VITICULTURE + VINIFICATION

1. IN THE VINEYARD

- Vitis Vinifera - "the eurasian grape vine" → origins in the near East at the meeting point of Europe + Asia.
- Vines in the wild
  - natural growth form is as woodland climbers, using trees for support
  - extensive root systems that enable them to compete for water + nutrients w/ the trees + bushes they are hitching a ride on.
  - vines also need shoots capable of rapid elongation to grow towards the outside of the host canopy to find sunlight.
    - → new green growths w/ leaves, tendrils & often flowers, developing from a bud of a cane or spur.
- Vine domestication → approx. 7,000 years ago
- PLANT PHYSIOLOGY
  - make everything they need by capturing energy from sunlight through the process of photosynthesis.
  - key molecule in capturing light energy is chlorophyll, which gives plants their green color.
  - Perenial plants: those whose structures last more than a season → aka: THE VINE!
    - → the outer layer is specialized to retain water + it becomes woody via the deposition of a molecule called lignin.
    - → the first few years of a vine's life is spent building a good root system + trunk, ideally
- MOBILITY
  - roots are fixed, but aerial parts can move. roots want to move toward water + nutrients.
  - phototropism: growing in response to light
  - thigmotropism: growing in response to touch/sensation (tendrils!)

- **REPRODUCTION**
  - 2 reproductive options: vegetative + sexual
  - seeds → multicellular, specialized sexual propagules
    → Seeds are of v. little importance for viticulture b/c no one propogates grape vines from seed, but the process of seed production - "vine sex" - is crucial. This is what produces grapes.
  - simplistically speaking, if conditions are good, a plant will focus on vegetative ~~growth~~ reproduction or growth, but if things are hard for the plant, it will focus on sexual reproduction, making fruit that will be eaten + transported elsewhere.

- **VINE STRUCTURE + DEVELOPMENT**
- Roots - two functions: anchorage + uptake.
  - low nutrient levels in the upper layers of soil, cause roots to grow deeper. improves the regularity of water supply to the vines.
- ABOVE GROUND - Complicated structures w/ a potential for leaves, flowers + tendrils → develop over 2 seasons w/ a rest in the dormant period.
- SHOOT MORPHOLOGY
  - the stem is separated into sections by structures known as nodes.
    vegetative growth
  - at each node, a leaf is formed on one side, w/ either a tendril or a flower bud on the other.
    ↳ reproductive growth

- FLOWERING
  - the flowering process in the grape vine is unusual in that it extends for 2 consecutive growing seasons.
  - flowering is first induced in latent (dormant) buds during the summer, but initiation & floral development occur the following spring.
  - buds are formed & are first detectable in early spring in the axils (the inside of the joint b/t the stem & leaf stalk) of the current year's leaves.

- when flowers are formed, their development & pollination occur best during a period of warm, settled weather. Domesticated vines are hermaphrodites and can self-pollinate. Poor weather during this process can result in poor or uneven fruit set, so flowering is one of the critical phases in the vineyard calendar.

- GRAPE DEVELOPMENT
  - vines want to produce ripe grapes to attract birds in the autumn, when conditions are right for seed germination.
  - three stages:
    - cell division: grapes develop their structure, accumulate acids.
    - veraison: color change (seeds are mature at this point)
    - cell enlargement: grapes accumulate sugar + phenolic compounds + acidity decreases.
  - Maturity → phenolic/~~physiological~~

    ↙ Sugar accumulation (physiological)

    ↓ sugar accumulation & loss of malic acid (dependent on climactic factors)

    ↘ color, aroma + tannin (less dependent on climate)

    in warmer climates, grapes only reach physiological maturity at sugar levels considerably higher than in cooler regions

- CLONES
  - vine propogation occurs vegetatively (cuttings from vines produce genetic clones) rather than sexually (from seed).
    - ↳ attempts to grow vines from seeds have failed b/c the genetic reassortment that occurs usually means the loss of positive features.
  - clones created by:
    - spontaneous bud mutation,
    - differing levels of virus infection
    - epigenetic difference
    - chimerism: two genetically distinct layers (i.e. Pino Meunier vs. Pino Noir)

LIFE CYCLE OF THE GRAPEVINE

WINTER

- **PRUNING!** The prior year's canes are cut back, and the pruner chooses the best canes to grow new shoots for the following year's harvest.

