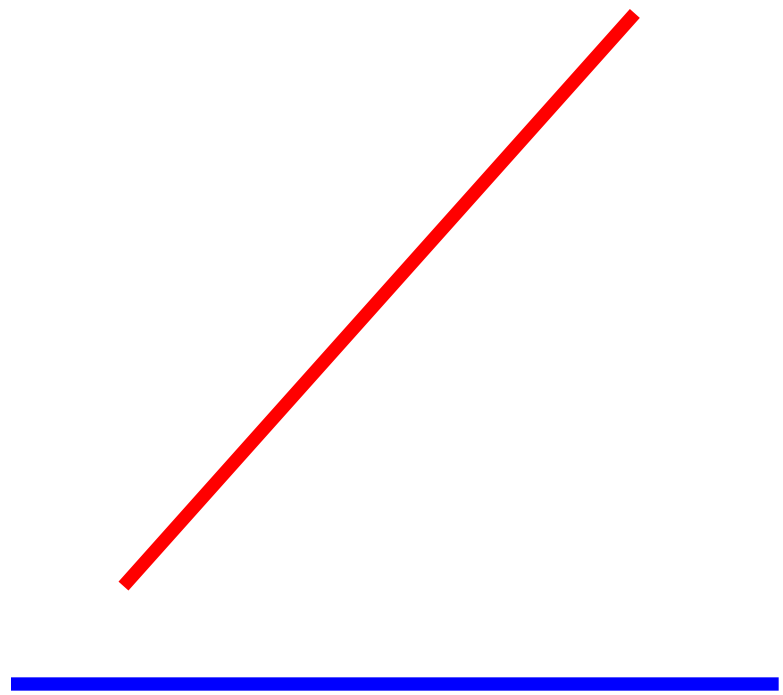

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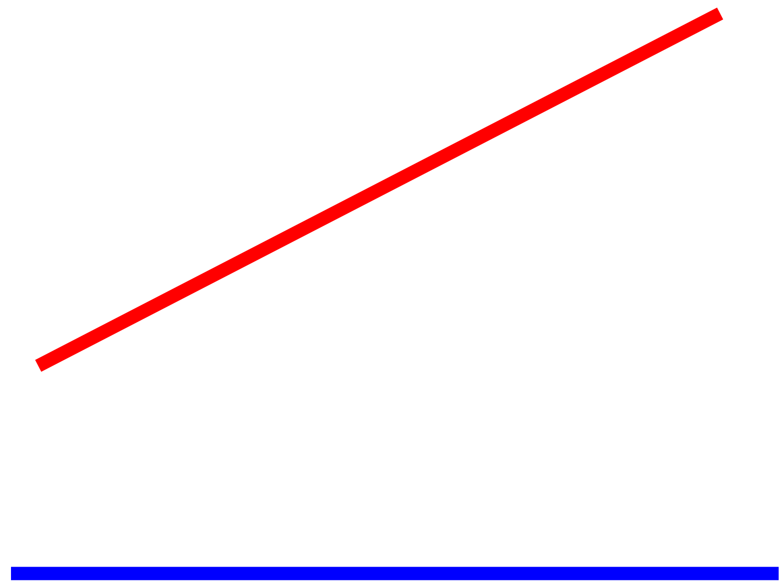
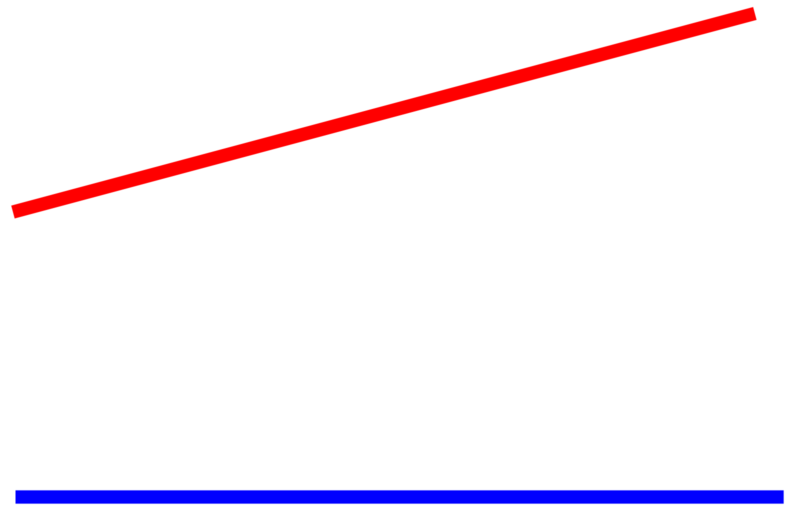
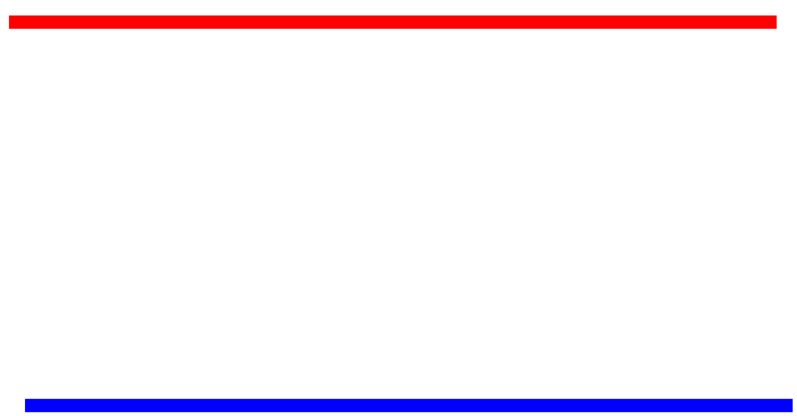


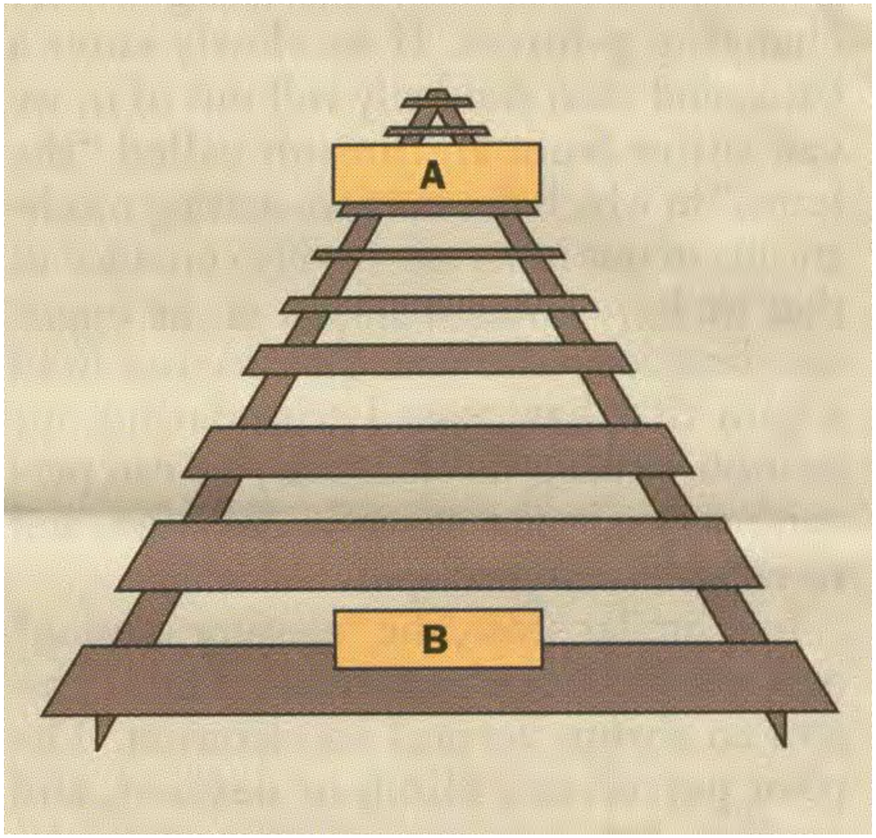
Which Line is Longer?



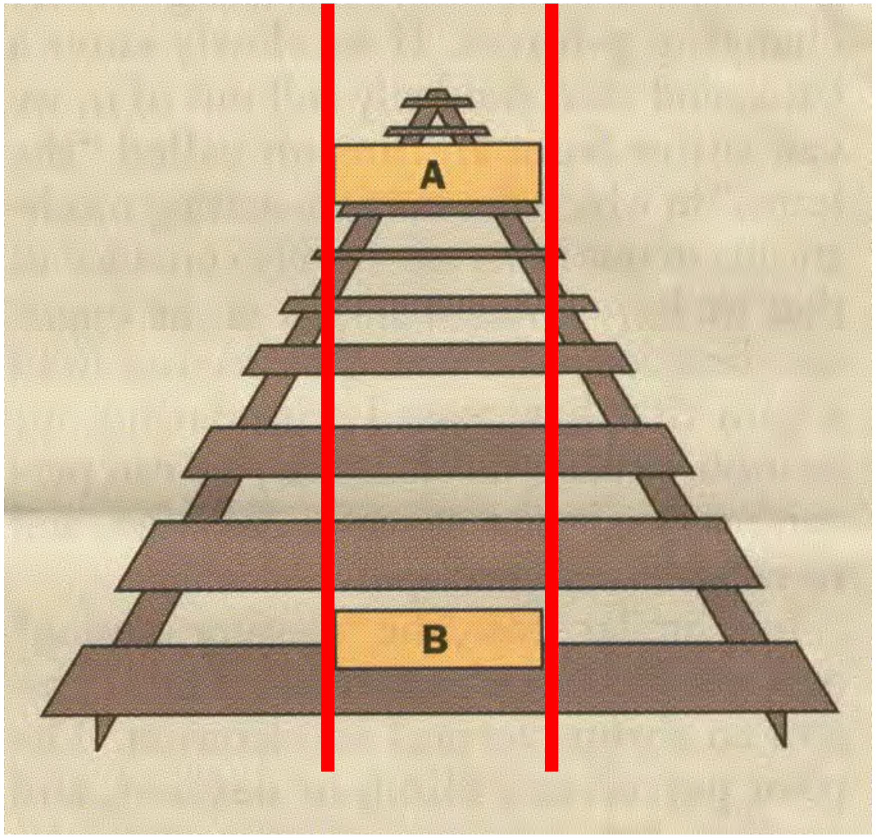
They’re the same length.



