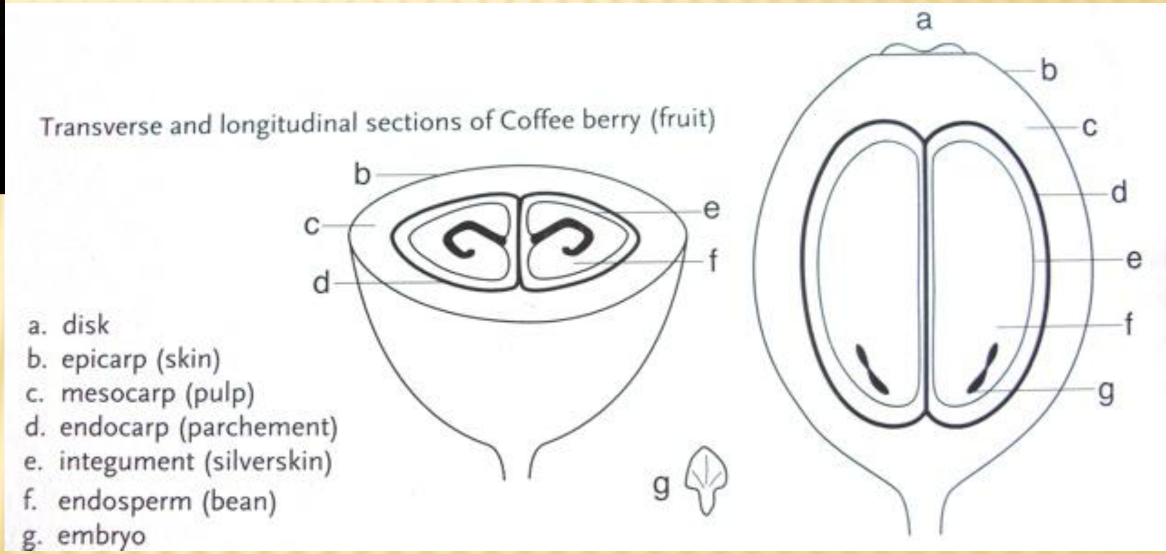
THE SCIENCE OF BREWING COFFEE

Kingdom:	Plantae
Division:	Magnoliophyta (Angiosperms)
(unranked):	Eudicots
Class:	Magnoliopsida
(unranked):	Asterids
Order:	Gentianales
Family:	Rubiaceae
Subfamily:	Ixoroideae
Tribe:	Coffeeae
Genus:	***Coffea***

Over 20 species, but only two of importance: *arabica* and *robusta*

THE COFFEA PLANT

http://en.wikipedia.org/wiki/Coffea



INSIDE THE BERRY

https://desertsuncoffee.wordpress.com/2011/10/13/the-life-cycle-of-coffee/
https://www.sweetmarias.com/Macro_Coffee_Images09/Images/11.jpg

WHERE COFFEA PLANTS ARE GROWN

http://www.coffeeforless.com/articles/coffee-articles/coffee-bean-growing-belt.html

EFFECT OF ALTITUDE ON TASTE

http://www.scribblerscoffee.com/flavor_effect_of_altitude

De-pulping

Drying

AFTER HARVESTING: PROCESSING

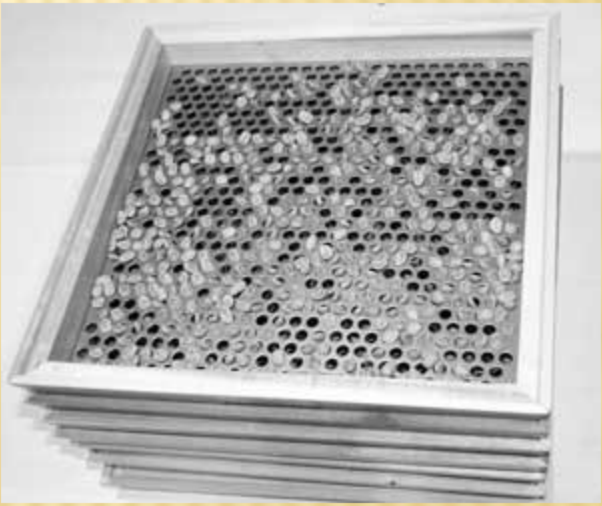
https://desertsuncoffee.wordpress.com/2010/12/29/journey-of-the-coffee-bean/
https://wideanglewords.files.wordpress.com/2010/02/coffee-drying.jpg

Parchment Removal

Grade = Bean size

For example, Grade 18 beans, also called AA, will pass through a sieve with 18/64" diameter holes, but are retained by the next smaller sieve with 16/64" diameter holes.

General correlation between bean size and flavour, but there are many exceptions.

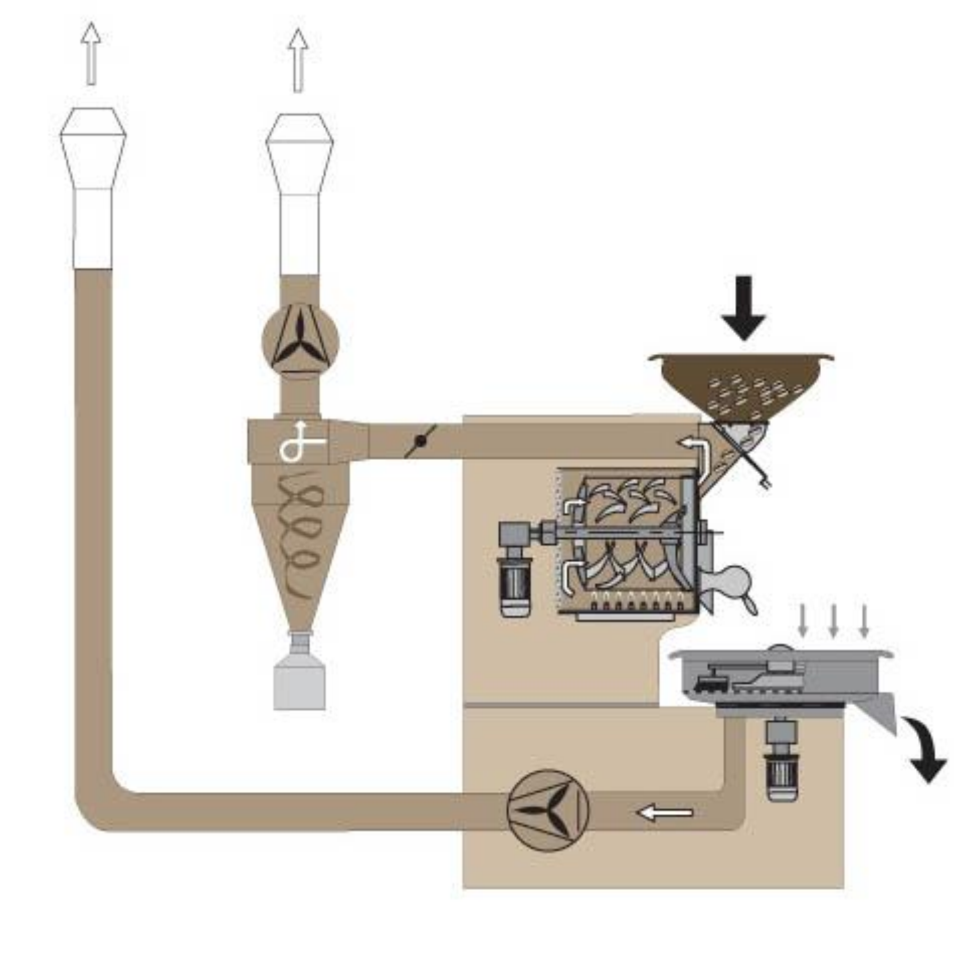


PARCHMENT REMOVAL, GRADING & SORTING

http://thevirtualbarandgrill.com/wordpress/wp-content/uploads/2014/02/IMG_1734.jpg
http://www.zecuppa.com/coffeeterms-bean-grading.htm

Table 2: Basic principles in modern roasting technology

Type	Characteristics
Rotating cylinder	Horizontal/vertical With/without perforated walls Direct heating by convective flow of hot gases Indirect heating by hot drum walls Batch-operated Continuously operated by an inner conveyer Gas temperatures: 400–550 °C Roasting times: 8.5–20 min
Bowl	Direct heating by convective flow of hot gases Continuously operated across the gas stream; rotating Gas temperatures: 480–550 °C Roasting times: 3–6 min
Fixed drum	Direct heating by convective flow of hot gases Batch operated Gas temperatures: 400–450 °C Roasting times: 3–6 min
Fluidized bed	Direct heating by fluidizing gas Batch operated Gas temperatures: 240–270 °C Roasting times: 5 min
Spouted bed	Direct heating by fluidizing gas Batch operated Fast roasting: Gas temperatures: 310–360 °C Roasting times: 1.5–6 min Slow roasting: Gas temperatures: 230 –275 °C Roasting times: 10–20 min
Swirling bed	Tangential gas inlet Spiral upward motion of the beans Direct heat transfer of a moved packed bed Gas temperatures: 280 °C Roasting times: 1.5–3 min



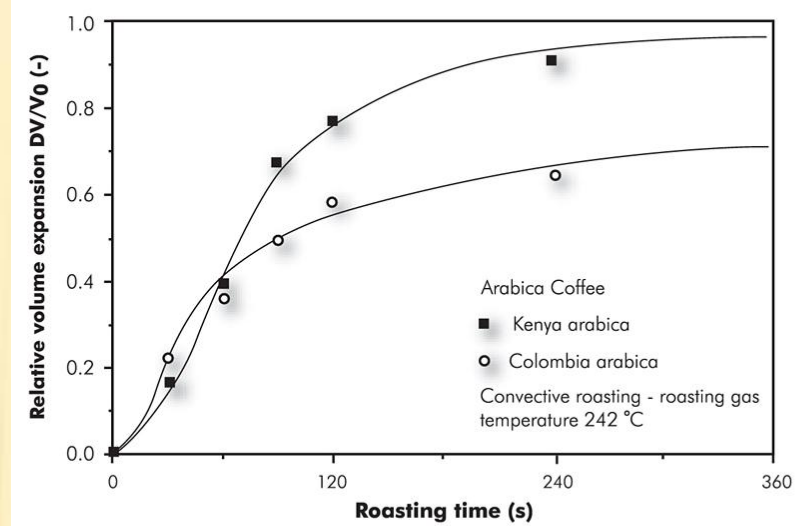
ROASTING

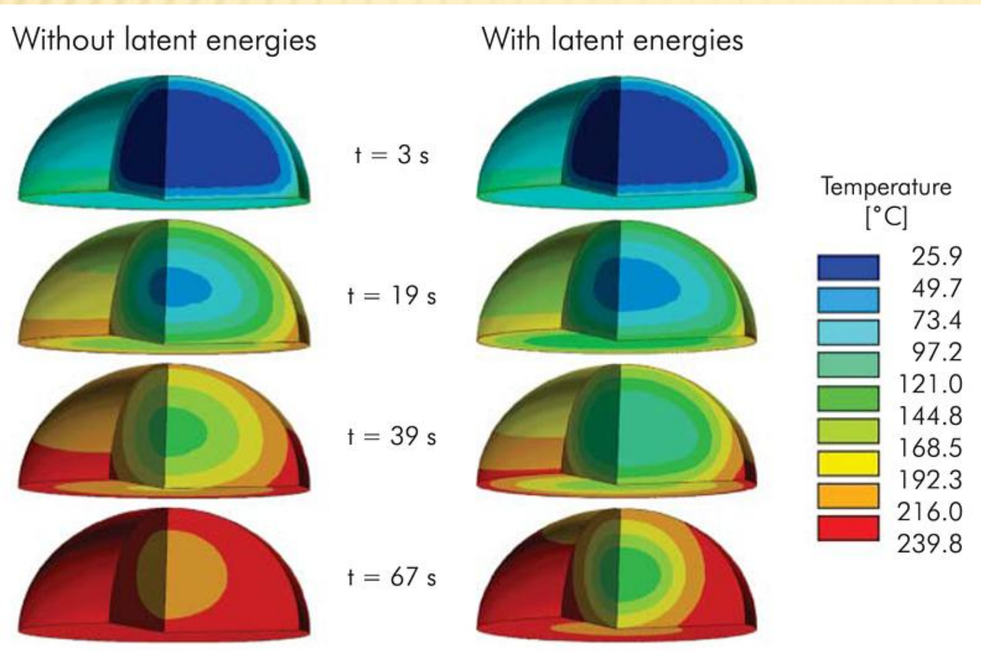
http://wiki.triestecoffeecluster.com/index.php?title=Roasting