SPRING

- **BUD BREAK!!** During ~~April/May~~ March/April (Sept/Oct in the Southern Hemisphere), sap rises up & buds begin to break. Buds are very delicate at this time & poor weather can devastate yields.
- **SPRING PRUNING** - as the shoots continue to grow, viticulturists often prune again, to ensure the proper yields & exposure.
- **FLOWERING** - the flowers of grapevines can polinate themselves. (May/November)

SUMMER

- **CLUSTERING** - young clusters of berries begin to appear.
- **VERAISON** - berries start to change color + ripen. Green berries become yellow, pink, red, or purple. If producers green harvest, it will be before Veraison. (Approx. August/February)

mid to late summer

FALL

- **LIGNIFICATION** - the wood (stems, canes, etc) ripens and turns brown & hardens. Grapes continue to ripen + sugar levels rise.
- **HARVEST**

II. TERROIR

- [redacted] pangkarra (Australia)
- terruño (Spain | S. America)
- minerality - a lack of fruitiness + a presence of sulphur compounds.
- the best terroirs are the ones where the soils are free-draining, with the water table high enough to ensure a regular supply of water to the vine roots, which then recedes on veraison, so the vegetative growth stops & the vine concentrates its growth on fruit ripening.
- excess nitrogen = excess vigor
- research currently supports the physical properties of the soil | site (drainage, water table, exposure, altitude, etc.) to be more important than the chemical ones.

III. PRECISION VITICULTURE

- splitting up vineyards into smaller plots to allow each to be targeted most effectively for irrigation, cover crops, harvest times, etc.
- chiefly used by large landowners in the New World

IV. GLOBAL WARMING

- surface air temp. has increased by 1°F since the beginning of the 20th century.
- "greenhouse gases" → CO_2 & methane → trap energy lower in the atmosphere + increase the earth's temperature.
- disparity b/t phenolic + physiological ripeness may widen.
- thus far, the effect has been largely positive, though: more consistently good vintages than ever before.

V. GM VINES

- Genetically modified
- research is underway globally, but it has not caught on in practice.
- fungal resistance → looser bunches, no botrytis

VI. PHYLLOXERA

- aphid that eats roots
- by 1850, 1/6 of france's revenue was from wine, and 1/3 of the workforce derived a living from it.
- Oidium hit before botrytis (also brought over from the US), but was irradicated quickly w/ the discovery of sulphur in the vineyards.
- S. Rhône was hit w/ phylloxera first in the 1860s, Champagne last in the 1890s.
- the root-feeding form of phylloxera is exclusively female. don't need sex to propogate.
- three potential mechanisms for phylloxera-induced vine damage:
  - removal of photosynthesis
  - physical disruption of the roots
  - ✱ secondary fungal infections of damaged roots. ← most likely
- Defeating phylloxera:
  - ~~Seas~~ seasonal flooding was reasonably effective
  - sandy soils were found to be immune
  - American vines were found to be resistant, but no one liked the wines
    - ↳ first documentation in 1874 of grafting Vitis vinifera onto American rootstock.

in the 1960s & 1970s in California, many of the plantings took place on AXR #1, a hybrid cross b/t an American & vinifera species - thought to be resistant but it was not!

VII. LUTTE RAISONÉE • IPM

- IPM = Integrated pest Management
  - ↳ a more scientific, holistic approach to killing pests
  - ↳ tools include natural enemies, biodiversity, cover cropping, weather monitoring, etc.
- oidium (powdery) + downey (peronospera) mildews, require traditional sprays like Bdx mixture or sulphur, or modern chemicals.

Pierce's Disease -

- serious problem in CA.
- bacterial disease spread by the glassy-winged sharpshooter (leafhopper insect), which has a very large range.
  - blocks the vessels of affected vines + killing them.

Leaf Roll Virus -

Can be seen through a downward rolling of the leaf late in the growing season. Doesn't kill the vine, but delays ripening, reducing wine quality. Only way to ~~gr~~ counter is by planting virus-free vines.

VIII. BIODYNAMICS

- has its roots in a series of lectures delivered by Rudolf Steiner in 1924. Mission was ~~to~~ to bridge the gap b/t the material & spiritual worlds using philosophy.
  - ↳ "spiritual science" of anthroposophy
- the farm as a living system → the soil is an organism in its own right.
- two main certifying bodies: Demeter + Biodyvin (Olivier Humbrecht = president)

BIODYNAMIC PREPARATIONS

PREPARATION	CONTENTS	MODE OF APPLICATION/ DESIRED EFFECT
500	Cow manure fermented in a cow horn, buried & spends winter in the soil.	Sprayed in the soil/ brings up calcium activity in the soil, causing seed germination, root development + growth of the plant.
501	Ground quartz (silica) mixed w/ rainwater & packed in a cow horn. Buried in spring + dig up in autumn	Sprayed on the crop plants/ stores light energy, aids photosynthesis, and uptake of nutrients from soil.
502-507: COMPOST PREPARATIONS		
502	Flower heads of yarrow fermented in a stag's bladder	Compost/ Activates beneficial bacteria, remedies weakness in fruiting + flowering, helps prevent against insect attack.
503	Flower heads of chamomile fermented in the soil.	Retains nitrogen + calcium, stimulates potassium, boron + manganese.
504	Stinging nettle tea	Helps decomp of organic matter, aids chlorophyll formation + stimulates iron
505	Oak Bark fermented in a cow skull	Helps calcium + phosphorus work into earth
506	Dandelion fermented in a cow's mesentery.	Stimulates silica + potassium.
507	Juice of valerian flowers.	Stimulates phosphorus process, generates heat & can protect against frost.
508	Tea prepared from the horsetail plant (Equisetum)	Used as a spray to counter fungal diseases

IX. PRD + REGULATED DEFICIT IRRIGATION

↳ only issues in irrigated regions.