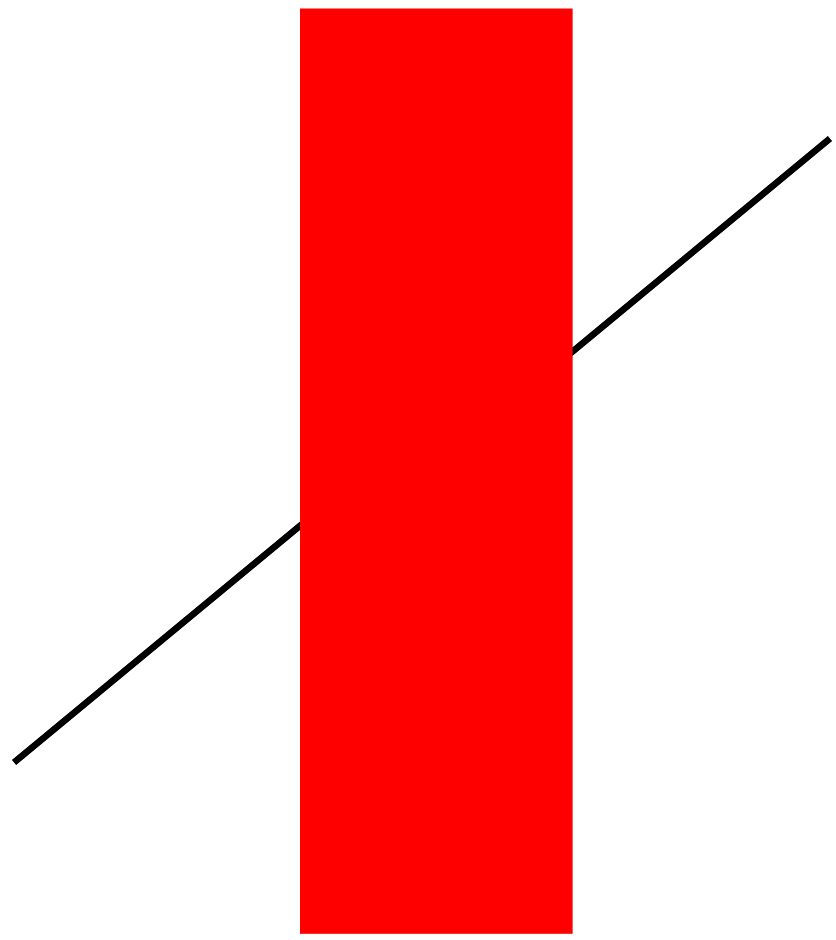
Which box is bigger?



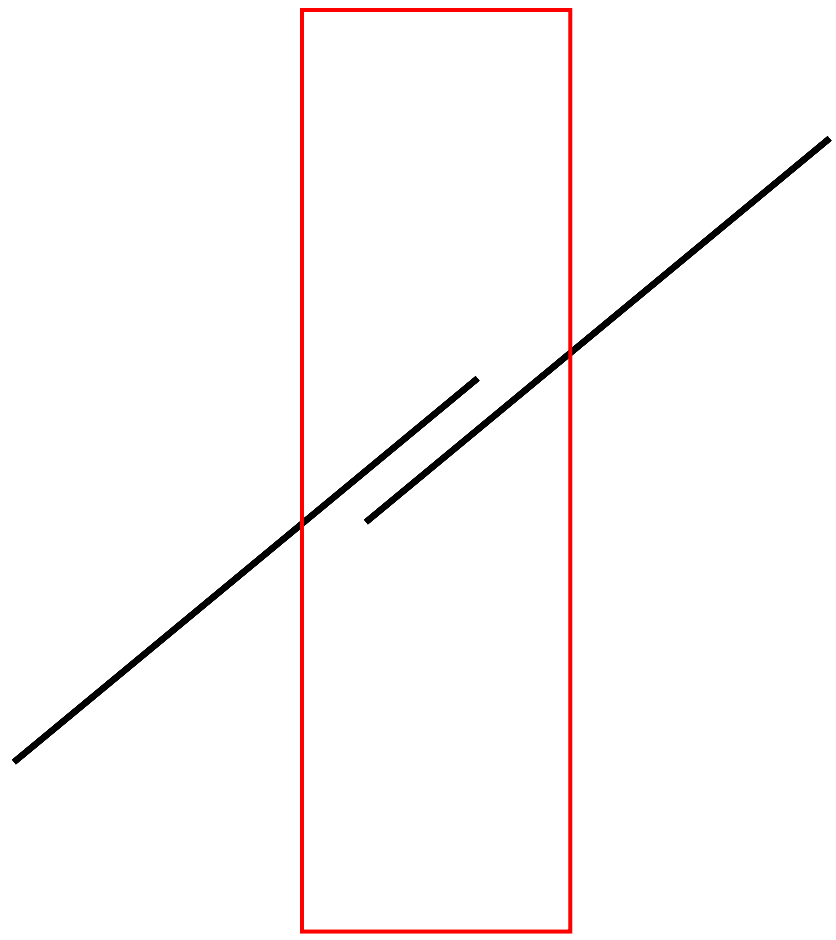
They’re both the same size.



Is this line straight?



Nope.



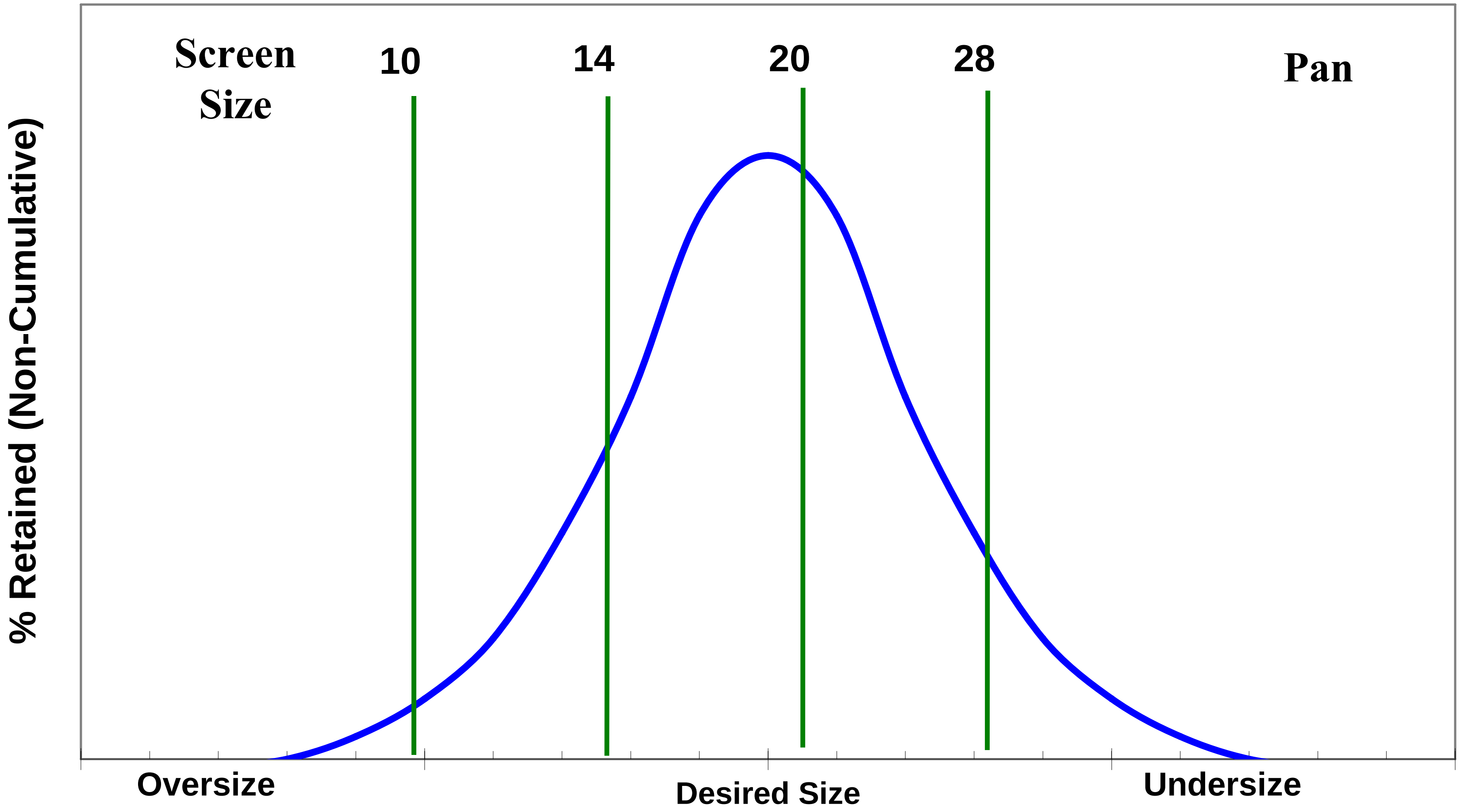
Which grind is smaller?

This one.