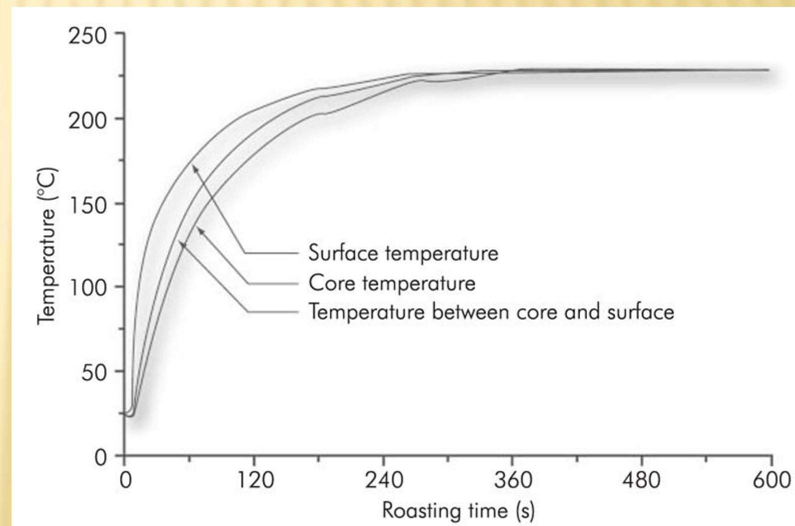
Table 1: Material data of arabica coffee beans

Coffee	Mass	Moisture	Roasting loss	Organic loss	Density	Volume	Radius*	Porosity
	(g)	(wt%)	(wt%)	(wt%)	(g/ml)	(ml)	(mm)	(-)
Green	0.15	10-12	0	0	1.2-1.4	0.11-0.13	3	<0.1
Medium to dark roast	0.13	2-3	15-18	5-8	0.7-0.8	0.16-0.19	3.5	0.5

*Of a sphere with the same volume.







CHANGES TO BEAN DURING ROASTING

CHANGES TO BEAN DURING ROASTING

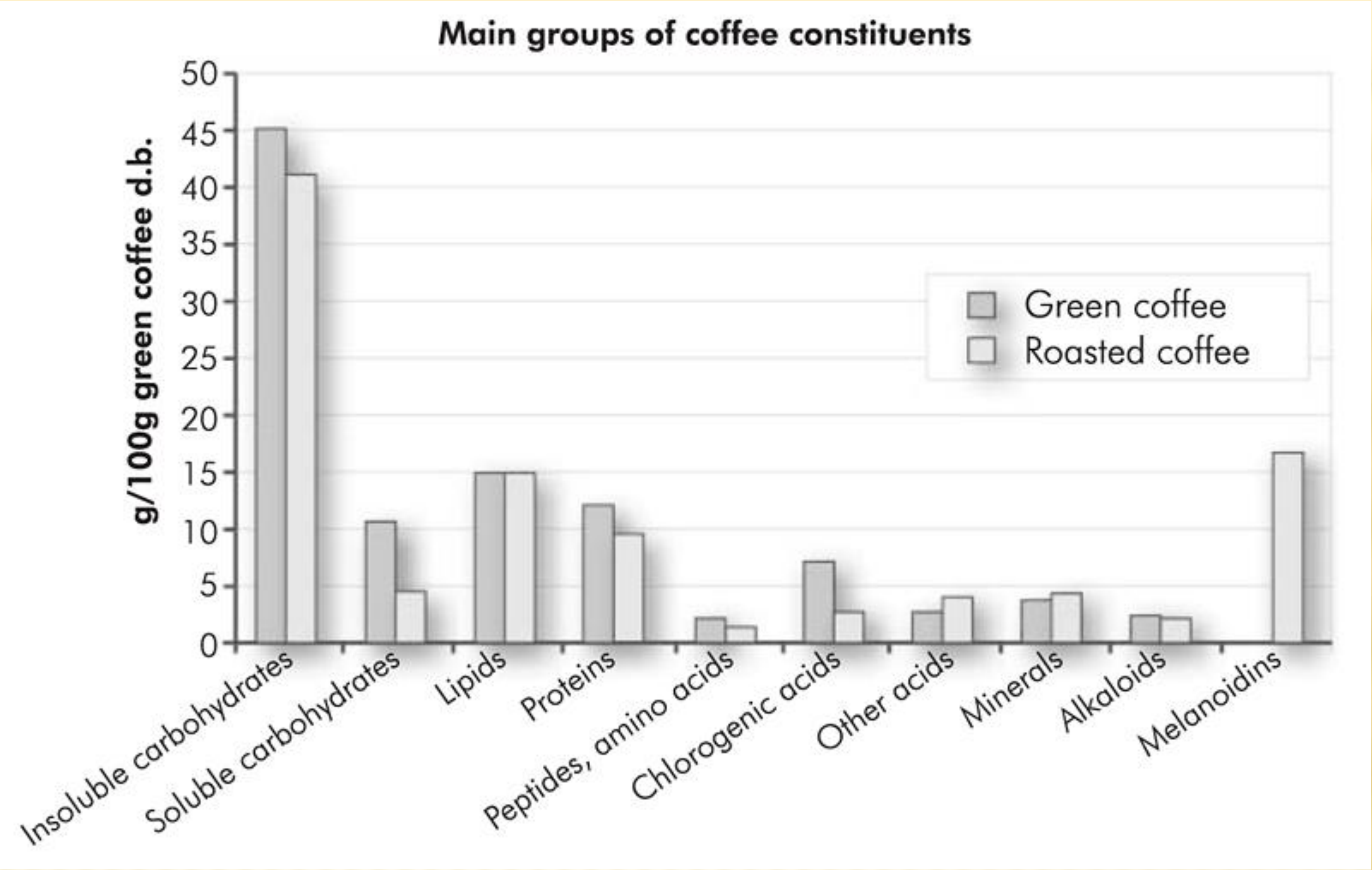
a. Green b. Toasted to 70 deg C c. Roasted (porous)

Table 3: Macroscopic changes during roasting

Temperature change within the bean (°C)	Effect
20-130	Liquid-vapour transition of water (bean drying). Colour fades
130-140	First endothermic maximum. Yellow colouring and swelling of bean with beginning of non-enzymatic browning. Roast gases are formed and begin to evaporate
140-160	Complex series of endothermic and exothermic peaks. Colour changes to light brown. Large increase in bean volume and micropores. Rests of silverskin are removed. Bean is very brittle. Some little fissures at the surface occur. Aroma formation starts
160-190	Roasting reactions move towards the inner dry structure of the bean (see also Figures 4 and 6)
190-220	Micro fissures inside the bean. Smoke escapes. Large volumes of carbon dioxide escape and leave the bean very porous. Typical flavour of roasted coffee appears

Table 4: Macroscopic changes brought about by roasting

Parameter	Comment
Colour of bean	It fades to whitish-yellow at the beginning of roasting, it darkens regularly with increasing temperature (see Figure 9); natural arabicas and robustas need a higher final temperature to reach the same colour as washed arabicas. There is a dark to light colour gradient from the surface within the bean, particularly noticeable with low-roasted fast-roasted coffees
Surface of bean	Oil sweats to the surface rendering it brilliant, particularly at high roasting levels
Structure of the bean	The large volumes of carbon dioxide freed render the bean porous (see Figure 9c)
Brittleness	It increases with roasting to a maximum, with an important modification of the internal texture of the bean, which under the microscope looks like a volcanic land covered with an amalgam of the original constituents
Density	Decreases regularly from 550 to 700 gl^{-1} in raw beans to 300–450 gl^{-1} in roasted beans (the lowest figures are attained with fast-roasted coffee)
Hot water extract	It decreases slightly from green to light-roasted beans, then increases again slightly with increasing roasting degree (highest with fast-roasted coffee)
Moisture	Both free water, which decreases regularly all through roasting, and chemically bound water, liberated above 100 °C, decrease to below 1% unless water quenching is applied (moisture release is less efficient with fast-roasted coffee)
Organic losses	Destruction of carbohydrates, chlorogenic acids, trigonelline, amino acids becomes important above 160 °C, varying between 1 and 5% at the lightest commercial roasts, 5–8% for medium-roasted coffees, to above 12% for dark-roasted ones (lower for fast-roasted coffee). Release of CO_2 continues for several days
Volatile constituents	Aroma content reaches a maximum at low roasting, while destruction becomes more important than generation at medium roasting losses (aroma generation is higher in fast-roasted coffees, where a maximum is reached at medium roast)
pH of beverage	In washed arabicas it increases from 4.9 for low-roasted coffees to 5.4 for dark-roasted one; higher for dry-processed coffees (lower values for fast-roasted coffee)



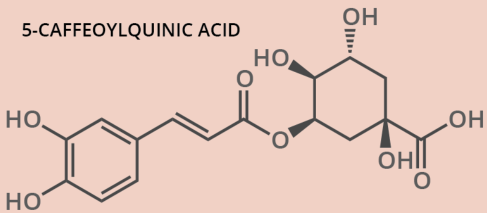
Main groups of coffee constituents
g/100g green coffee d.b.
50
45
40
35
30
25
20
15
10
5
0
Green coffee
Roasted coffee
Insoluble carbohydrates
Soluble carbohydrates
Lipids
Proteins
Peptides, amino acids
Chlorogenic acids
Other acids
Minerals
Alkaloids
Melanoidins

WHAT'S LEFT

THE CHEMISTRY OF COFFEE

WHY IS COFFEE BITTER?

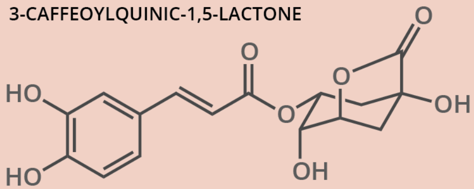
5-CAFFEOYLQUINIC ACID



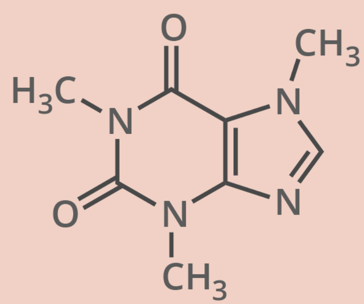
Chlorogenic acids account for up to 8% of the composition of unroasted coffee beans. More than 40 different varieties have been identified in green coffee beans, with 5-caffeoylquinic acid the most prevalent.

Chlorogenic acid content decreases when coffee beans are roasted, as they react to form quinolactones, phenylindanes & melanoidins. These contribute to flavour and bitterness.

3-CAFFEOYLQUINIC-1,5-LACTONE



THE CAFFEINE CONTENT OF COFFEE



The caffeine content of coffee is variable but is approximately 100mg in a cup.

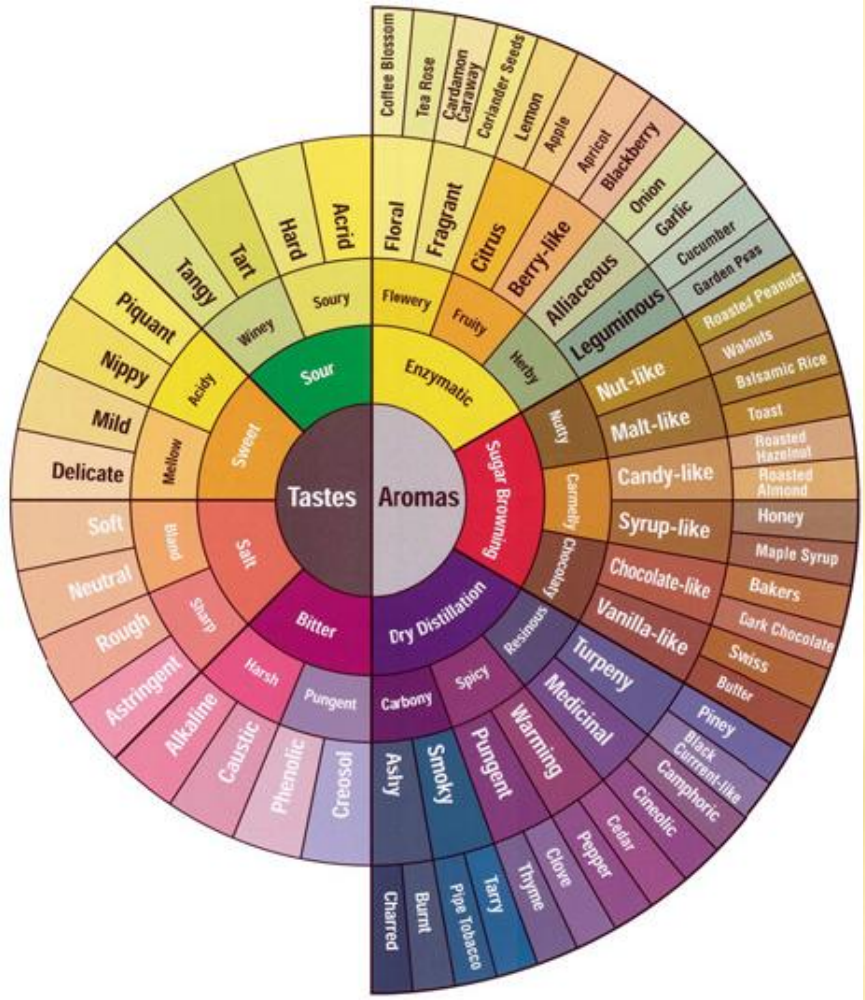
Caffeine works by blocking the action of a group of brain chemicals called adenosines, which work to naturally trigger tiredness.

The amount of caffeine in your bloodstream peaks 15 to 45 minutes after ingestion.

CHEMISTRY: CHLOROGENIC ACID AND CAFFEINE

http://www.compoundchem.com/wp-content/uploads/2014/01/The-Chemistry-of-Coffee-Sept-14-v2.png

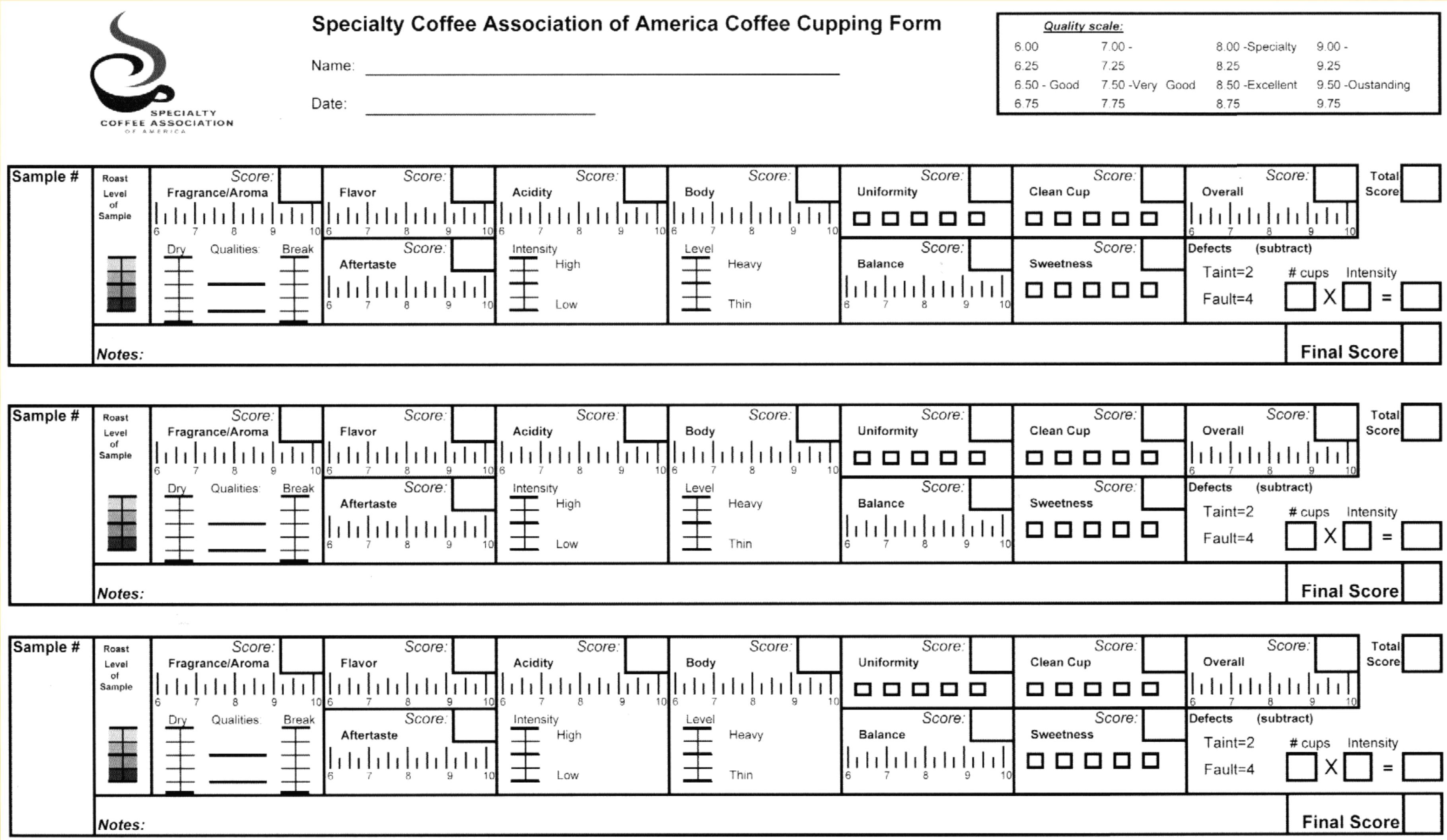
The process used by professionals to evaluate and compare the characteristics and quality of coffee.



- Aroma
- Acidity
- Body
- Flavour
- Finish

CUPPING

https://desertsuncoffee.wordpress.com/2011/08/30/experiencing-coffee/
http://wiki.triestecoffeecluster.com/index.php?title=Perception



SPECIALTY COFFEE ASSOCIATION OF AMERICA

Specialty Coffee Association of America Coffee Cupping Form

Name: ______________________

Date: ______________

Quality scale:

6.00	7.00 -	8.00 -Specialty	9.00 -
6.25	7.25	8.25	9.25
6.50 - Good	7.50 -Very Good	8.50 -Excellent	9.50 -Oustanding
6.75	7.75	8.75	9.75

Sample # | Roast Level of Sample | Fragrance/Aroma Score: (6 7 8 9 10) Dry Qualities: Break | Flavor Score: (6 7 8 9 10) | Aftertaste Score: (6 7 8 9 10) | Acidity Score: (6 7 8 9 10) Intensity High Low | Body Score: (6 7 8 9 10) Level Heavy Thin | Uniformity Score: | Balance Score: (6 7 8 9 10) | Clean Cup Score: | Sweetness Score: | Overall Score: (6 7 8 9 10) | Total Score | Defects (subtract) Taint=2 Fault=4 # cups X Intensity = | *Notes:* | Final Score

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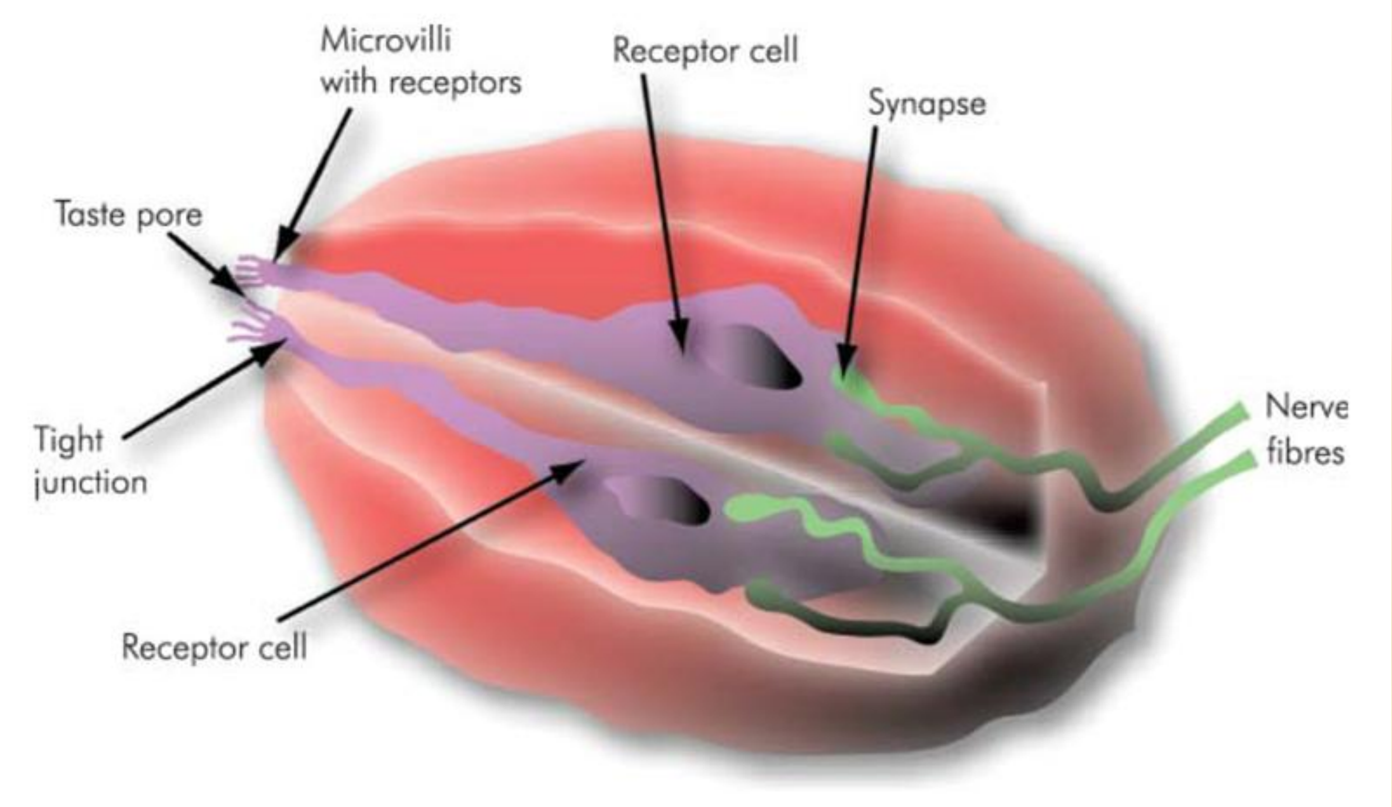
CUPPING

https://roastlog.files.wordpress.com/2010/08/scaa-form.gif



Tastebud with two receptor cells (Lindemann, 2001). On the top surface of the bud, microvilli are noticeable; on the bottom part the synapses are shown. Tastants enter the bud through the pore, are processed in the cells, and a signal is sent to the brain by the nerve fibres.