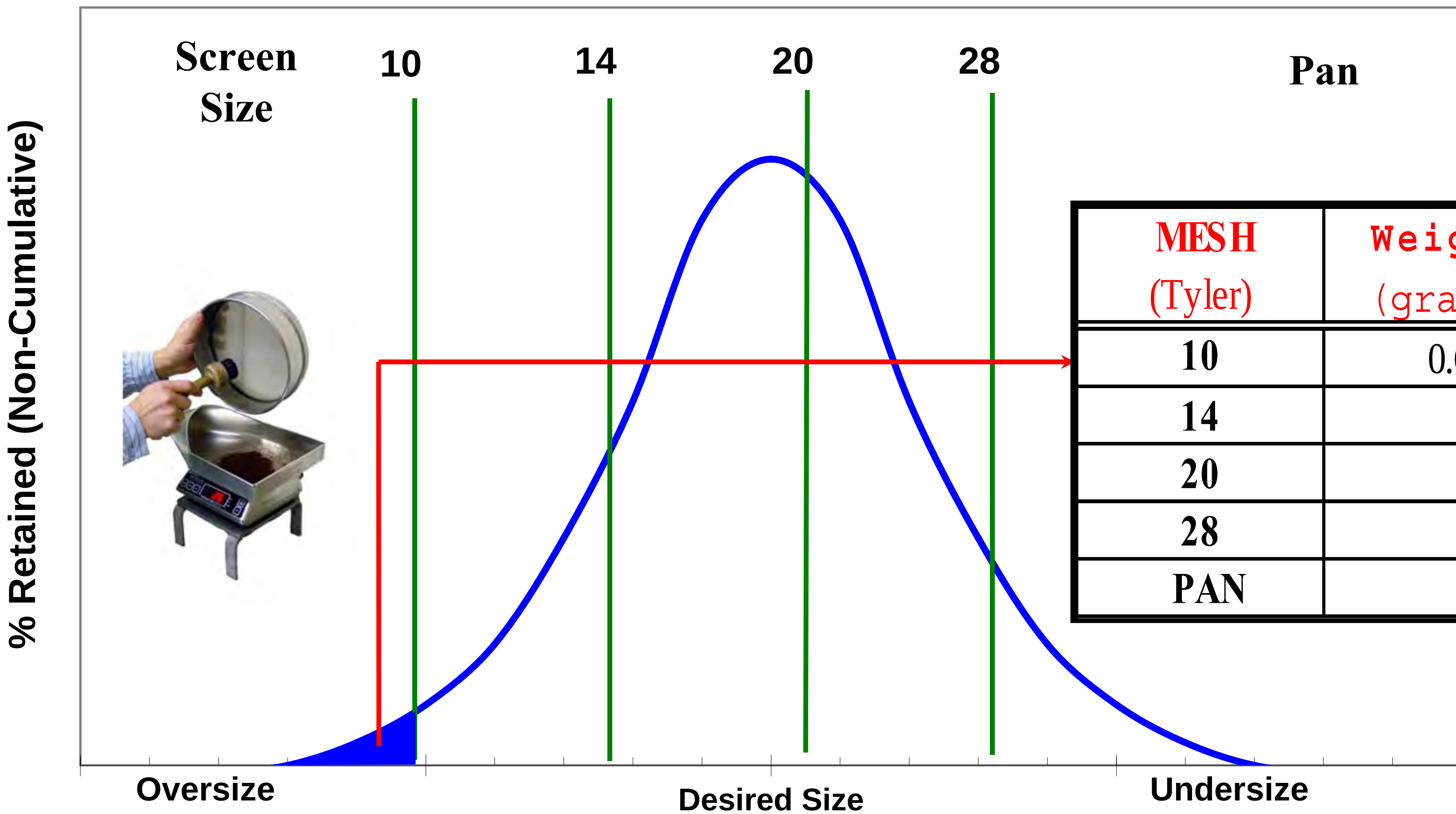
Analyzing and Testing Ground Coffee

The Ro-Tap Method

The Ro-Tap Method

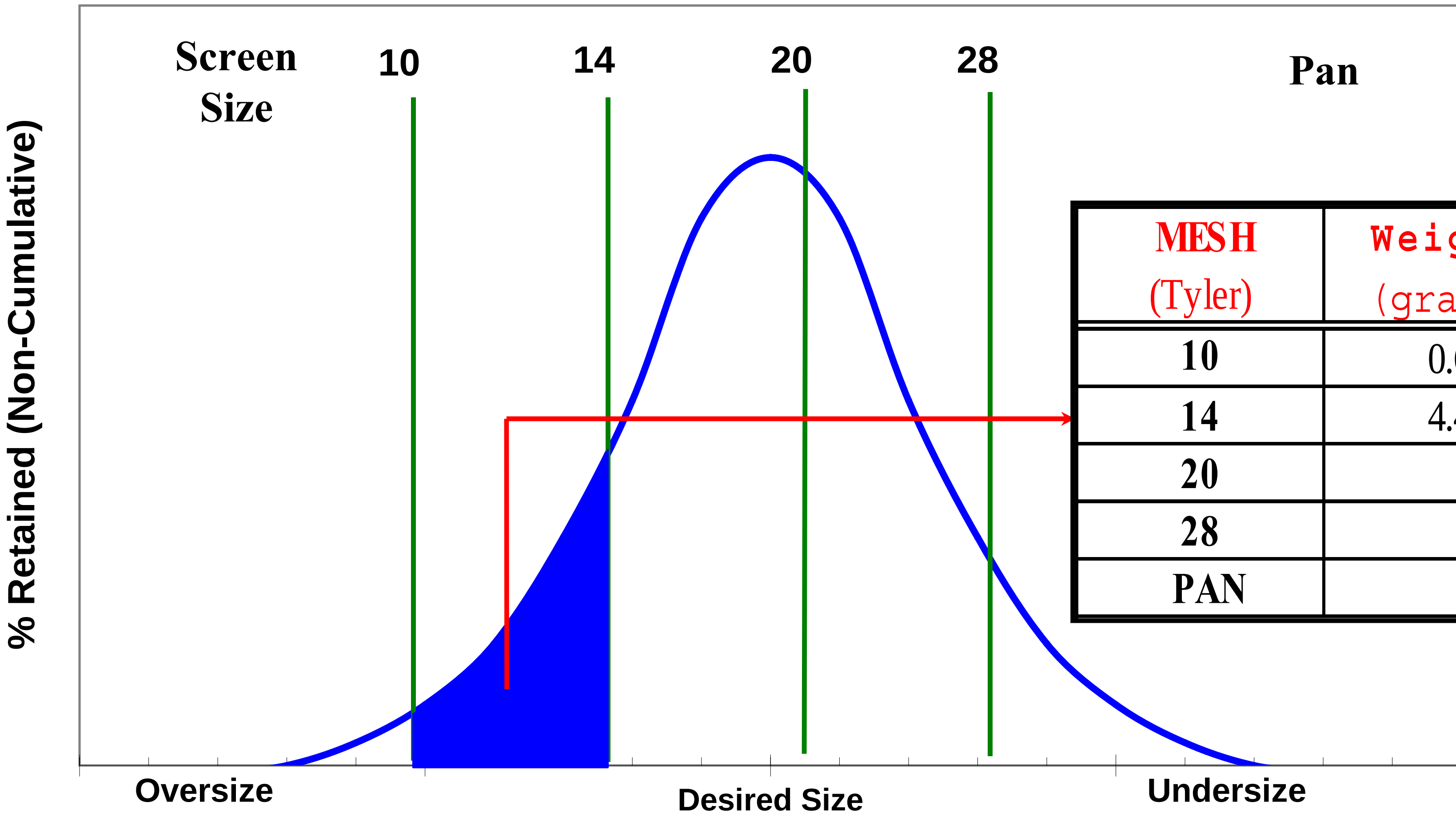


The Ro-Tap Method



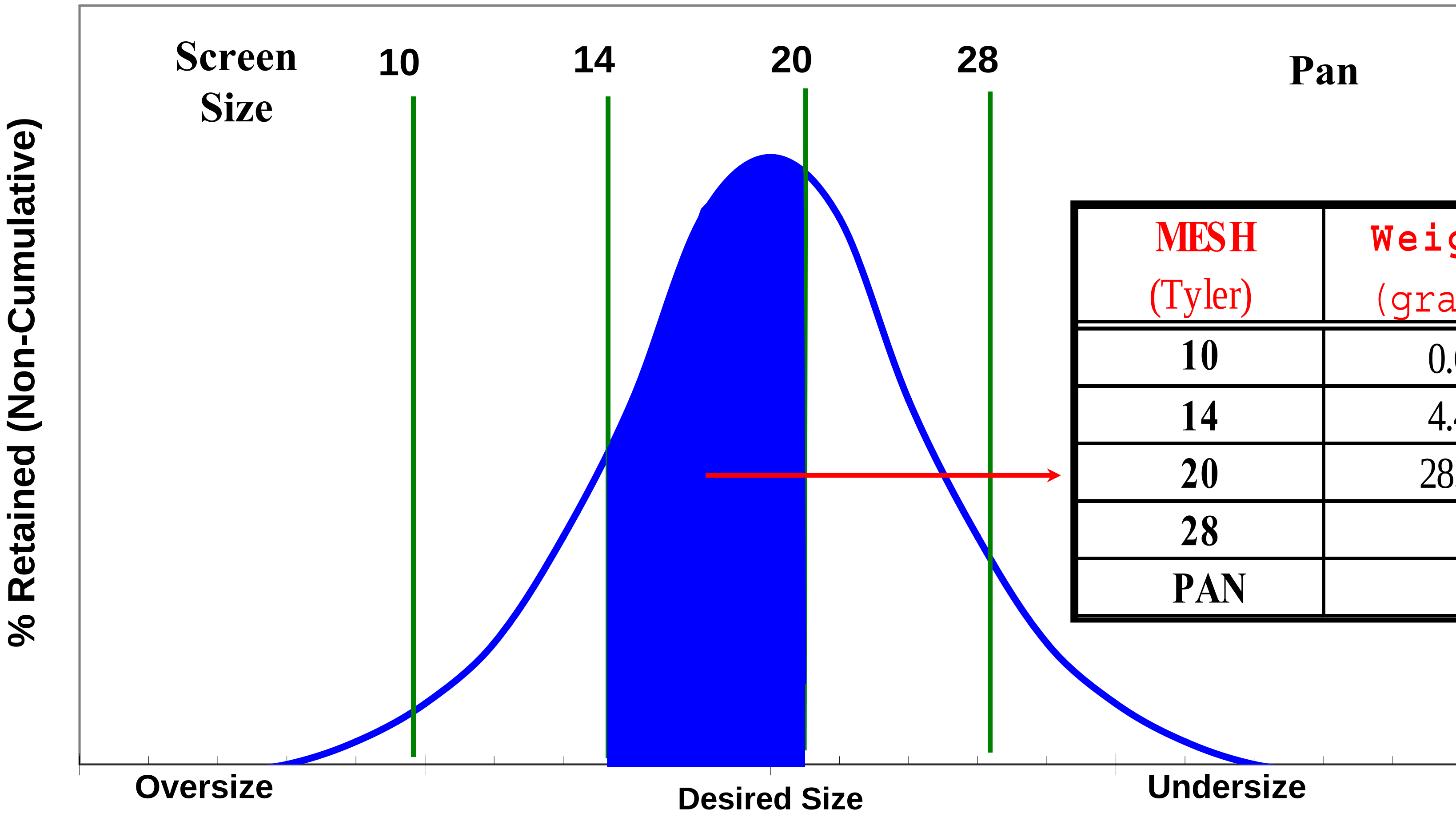
MESH (Tyler)	Weight (grams)
10	0.6
14	
20	
28	
PAN	