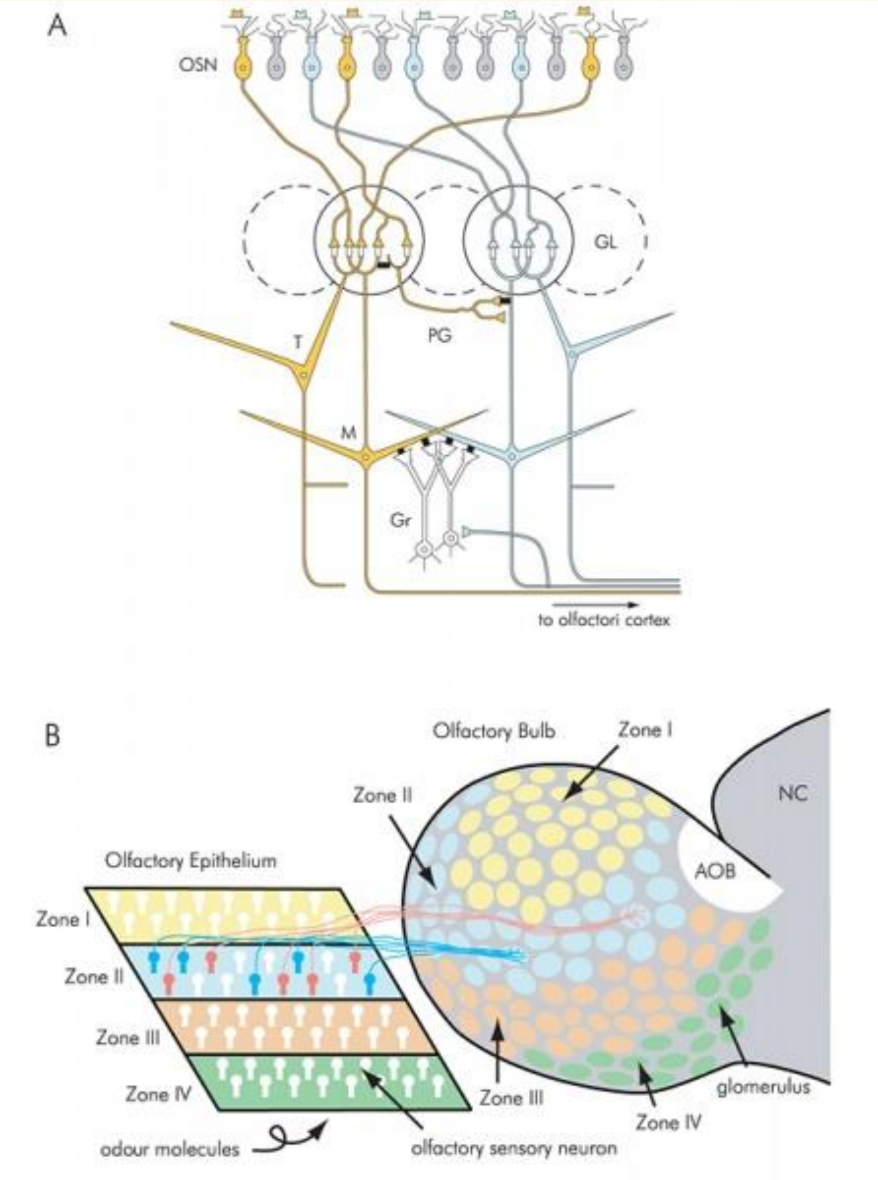
MORE ON TASTE (GUSTATION)

http://wiki.triestecoffeecluster.com/index.php?title=Gustation

Memories associated with odours are linked to emotions; conversely they appear to play a special role for memories: it is the 'Proust effect'. In À la recherche du temps perdu, French novelist Marcel Proust described his feelings after consuming a spoonful of tea in which he had soaked a madeleine:

The taste [meaning, of course flavour] was that of a little piece of madeleine which on Sunday mornings in Combray . . . my Aunt Leonie used to give me, dipping it first in her own cup of tisane . . . Immediately the old grey house on the street, where her room was, rose up like a stage set . . . and the entire town, with its people and houses, gardens, church, and surroundings, taking shape and solidity, sprang into being from my cup of tea.

What if he had been drinking an espresso?!?

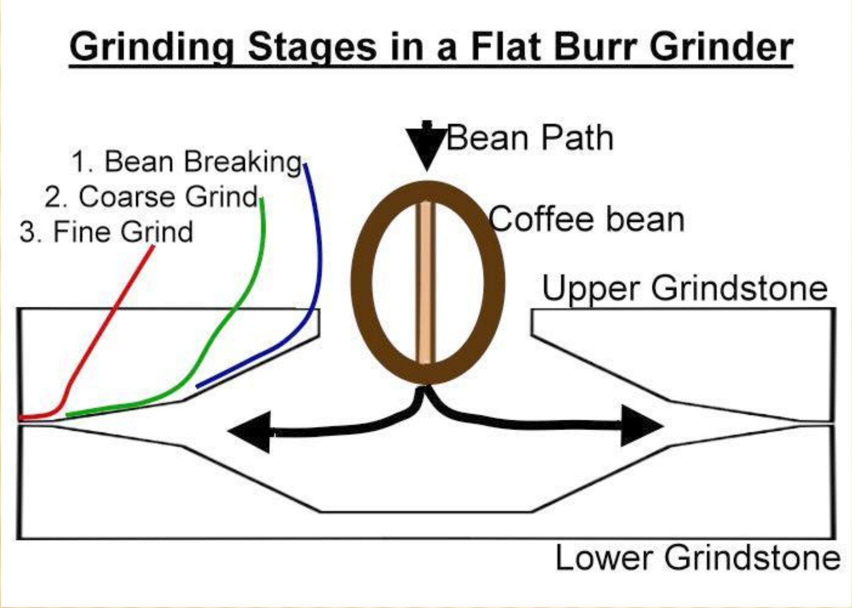


Schematic synaptic organization circuit, from the olfactory sensory neurons (OSNs) to higher regions in the brain (Mori et al., 1999). The olfactory epithelium is mapped onto the olfactory bulb in the brain with a convergent topography. Axons from OSNs expressing the same odorant receptor converge to defined glomeruli.

MORE ON SMELL (OLFACTION)

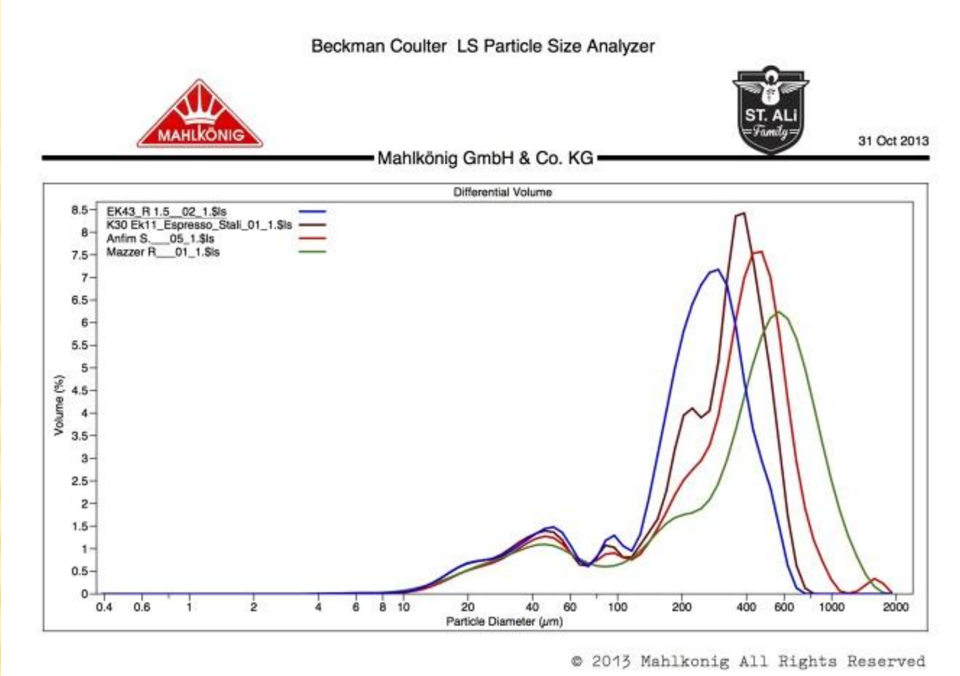
Odours: Volatile and hydrophobic

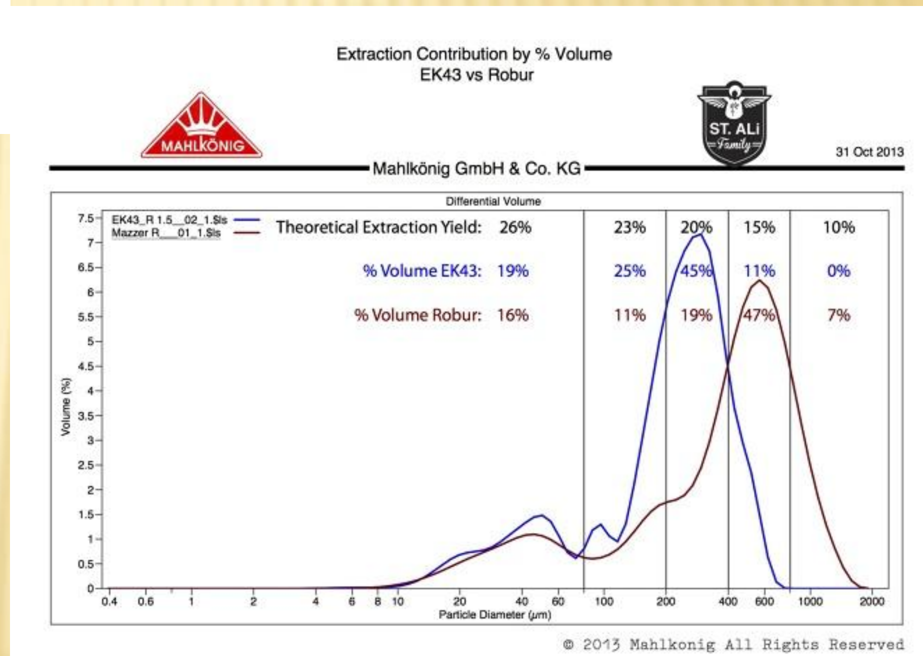
http://wiki.triestecoffeecluster.com/index.php?title=Olfaction



GRINDING

http://www.coffeeomega.co.uk/image/cache/data/Makhlkonig/EK43%20T%20Black-500x500.jpg
http://knowyourgrinder.com/wp-content/uploads/2015/01/556x191xconical-vs-flat-burrs.jpg.pagespeed.ic_.Xf8EBm0s8R.jpg
https://static.prima-coffee.com/styles/uc_product_full/s3/mazzer/commercial/robur-silver-electronic-angle_0.jpg?itok=238quTtr





GRINDER PERFORMANCE

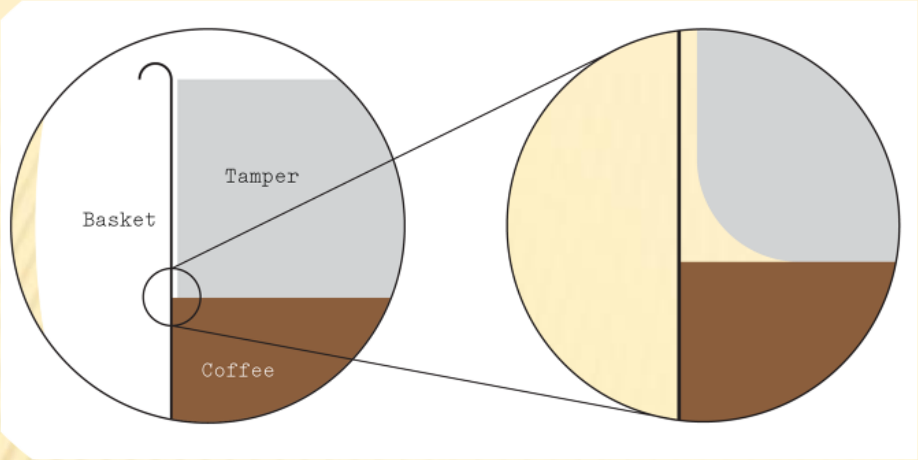
http://mattperger.com/The-EK43-Part-Three
http://www.mahlkoenig.com/file/file/image/5495?img%5Bw%5D=300&img%5Bh%5D=500

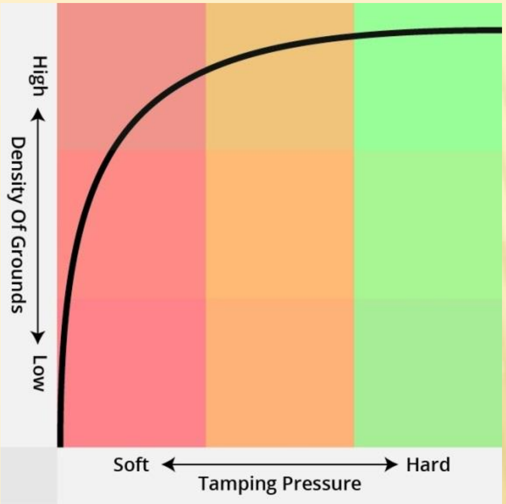
- Particle size
  - Too small – overextracted (bitter)
  - Too big – underextracted (sour/astringent)
- Temperature
  - Higher – faster extraction
  - Colder – slower extraction
- Pressure (Flow Rate)
  - Higher – faster extraction
  - Lower – slower extraction
- Tamper Force
  - Higher – slower extraction
  - Lower – Faster extraction
- Time
  - Longer – overextracted
  - Shorter - underextracted

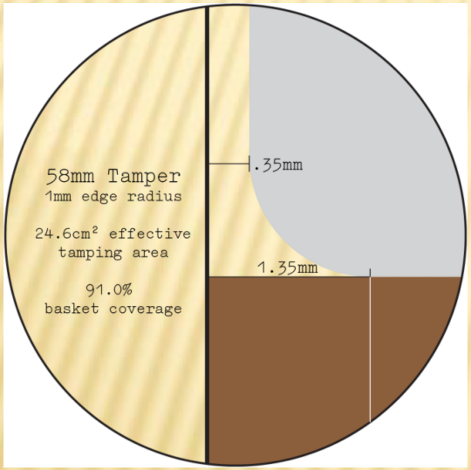
So, how do we get the correct extraction for a bright, fruity, sweet, creamy, heavy espresso that sits in your mouth for hours?

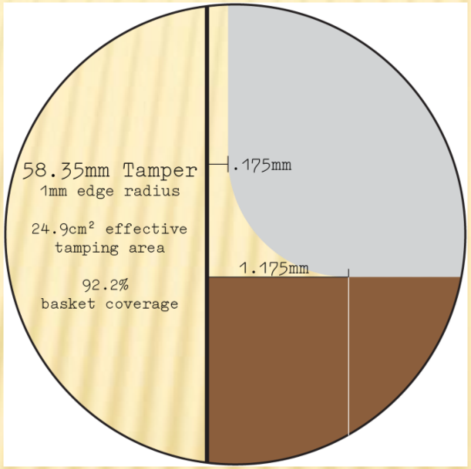
INDEPENDENT VARIABLES AFFECTING EXTRACTION LEVEL

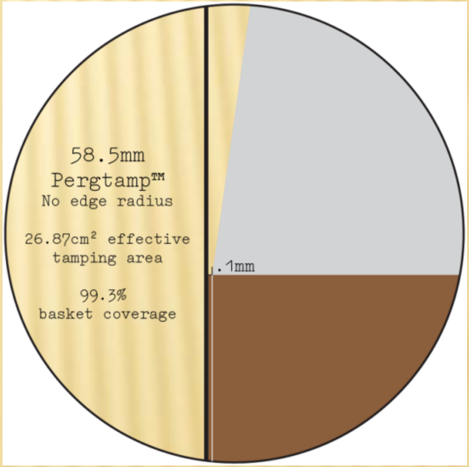
http://cdn.shopify.com/s/files/1/0092/7622/products/Black_Tamper_Image_3_1024x1024.jpg?v=1327947852







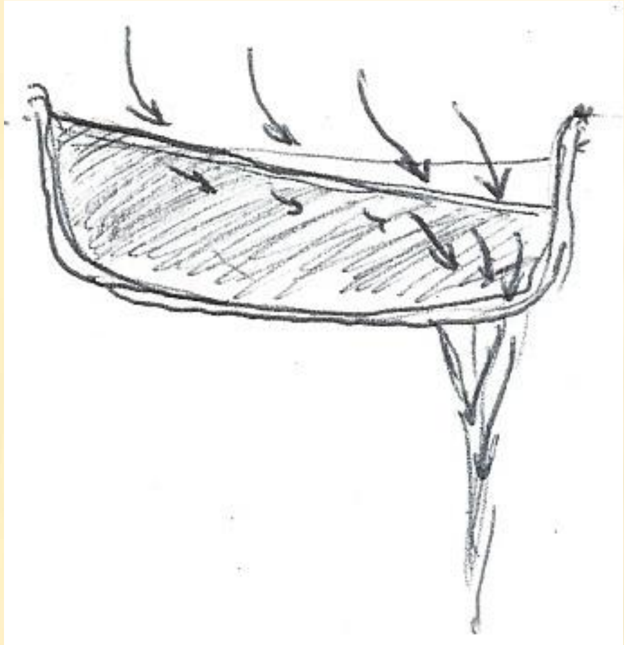




Extraction yield % increases by average of 1% using the Pergtamp

TAMPING

http://mattperger.com/Pergtamp#.VXFqB4x0y1s



CHANNELING

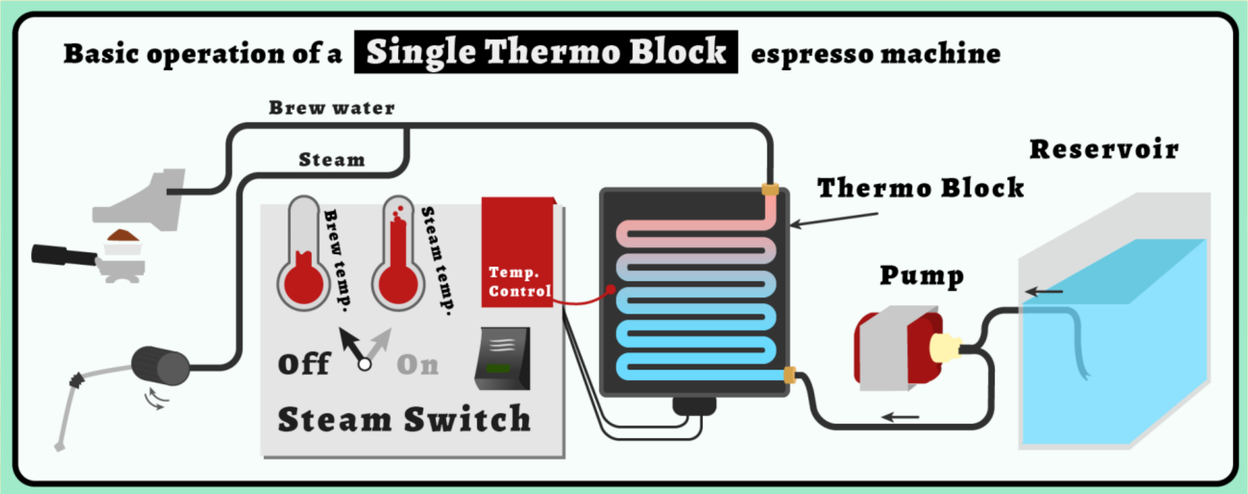
https://www.home-barista.com/professional-baristas-handbook_files/channeling.jpg
http://static1.squarespace.com/static/4fe98cf4c4aa49ccfa2b2e3c/t/52a89ccbe4b08fc252c44b15/1386781911944/sloped+basket.jpg
http://www.home-barista.com/forums/userpix/14484photo_mar_09__1_03_34_pm_1.jpg

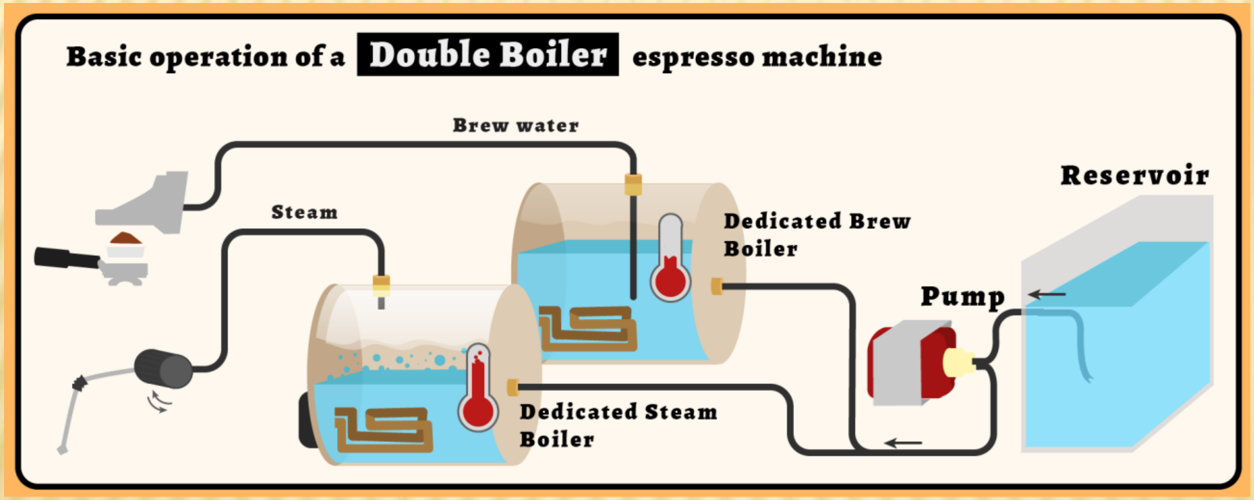
https://www.youtube.com/watch?v=FTd2RRewaf4