The Ro-Tap Method



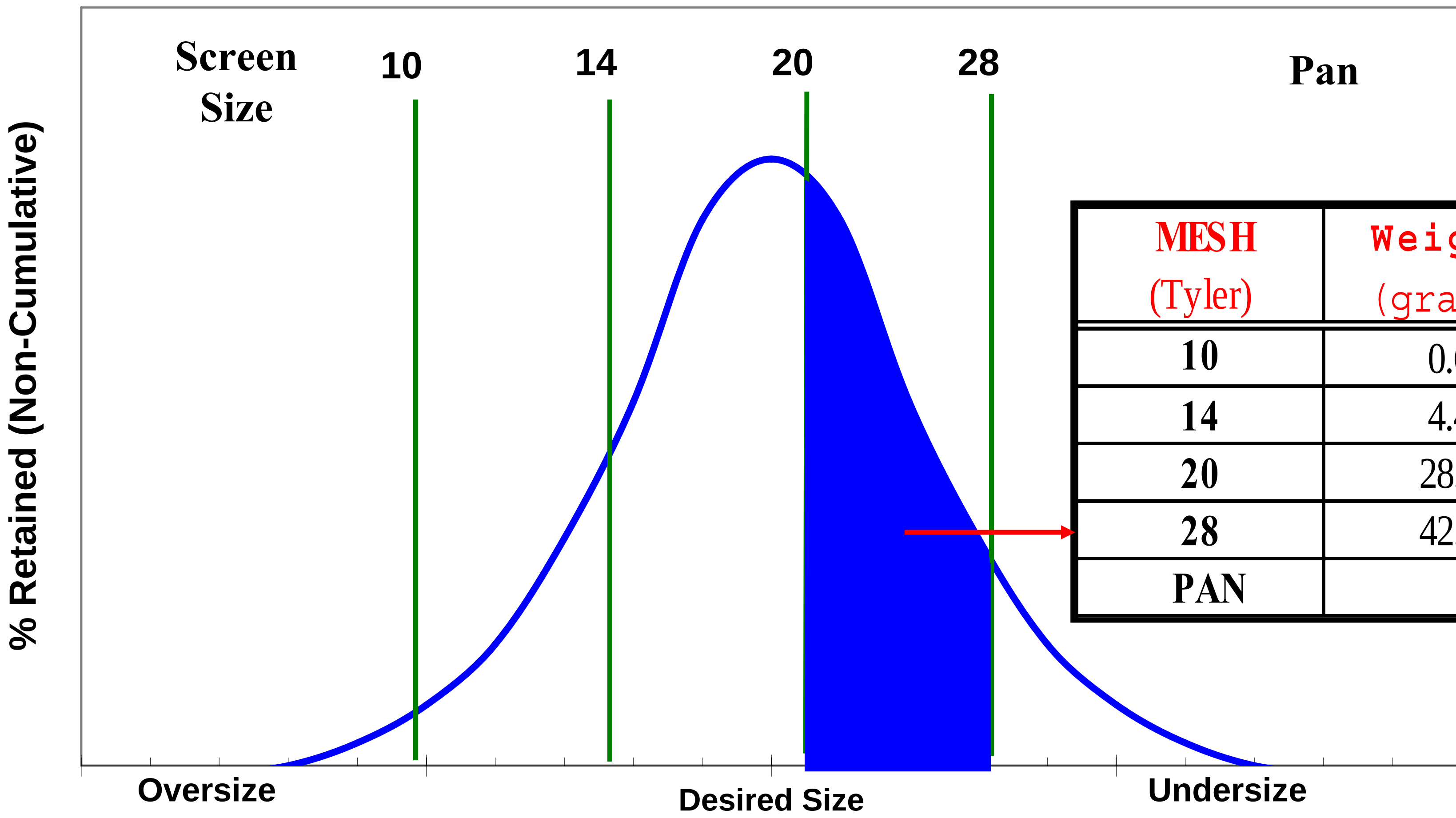
MESH (Tyler)	Weight (grams)
10	0.6
14	4.4
20	
28	
PAN	

The Ro-Tap Method



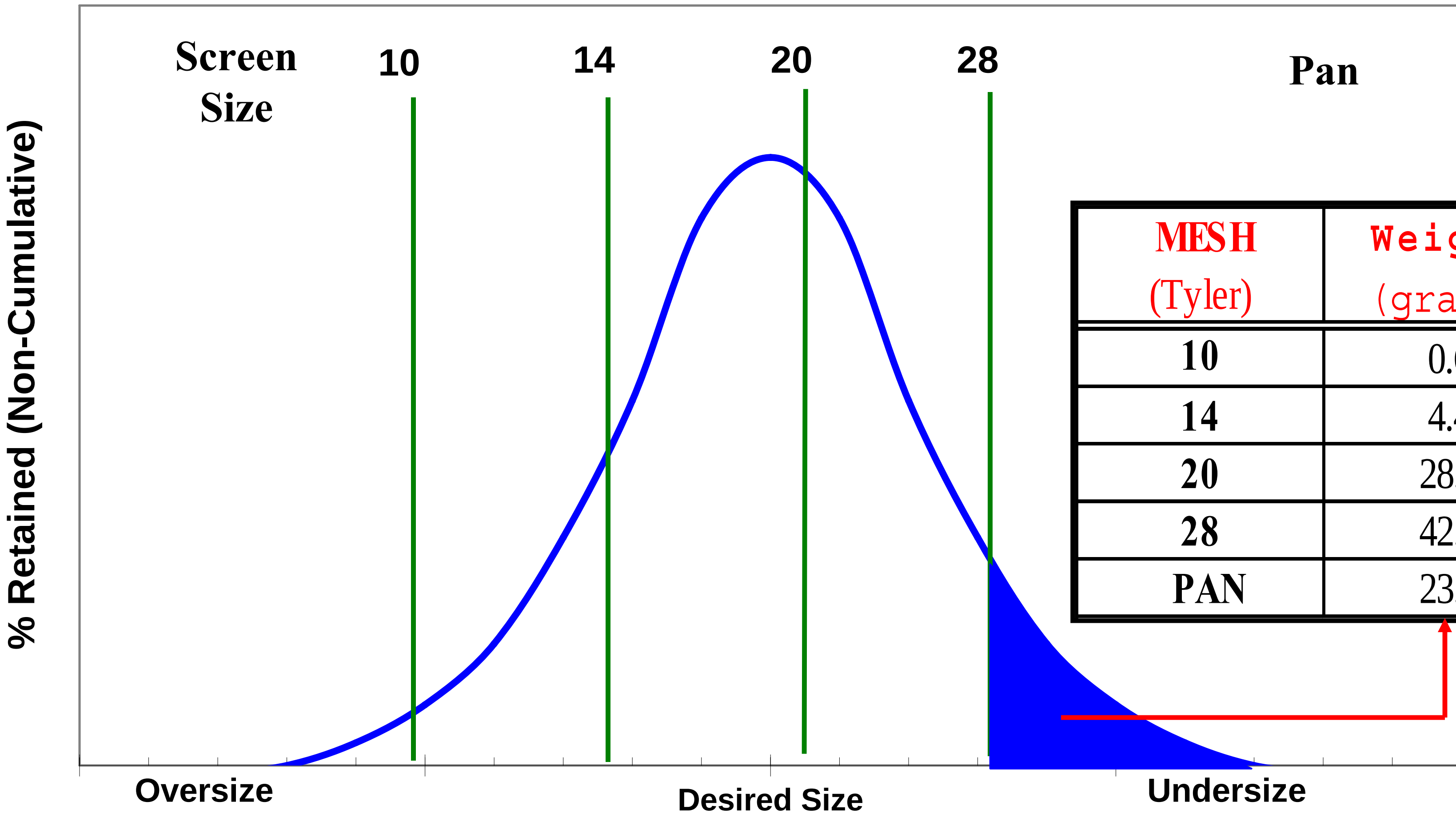
MESH (Tyler)	Weight (grams)
10	0.6
14	4.4
20	28.9
28	
PAN	

The Ro-Tap Method



MESH (Tyler)	Weight (grams)
10	0.6
14	4.4
20	28.9
28	42.2
PAN	

The Ro-Tap Method



MESH (Tyler)	Weight (grams)
10	0.6
14	4.4
20	28.9
28	42.2
PAN	23.9

Ro-Tap Calculation

TEST #	1	
DATE:	25-Apr-03	
NOTES	Fine Drip Grind Sample	
MESH (Tyler)	grams	%
10	0.6	0.6%
14	4.4	4.4%
20	28.9	28.9%
28	42.2	42.2%
PAN	23.9	23.9%