VIDEO ON EXPECTATION OF TASTE FROM AROMA

ESPRESSO MACHINES

http://www.idrinkcoffee.com/v/vspfiles/photos/COM-SYN-HYD-2.jpg





ESPRESSO MACHINES

http://cdn.shopify.com/s/files/1/0278/1973/files/CupAndBrew-How_It_Works-_Double_Boiler_Espresso_Machine.png?13615
http://cdn.shopify.com/s/files/1/0278/1973/files/CupAndBrew-How_It_Works-_Thermalblock_for_Steam_Espresso_Machine.png?13615

Proportional-Integral-Derivative Controller

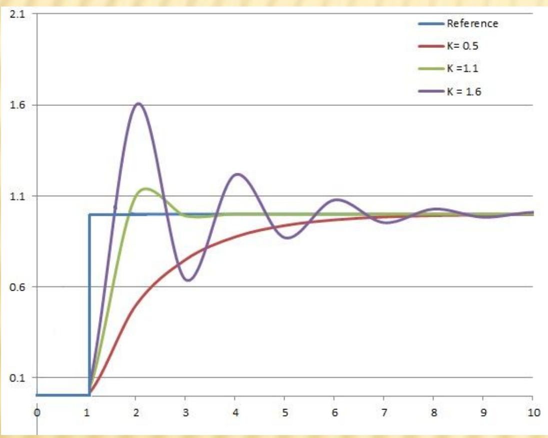
Simple example PID code

```
previous_error = 0
integral = 0
start:
    error = setpoint - measured_value
    integral = integral + error*dt
    derivative = (error - previous_error)/dt
    output = Kp*error + Ki*integral + Kd*derivative
    previous_error = error
    wait(dt)
    goto start
```

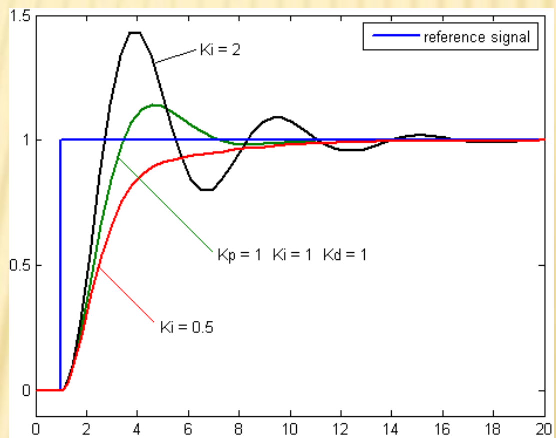
$$\mathrm{u}(t) = \mathrm{MV}(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{d}{dt} e(t)$$

where

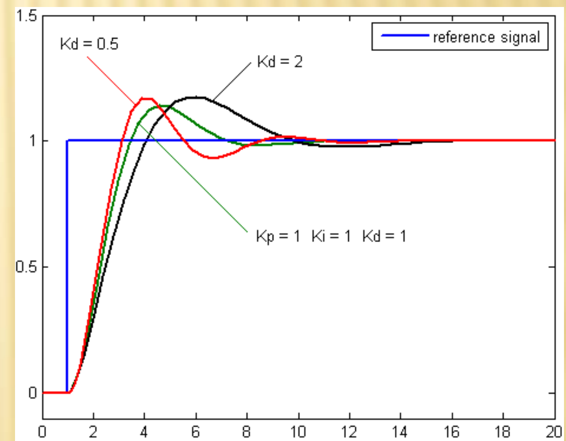
- K_p: Proportional gain, a tuning parameter
- K_i: Integral gain, a tuning parameter
- K_d: Derivative gain, a tuning parameter
- e: Error $= SP - PV$
- t: Time or instantaneous time (the present)
- τ: Variable of integration; takes on values from time 0 to the present t.



Changing Kp; Ki and Kd constant



Changing Ki; Kp and Kd constant



Changing Kd; Kp and Ki constant

ESPRESSO MACHINES: THE PID TEMPERATURE CONTROLLER

http://en.wikipedia.org/wiki/PID_controller

Manual tuning [edit]

If the system must remain online, one tuning method is to first set K_i and K_d values to zero. Increase the K_p until the output of the loop oscillates, then the K_p should be set to approximately half of that value for a "quarter amplitude decay" type response. Then increase K_i until any offset is corrected in sufficient time for the process. However, too much K_i will cause instability. Finally, increase K_d, if required, until the loop is acceptably quick to reach its reference after a load disturbance. However, too much K_d will cause excessive response and overshoot. A fast PID loop tuning usually overshoots slightly to reach the setpoint more quickly; however, some systems cannot accept overshoot, in which case an *over-damped* closed-loop system is required, which will require a K_p setting significantly less than half that of the K_p setting that was causing oscillation.[citation needed]

Effects of *increasing* a parameter independently[13]

Parameter	Rise time	Overshoot	Settling time	Steady-state error	Stability[11]
K_p	Decrease	Increase	Small change	Decrease	Degrade
K_i	Decrease	Increase	Increase	Eliminate	Degrade
K_d	Minor change	Decrease	Decrease	No effect in theory	Improve if K_d small

Ziegler–Nichols method [edit]

For more details on this topic, see Ziegler–Nichols method.

Another heuristic tuning method is formally known as the Ziegler–Nichols method, introduced by John G. Ziegler and Nathaniel B. Nichols in the 1940s. As in the method above, the K_i and K_d gains are first set to zero. The proportional gain is increased until it reaches the ultimate gain, K_u, at which the output of the loop starts to oscillate. K_u and the oscillation period P_u are used to set the gains as shown:

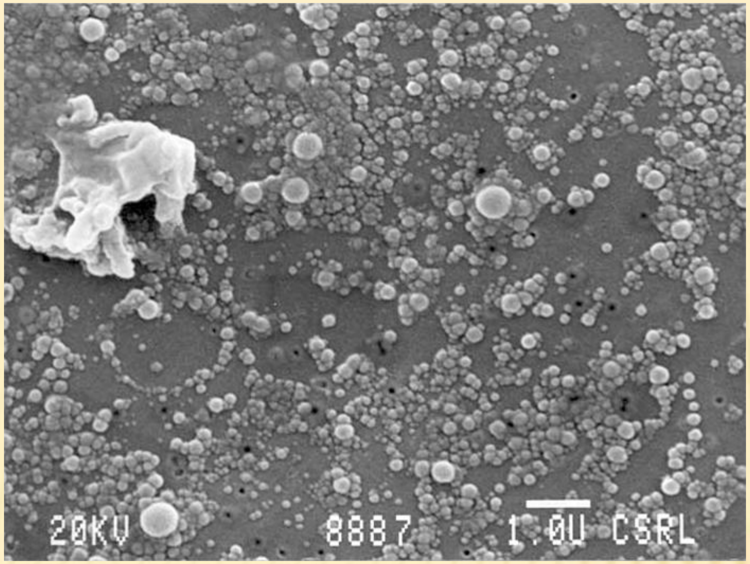
Ziegler–Nichols method

Control Type	K_p	K_i	K_d
P	$0.50K_u$	-	-
PI	$0.45K_u$	$1.2K_p/P_u$	-
PID	$0.60K_u$	$2K_p/P_u$	$K_pP_u/8$

These gains apply to the ideal, parallel form of the PID controller. When applied to the standard PID form, the integral and derivative time parameters T_i and T_d are only dependent on the oscillation period P_u. Please see the section "Alternative nomenclature and PID forms".

PID TUNING

http://en.wikipedia.org/wiki/PID_controller
http://i00.i.aliimg.com/wsphoto/v0/355749670/2-X-PID-Temperature-font-b-Control-b-font-Controller-font-b-OMRON-b-font-font.jpg



SEM of coffee lipid droplets and solid particles filtered out from their liquid matrix

Table 1: Typical analysis of an espresso brew

Parameter	Pure arabica	Pure robusta
Density at 20 °C (g/ml)	1.0198	1.0219
Viscosity at 45 °C (mPa-s)	1.70	1.74
Refractive index at 20 °C	1.341	1.339
Refractive index of filtrate at 20 °C	1.339	1.339
Surface tension at 20 °C (mN/m)	46	48
Total solids (mg/ml)	52.5	58.2
Total solids of filtrate (mg/ml)	47.3	55.6
Total lipids (mg/ml)	2.5	1.0
Unsaponifiable lipids (mg/ml)	0.4	0.2
pH	5.2	5.2
Chlorogenic acids (mg/ml)	4.3	5.0
Soluble carbohydrates (mg/ml)	8.0	10.0
Total elemental nitrogen (mg/ml)	1.8	2.3
Caffeine (mg/ml)	2.6	3.8
Ash (mg/ml)	7.2	7.0
Elemental potassium (mg/ml)	3.2	2.9

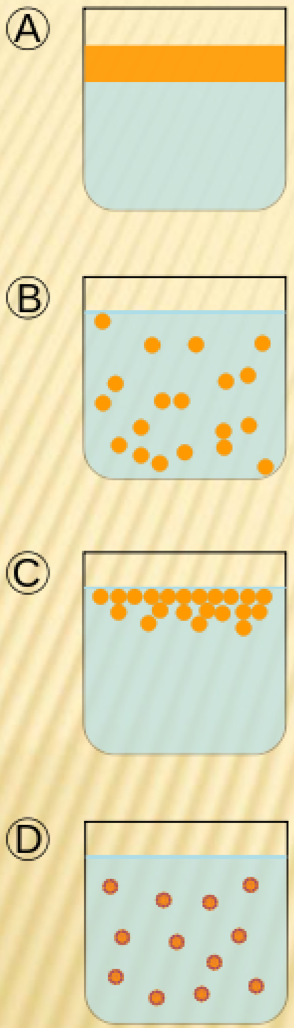
The peculiarity of espresso beverage is the simultaneous presence of three dispersed phases coexisting within a matrix, namely a concentrated solution of salts, acids, sugars, caffeine and many other hydrophilic substances. These phases are:

1. an emulsion of oil droplets (stable for weeks/months);
2. a suspension of solid particles (stable for days);
3. an effervescence of gas bubbles, which evolves into a foam (stable for only 1-3 minutes)

ESPRESSO

http://wiki.triestecoffeecluster.com/index.php?title=Liquid
http://www.cuculinary.com/wp-content/uploads/2014/11/espresso.png

EMULSIONS, SUSPENSIONS, AND EFFERVESCENCE



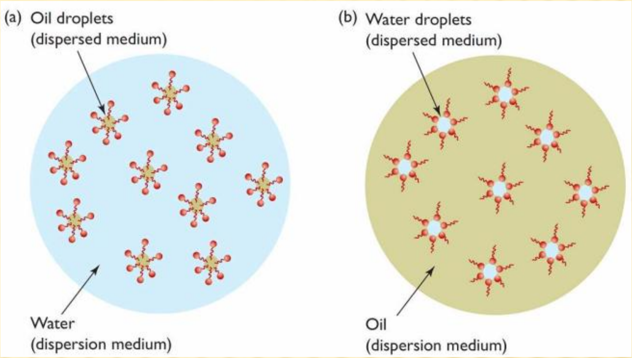
Two immiscible liquids, not yet emulsified

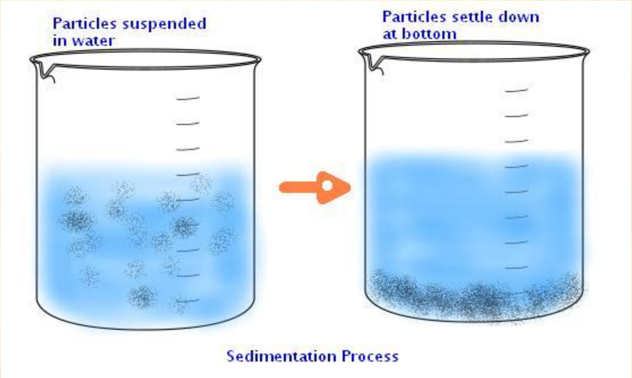
B. An emulsion of Phase II dispersed in Phase I

C. The unstable emulsion progressively separates

D. The surfactant (outline around particles) positions itself on the interfaces between Phase II and Phase I, stabilizing the emulsion

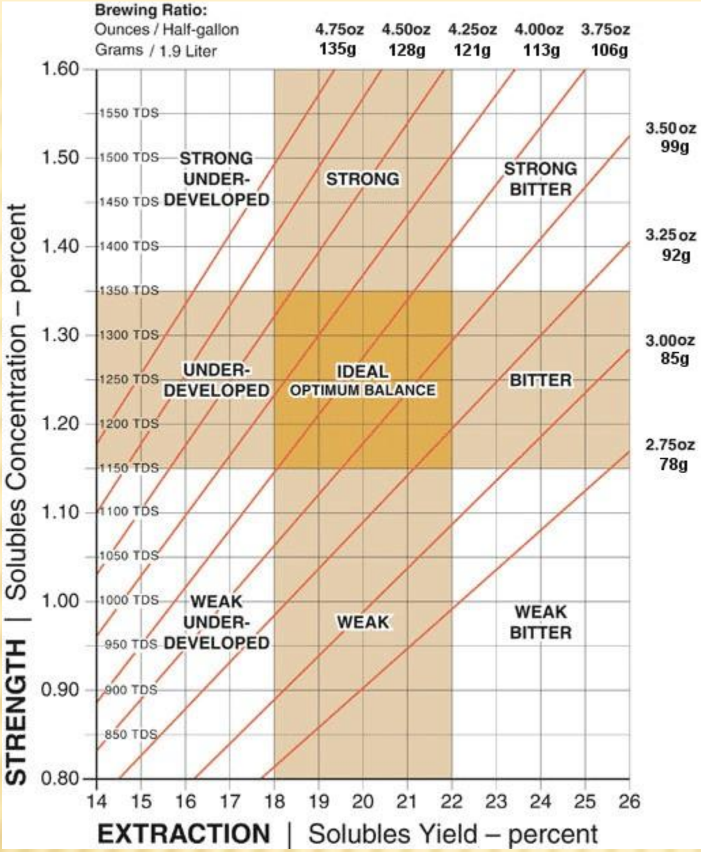
- An **emulsion** is a mixture of two or more liquids that are normally immiscible (unmixable or unblendable).
- In chemistry, a **suspension** is a heterogeneous mixture containing solid particles that are sufficiently large for sedimentation. Usually they must be larger than one micrometer.
- **Effervescence** is the escape of gas from an aqueous solution and the foaming or fizzing that results from a release of the gas.
- A **foam** is a substance that is formed by trapping pockets of gas in a liquid or solid.





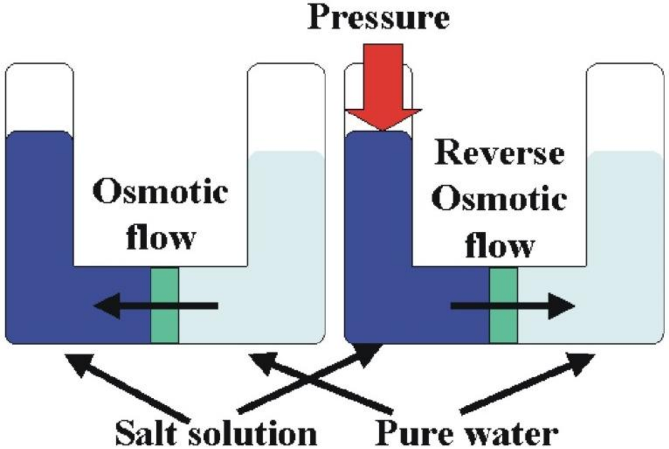
http://en.wikipedia.org/wiki/Effervescence
http://en.wikipedia.org/wiki/Suspension_(chemistry)
http://en.wikipedia.org/wiki/Emulsion
http://nsb.wdfiles.com/local--files/c-9-5-5-4/Emulsion%202.jpg
http://2.bp.blogspot.com/-_xOs3YCHvyo/UDr_CLJ6pgI/AAAAAAAABjI/w5ZGXkGjfVQ/s1600/cl9SciCH2Fig5.jpg
https://punctalucis.files.wordpress.com/2014/02/puncta_2014_02_effervescence_i.jpg

TOTAL DISSOLVED SOLIDS & EXTRACTION YIELD



- **Extraction yield %** - The percentage by mass of coffee grounds that ends up dissolved in the brewed coffee.
  - Extraction yield % = Brewed Coffee[g] (espresso/ristretto shot) x TDS[%] /Coffee Grounds[g] E.g. 55g brewed coffee x 6.5% TDS / 18g ground coffee = Extraction yield of 19.86%
- **Total Dissolved Solids (TDS)** - If you have a standard refractometer the TDS is expressed in parts per million. (ppm). To convert ppm into a percentage: Divide the ppm by 10000. E.g. 10000ppm /10000 = 1%
- **Strength** - Also known as "solubles concentration", as measured by Total Dissolved Solids – how concentrated or watery the coffee is.
- **Brew ratio** - The ratio of coffee grounds (mass) to water (volume): how much coffee is used for a given quantity of water. This may be expressed in units of either grams per litre or ounces per US half gallon. Since the density of the liquid coffee beverage is essentially equal to the density of pure water (1 g/mL), this ratio is often expressed as the mass of coffee grounds to mass of liquid coffee (a unit-less ratio).

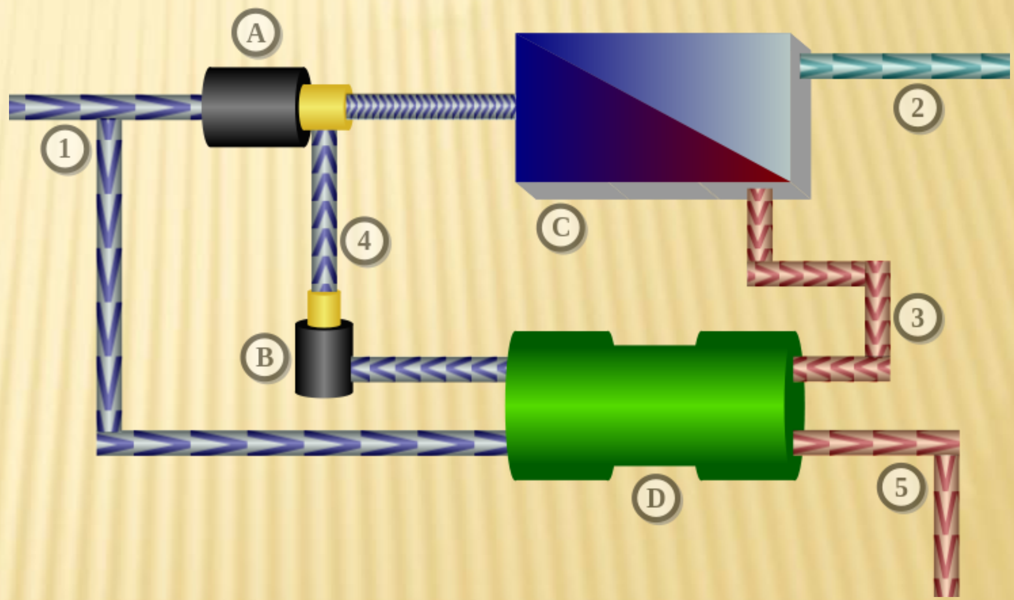
http://en.wikipedia.org/wiki/Coffee_extraction
https://dahtac.files.wordpress.com/2011/07/vst-refractometer.jpg



This process requires that a high pressure be exerted on the high concentration side of the membrane, usually 2–17 bar (30–250 psi) for fresh and brackish water, and 40–82 bar (600–1200 psi) for seawater, which has around 27 bar (390 psi) natural osmotic pressure that must be overcome.

"Ideal" water according to Jim Schulman:
Total Dissolved Solids 150 ppm
Total Hardness 3-5 gpg (51-85ppm)
Total Alkalinity 80 ppm
pH 7.0 gpg
Calcium Hardness 3-4 gpg
Total Chlorine <0.1 ppm
Free Chlorine <.05
Total Chlorides <30 ppm
Total Iron 0 mg/L
Silica not more than 5 mg/L
Sulfate 25-50 mg/L
Hydrogen Sulfide 0 mg/L
Manganese 0 mg/L
Nitrate 0 mg/L

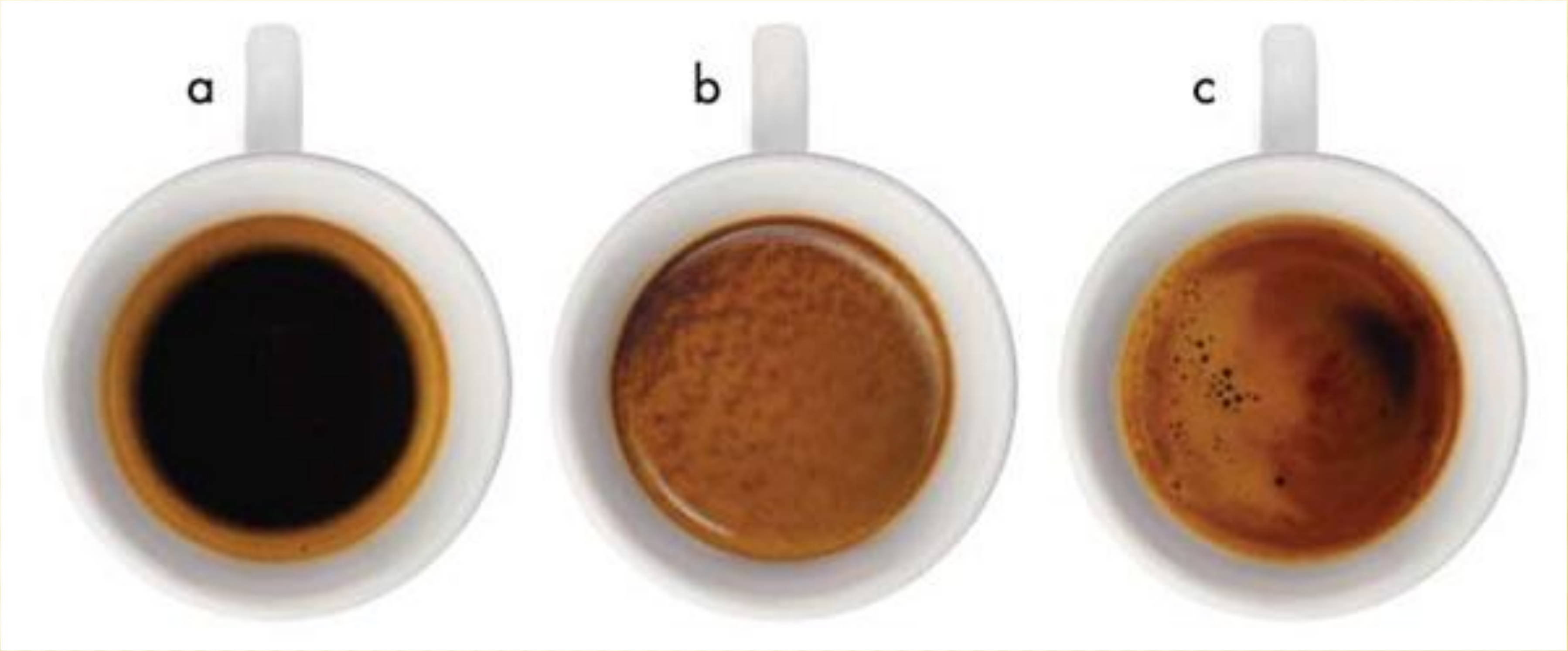
Schematics of a reverse osmosis desalination system using a pressure exchanger.
1: Sea water inflow,
2: Fresh water flow (40%),
3: Concentrate flow (60%),
4: Sea water flow (60%),
5: Concentrate (drain),
A: Pump flow (40%),
B*: Circulation pump,*
C*: Osmosis unit with membrane,*
D*: Pressure exchanger*