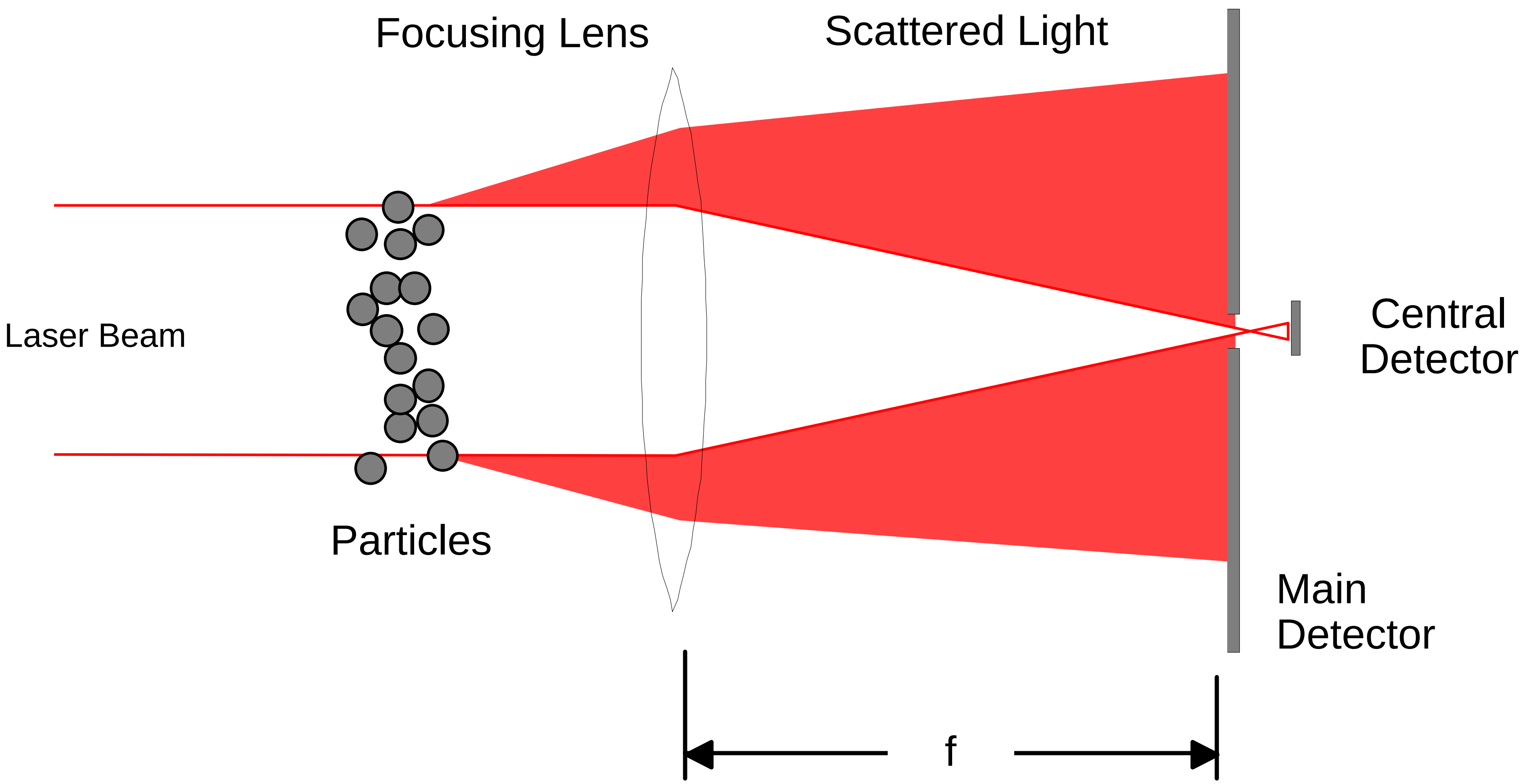
Ro-Tap Graph

	10	14	20	28	PAN
Drip Grind	0.6%	4.4%	28.9%	42.2%	23.9%

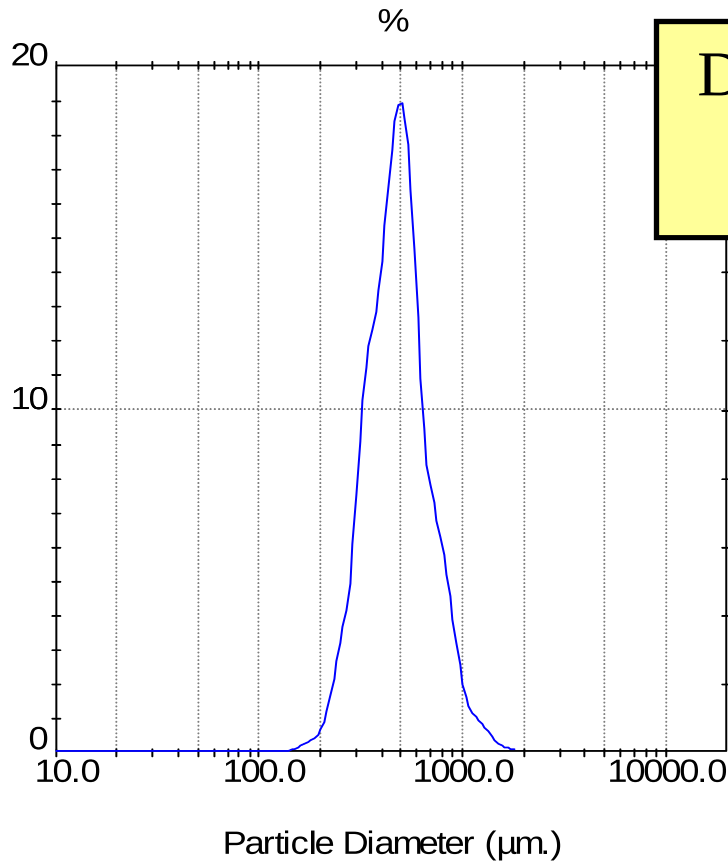
Screen Size (Tyler Mesh)

Laser Particle Size Analysis

Principle of Laser Particle Size Analysis



Laser Analysis Results



D(v,0.1) = 306 um

10% Percentile

D(v,0.9) = 772 um

90% Percentile

D(v,0.5) = 478 um

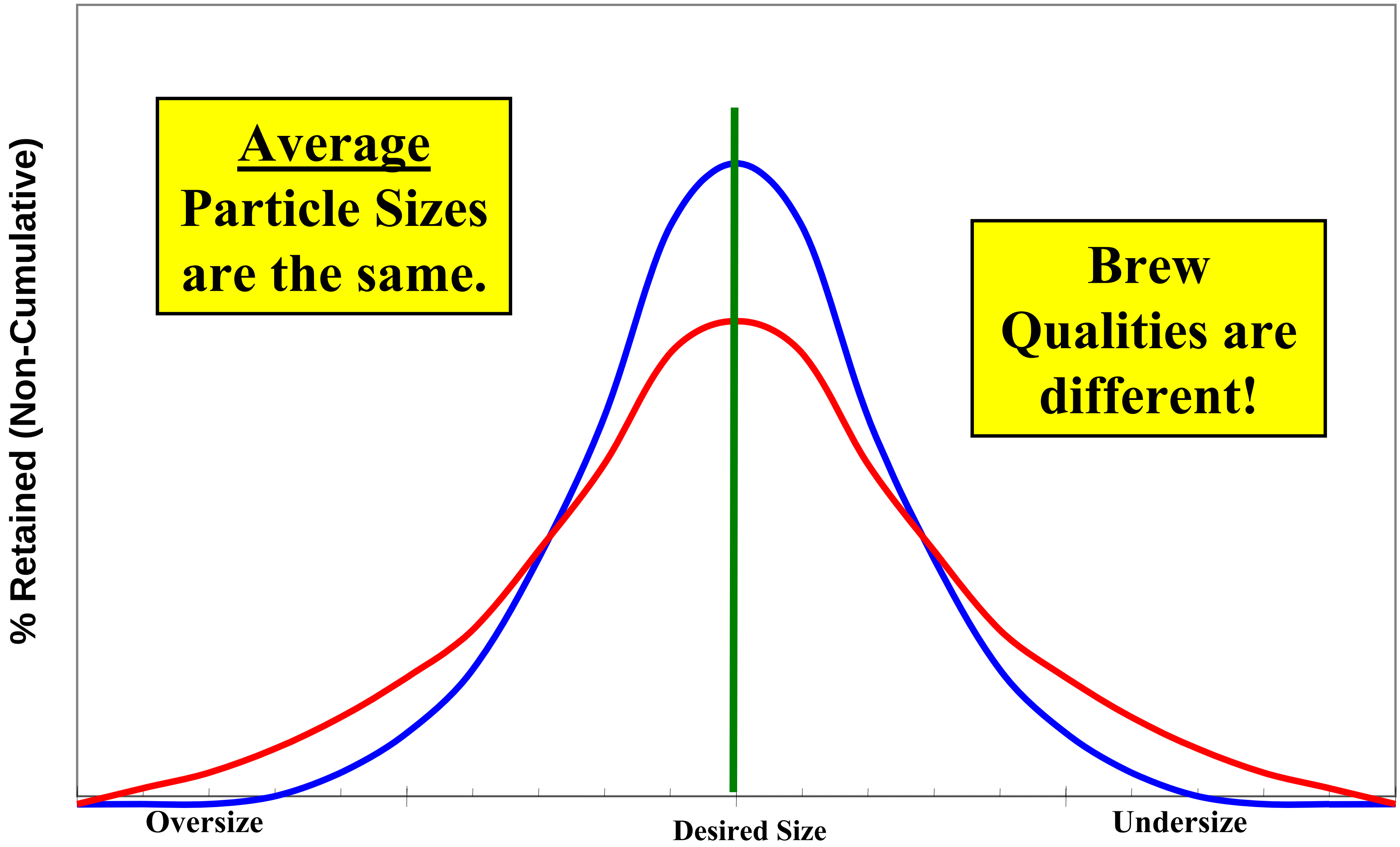
Average Particle Size

Result: Sieve ASTM E11:61 Table

Conc. = 0.30 | S.A.= 0.0144 m^2/g
Distribution: Vo | [3, 2] = 416.72 um
D(v, 0.1) = 30 | , 0.9) = 772.27 um
Span = 9.760E