WATER – REVERSE OSMOSIS

Lots of magnesium, not much bicarbonate

http://en.wikipedia.org/wiki/Reverse_osmosis
http://bestreverseosmosissystem.net/wp-content/uploads/2014/10/What-Is-Reverse-Osmosis.jpg



(a) under-extracted; (b) correctly extracted; (c) overextracted

https://youtu.be/qaUZcbLPTBA

EXTRACTION: WHAT IT LOOKS LIKE, AND THE IMPORTANCE OF CREMA

http://wiki.triestecoffeecluster.com/index.php?title=Visual_characteristics




LATTE ART

http://www.venezianocoffee.com.au/shop/product_images/l/488/Latte-Art-Training-Product-Image__18860__17179_zoom.jpg
http://www.ratemyrosetta.com/latte-art-37_erjM5hCd.jpg
https://coffeeinfo.files.wordpress.com/2007/06/latte_art_rosetta_mid_pour.jpg
http://www.ratemyrosetta.com/latte-art-3241_y4R7TX0S.jpg

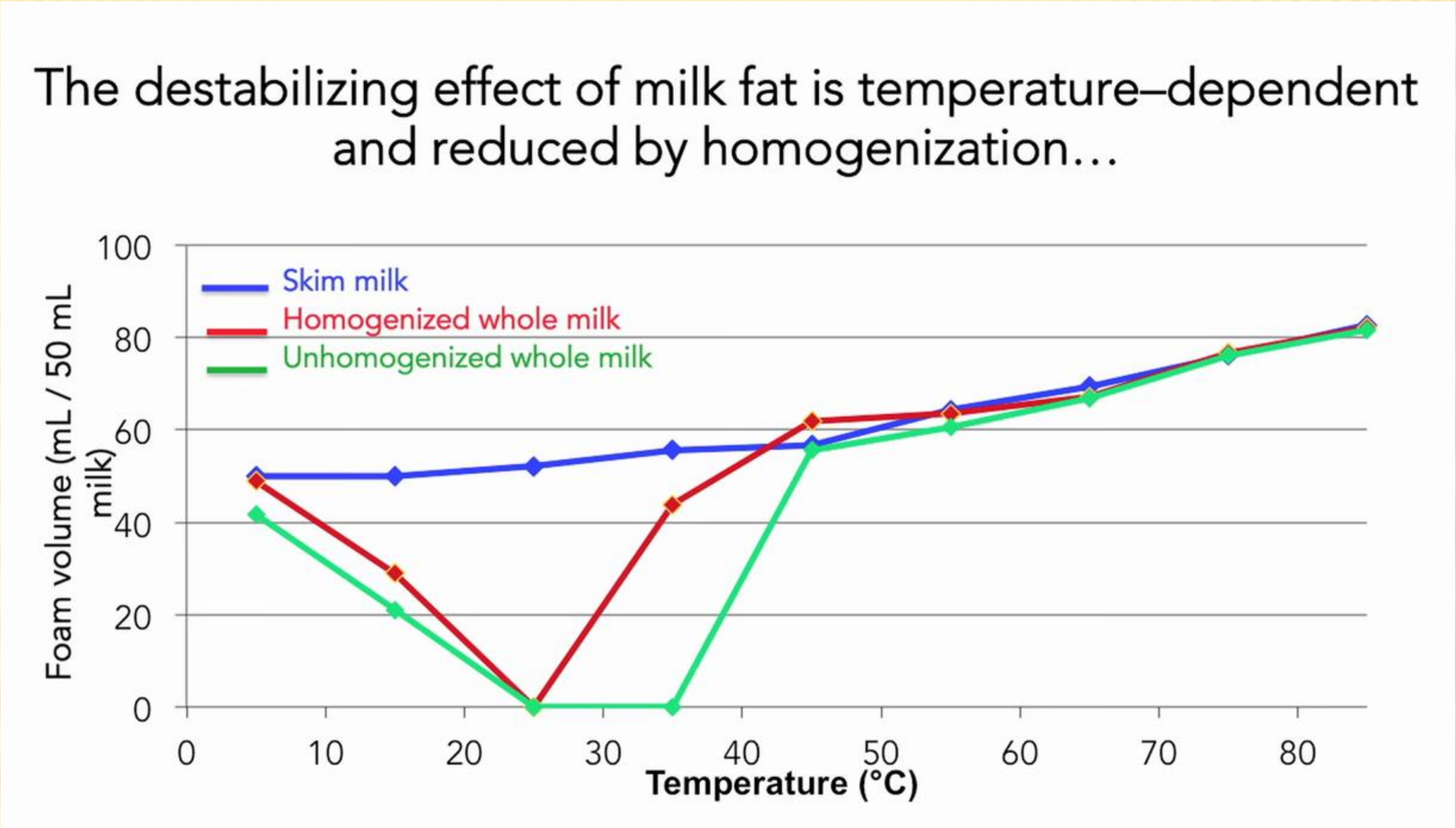
MILK STEAMING

http://drinks.seriouseats.com/images/04172012-milk-steaming-main.jpg

1 oz = 28.4 mL

COFFEE MENU

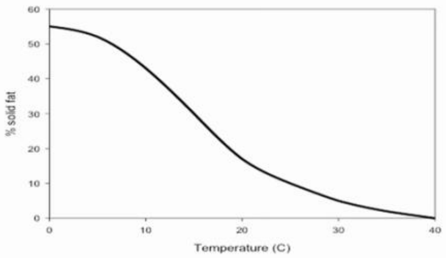
http://www.coffeenate.com/wp-content/uploads/2011/10/espresso_field_guide.jpg



A typical example is the homogenization of milk, where the milk fat globules are reduced in size and dispersed uniformly through the rest of the milk.

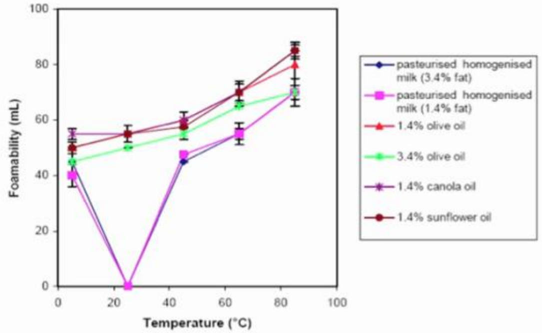
MILK

https://www.youtube.com/watch?v=BTi87en4qjY

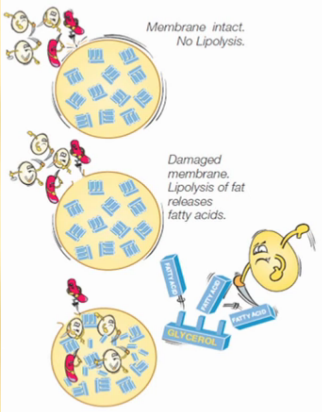


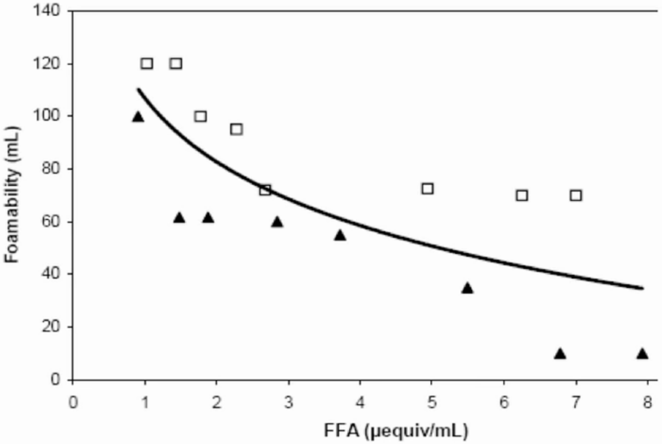
Partially crystalline fat causes damage to fat globules in foams spreading of liquid fat on interface detrimental

Replacement of milk fat with oil stabilizes fat globules and improves foaming



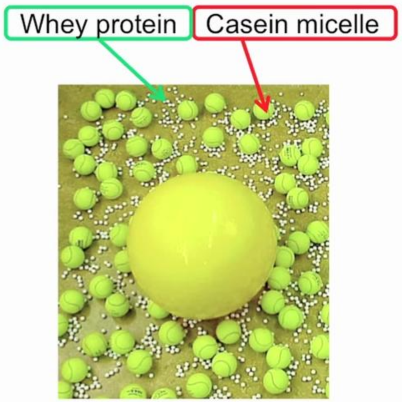
Lipolysis creates rancidity and reduces foaming…





MILK

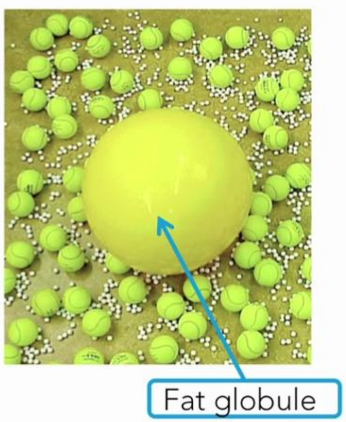
Milk foams: using proteins to stabilize foams…



- Milk proteins crucial for stabilizing foams
- Milk contains more than enough protein to stabilize the foam
- Little effect of heat treatment and other processing
- But interactions of milk proteins with coffee constituents:
    - Reduced flavour release
    - Reduced bitterness

Lipolysis /lɨˈpɒlɨsɪs/ is the breakdown of lipids and involves hydrolysis of triglycerides into glycerol and free fatty acids. The following hormones induce **lipolysis**: epinephrine, norepinephrine, ghrelin, growth hormone, testosterone, and cortisol.

Milk foams: controlling fat particles



- Fat globules are crucial for taste and mouthfeel of milk foams, but have a major destabilizing effect
- Fat globule size should be reduced by homogenization (but not too far)
- Lipolysis should be prevent at all cost
- Interactions of milk fat with coffee flavor compounds

MILK