Mesh No	Ape u			Mesh No		Volume In%	Volume Below%
10	2000		100.00	60	250		3.44
12	1680	0.14	99.86	70	210	2.25	1.19
14	1410	0.31	99.55	80	177	0.59	0.60
16	1190	0.83	98.72	100	149	0.26	0.34
18	1000	1.50	97.22	120	125	0.09	0.25
20	841	3.99	93.23	140	105	0.05	0.20
25	707	7.26	85.97	170	88	0.03	0.17
30	595	10.70	75.27	200	74	0.02	0.16
35	500	19.58	55.69	230	63	0.01	0.15
40	420	20.47	35.22	270	53	0.01	0.14
45	354	14.96	20.27	325	44	0.01	0.13
50	297	11.80	8.47	400	37	0.01	0.12
60	250	5.03	3.44				

Two Different Fine Grinds

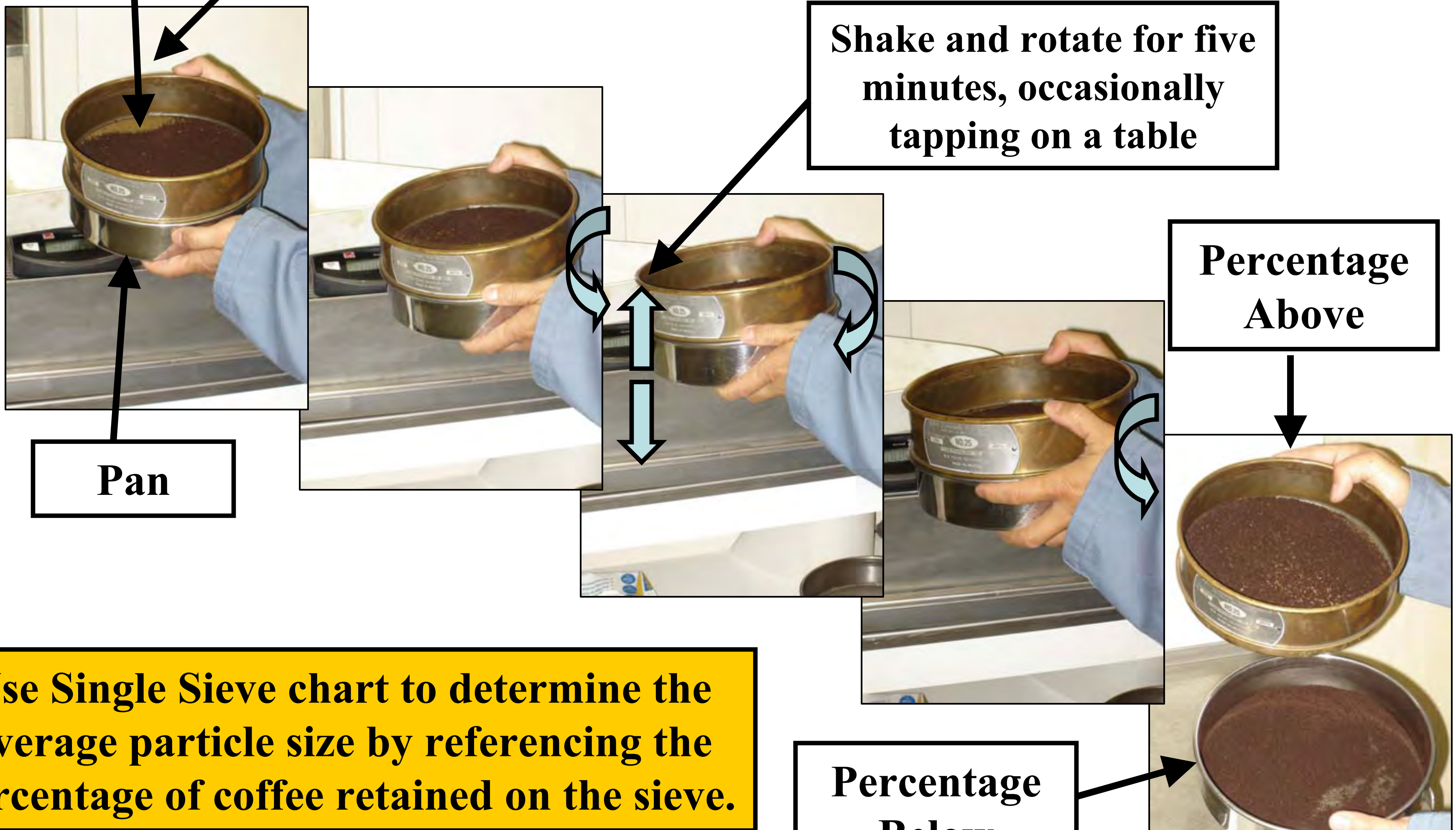


The MPE Single Sieve "Hand" Ro-Tap Method

Use about 50 grams

24 mesh/700 um screen size

Shake and rotate for five minutes, occasionally tapping on a table



Percentage Above

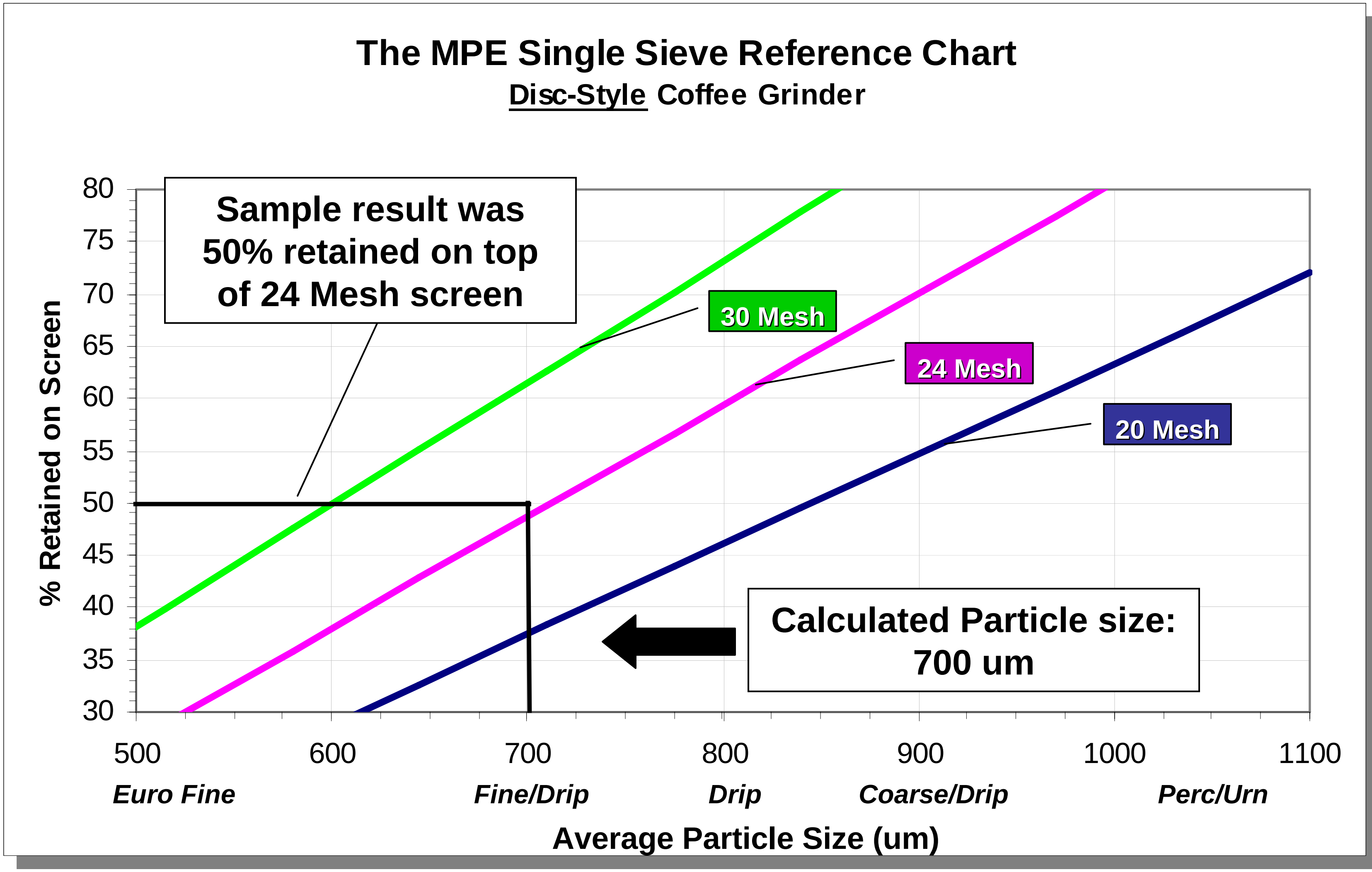
Pan

Percentage Below

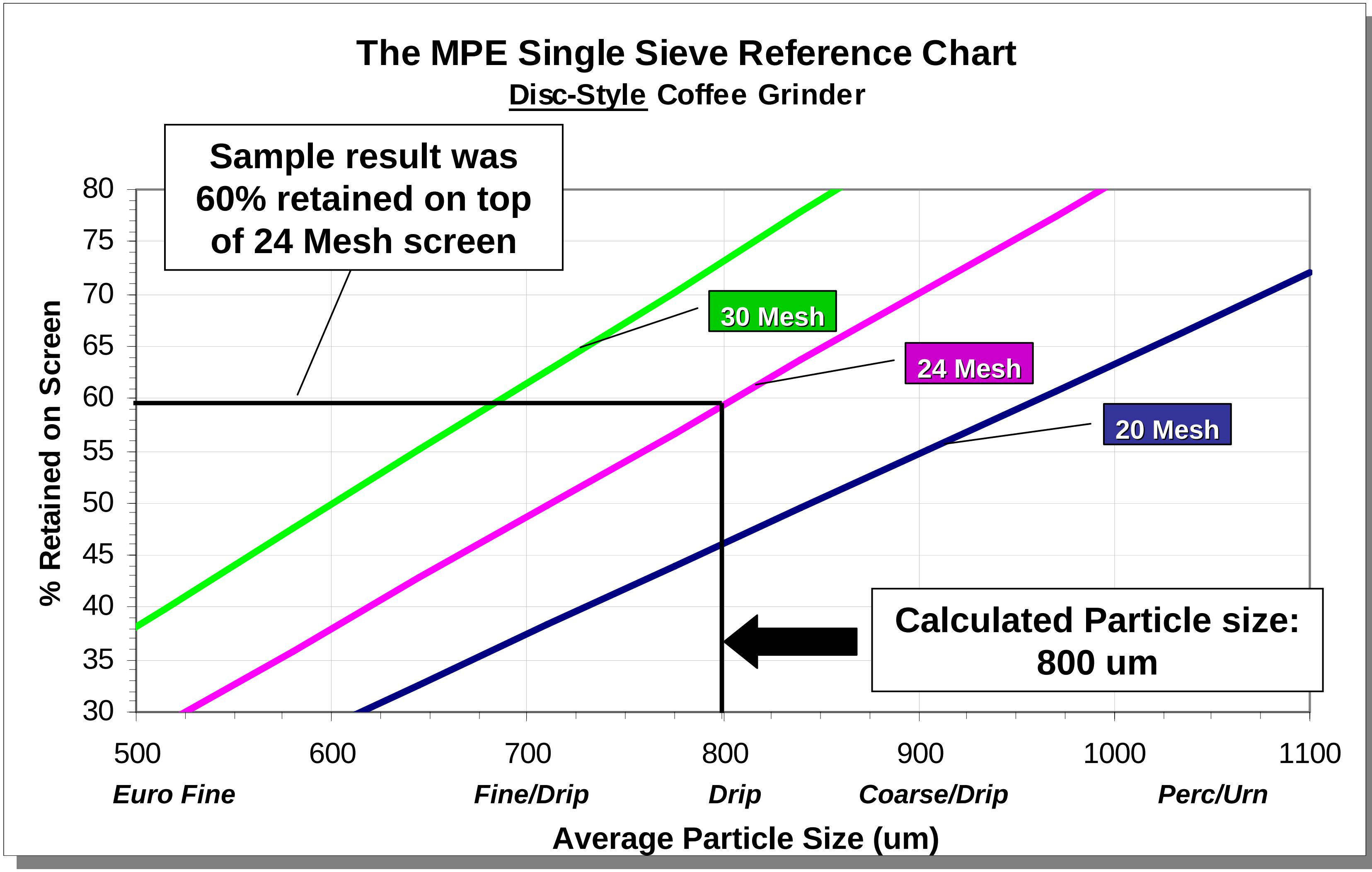
Use Single Sieve chart to determine the average particle size by referencing the percentage of coffee retained on the sieve.

The MPE Single Sieve “Hand” Ro-Tap Method

Weigh your results using a portable scale.



Note: Use Roller-Style Reference Chart for Roller-Style Coffee Grind Results



Note: Use Roller-Style Reference Chart for Roller-Style Coffee Grind Results

Size Conversion and Grind Reference Table

SIZE CONVERSION AND GRIND REFERENCE TABLE				
U.S. Mesh	Tyler Mesh	Inches	Microns	Grind*
4	4	0.1850	4699	
5	5	0.1560	3962	
6	6	0.1310	3327	
7	7	0.1100	2794	
8	8	0.0930	2362	
10	9	0.0780	1981	Extract Grinds and French Press
12	10	0.0650	1651	
35	32	0.0195	495	Espresso Coarse
40	35	0.0164	417	Vending
45	42	0.0138	351	Espresso Fine
50	48	0.0116	295	
60	60	0.0097	246	
70	65	0.0082	208	
80	80	0.0069	175	Coarse Turkish
100	100	0.0058	147	
120	115	0.0049	124	Medium Turkish
140	150	0.0041	104	
170	170	0.0035	89	Fine Turkish
200	200	0.0029	74	
230	250	0.0024	61	
270	270	0.0021	53	
325	325	0.0017	43	
400	400	0.0015	38	
Modern Process Equipment, Inc. Chicago, Illinois USA				
				*=Average Particle Size

SIZE CONVERSION AND GRIND REFERENCE TABLE				
U.S. Mesh	Tyler Mesh	Inches	Microns	Grind*
25	24	0.0276	701	Fine Grind

Available online at: www.mpechicago.com/coffee

Segregation

Once coffee is ground, care must be taken so that the particles don’t “declassify” between the grinder and the package, pod or other delivery container.

Segregation

Segregation Video

Courtesy of Jenike and Johanson, Inc.

Espresso and Single-Cup Serving methods are the toughest grinds to achieve!

Brewer Examples

Flavia

Flavia Filter Pack

Keurig

Keurig K Cup

Tassimo

Tassimo T-Discs

Filter-Type Packages

… or shaped like these

Pod vs. Fresh Brew
Performance Comparison

Brewing Dynamics	1 Pod/8 oz. cup	Equivalent Coffee Pack for 64 oz. Brew	Ratio
Coffee Weight	9 grams	3.75 oz.	**1/12th the weight**
Water Pressure (psi)	10 – 70	Gravity: 0.1 – 0.5	
Brew Time	10 – 15 sec.	3 – 6 min.	
Grind Size (microns)	400 - 600	800 – 900	

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Brew Time	10 – 15 sec.	3 – 6 min.	**1/20th the time**
Grind Size (microns)	400 - 600	800 – 900	**1/2 the grind size**

A pod grind is one of the most technical and <u>challenging</u> grinds, yet is typically produced on the most basic, limited grinder as a matter of convenience.

The grind must be the <u>correct size</u> and <u>uniformity</u> to produce a comparable coffee brew!

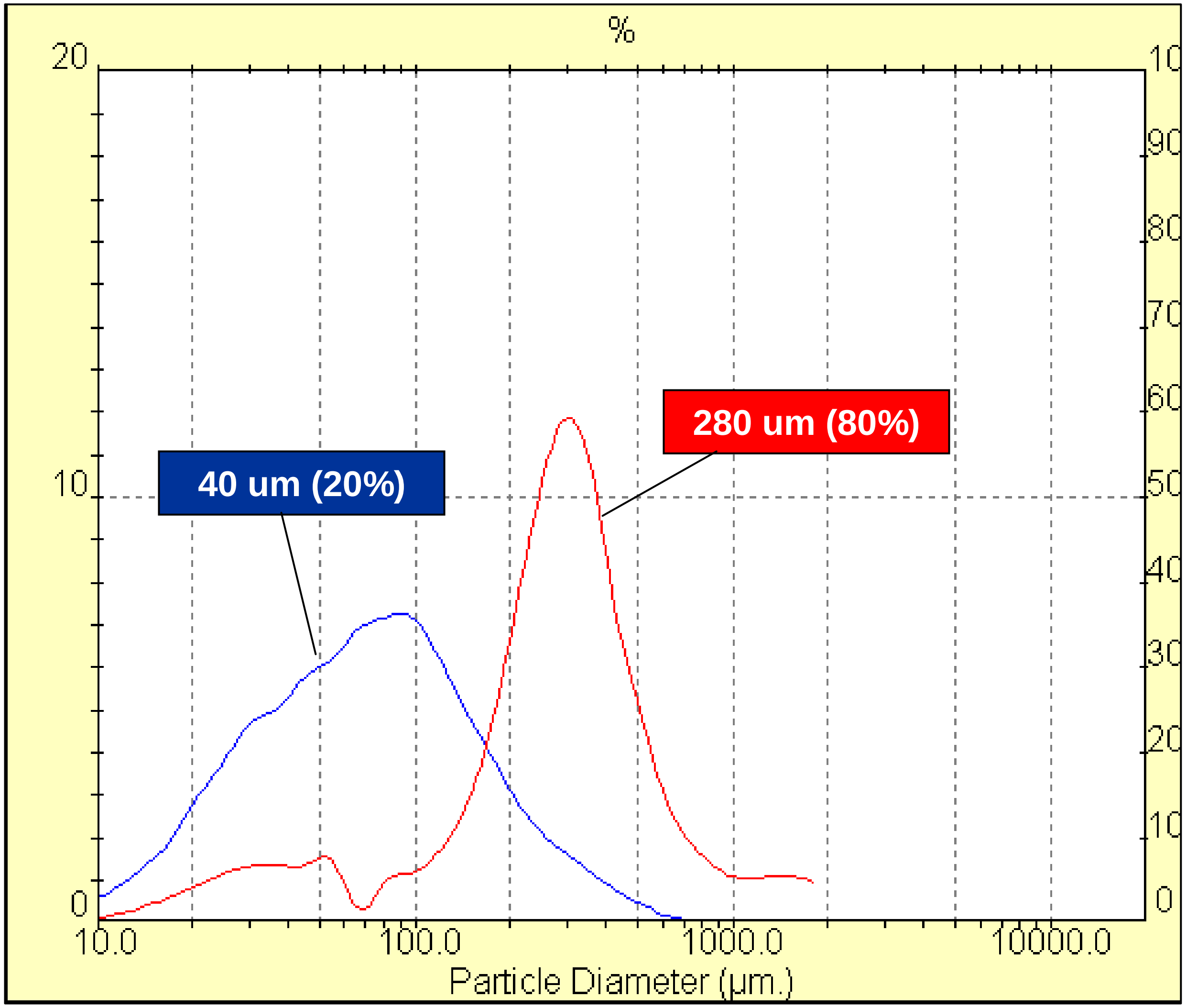
Now let's take a closer look at Espresso Grinding:

Two apparently contradictory needs must be satisfied to prepare a good cup of espresso:

1) On the one hand, a short percolation time is required;
2) On the other hand, a high concentration of soluble solids must be reached.

… Both requirements can only be attained if a close contact between solid particles and extraction water can be achieved.

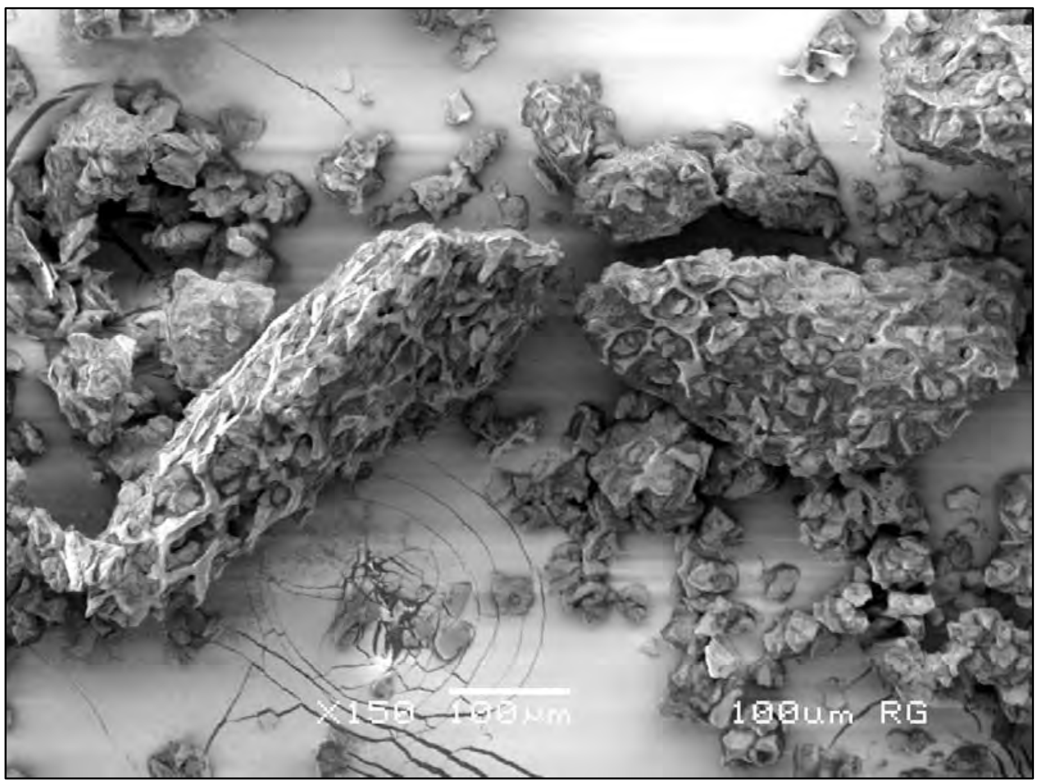
Thus, espresso percolation needs a plurimodal particle size distribution, where the finer particles enhance the exposed extraction surface (chemical need) and the coarser ones allow the water flow (physical need).



Let’s look at an espresso particle distribution using an electron microscope.

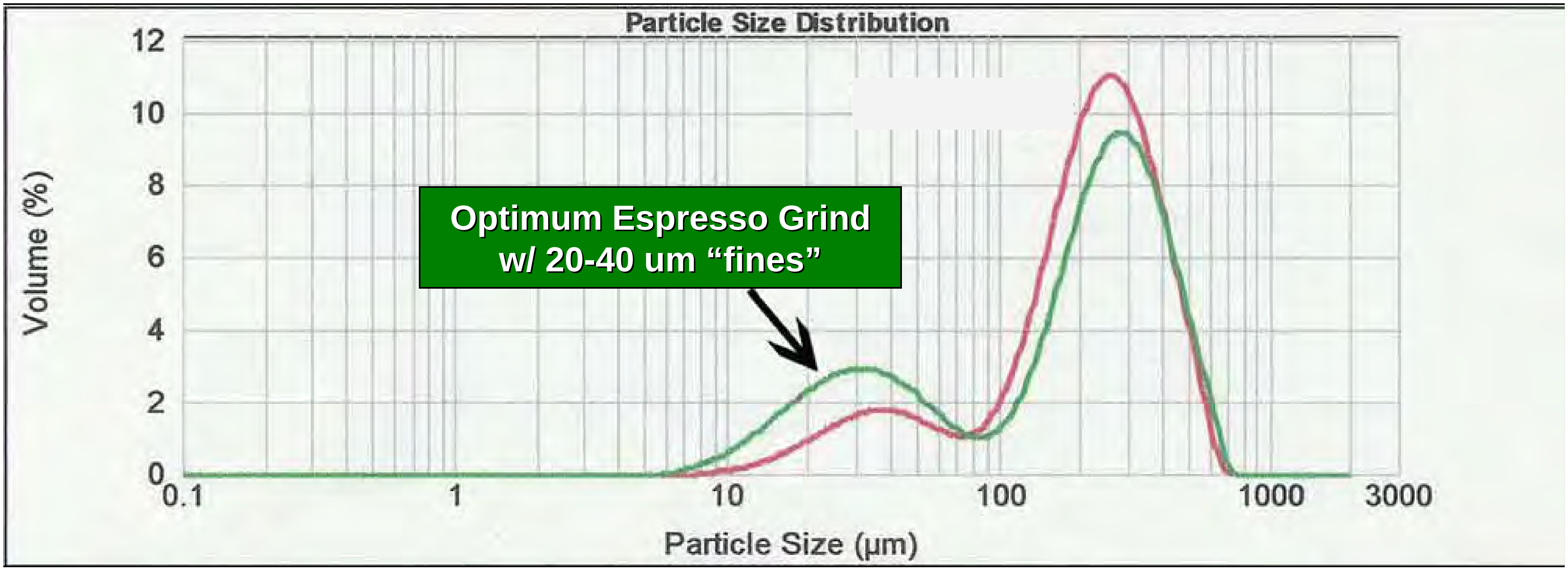
Upon further magnification, we can see the cellular structure and hexagonal structure in more detail, as well as the “fines” which are an essential and integral part of espresso grinding.

We can also see the rupture of the cellular walls, which are 30 um in diameter, which is the same size as the “superfines” that are a required element in espresso grinding.

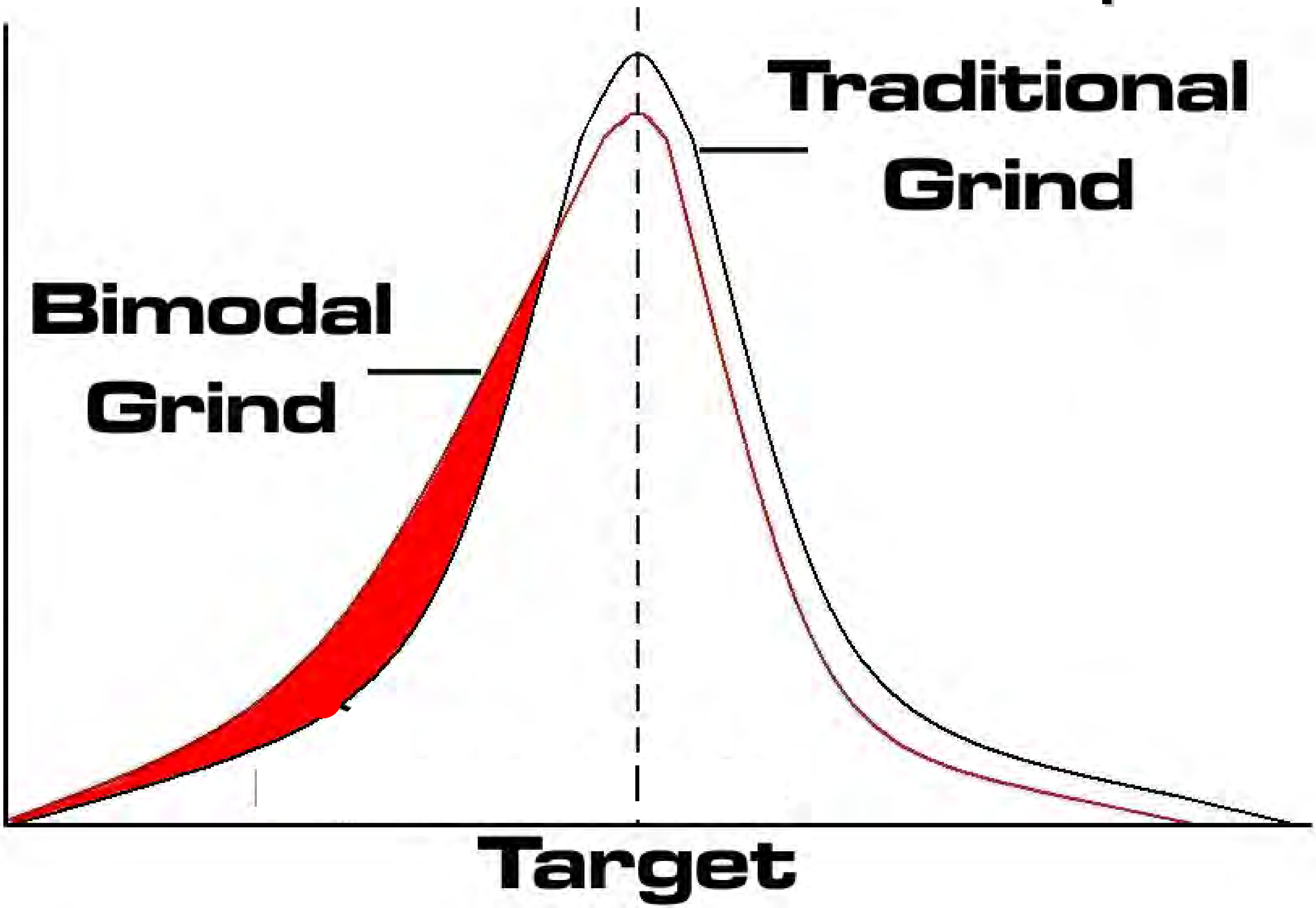


Ideal Espresso Grinding

It is typically desirable to generate "fines" (20-40 um) when grinding for espresso to promote the <u>proper infusion</u>.



Basic Illustration of Bimodal/Plurimodal Concept



How do you determine the optimal grind for your application?

1) Use a grind reference document (SCAA, MPE, etc.) to determine the correct grind for your application or, alternatively:

2) Perform a grind test using the ro-tap, hand ro-tap or laser method to ensure that your actual grind matches your target.

3) In conjunction with the above, utilize a soluble solids tester* to establish:
   - Your brewed solids and;
   - Your desired grind to achieve or maintain those brewed solids.

   ** Either a hydrometer or soluble solids "Ultrameter" can be used for the above.*

Questions?

Enjoy the show!

The SPECIALTY COFFEE Event OF THE YEAR

SCAA's 22ND ANNUAL EXPOSITION

Anaheim, California

APRIL 15 – 18* 2010

*Symposium runs April 14-15, 2010