- PRD = Partial Root Drying
- ABA is a plant growth hormone that is produced when water supply is low that signals to the plant to stop growing vegetatively.
  - ↳ the French term for this heat/drought induced shutdown is blocage.
- the premise of PRD is to deprive part of the root system of water to control vine canopy vigour, w/o experiencing any deleterious effects b/c the other part is receiving irrigation.
  - ↳ Australian pioneered.
- RDI = Regulated Deficit Irrigation
  - ↳ reduce or cut irrigation at the right point ~~(after veraison)~~
  - ↳ studies conflict on what the right point is. A Bordeaux based study says the water supply should recede after veraison. An Australian study found that cutting water supply after fruit set & restoring at veraison is the way to go.
- the chief benefit of PRD is reduced water use.
  - ↳ question of wine quality is more difficult.
- these techniques have been used significantly in Australia, California, Spain + South America.

X. PRUNING, TRELLISING SYSTEMS + CANOPY MANAGEMENT

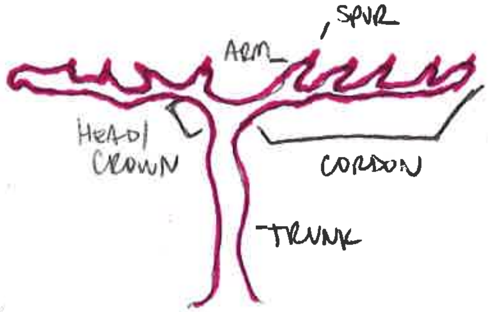
- Shoot structure is simple, w/ each node having the ability to produce tendrils or flower buds opposite each leaf.
- Tendrils exist to help the vine climb its host to find sunlight. When it does, the tendrils are discarded in favor of flowers, resulting in fruit production.

PRUNING

- an intervention that aims to improve vine fertility, encourage optimum canopy development, and regulate crop load.
- two different styles of pruning, both widely used

SPUR PRUNING

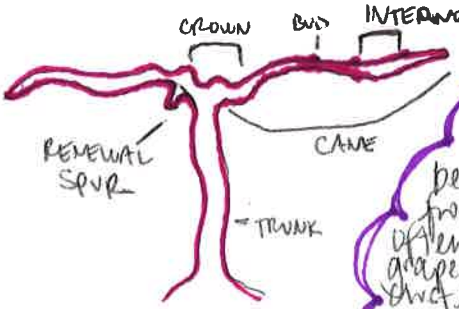
this example is cordon trained



- Spur pruning involves cutting the previous season's growth back to 2-3 buds on each cane. These are housed on a more permanent vine structure, usually consisting of a trunk & horizontal cordons.
- more typical in warmer climates: California, Washington + Spain.
- better to produce outstanding old vines.
- easier to perform in the vineyard & can be partially mechanized.
- Common styles include: gobelet, cordon de royat, geneva double curtain, Smart dyson

CANE PRUNING

can hinder the spread of infection, especially eutypa



Because cane-pruning allows more buds to remain and disperses the fruit-bearing shoots away from the crown, it is often implemented in grapes that produce smaller clusters (PN, Chard, Riesling) or when a vine's yields decrease.

- Cane pruning involves selecting one or two shoots from the previous season's growth and cutting them back to b/t 6 & 15 buds.
- These shoots form the basis of the following year's growth when they are tied down horizontally.
- A renewal spur is left for generating new canes.
- The only permanent vine growth is a vertical trunk → by limiting the vine's lignified growth to the trunk, **less frost prone**
- Commonly used in **cooler climate** growing regions: Burgundy, Sonoma, and Oregon among others.
- more laborious in the vineyard
- includes: guyot, scott henry

TRAINING

- training determines the form & direction of the trunk and arms (and the position of the shoots that develop from the buds retained at pruning.
- most are broadly classified as either

CORDON-TRAINED

- a trunk and two or more permanent horizontal arms, or cordons, are established → **spur-pruning** is typically practiced.

HEAD-TRAINED

→ basically, the absence of a cordon!

- a trunk is established and a few to several short main branches are developed that sustain renewal spurs (**spur-~~pruned~~ pruned**) or fruiting canes (**cane-pruned**).
- head-trained + spur-pruned = **goblet** (no trellis - vine is free standing)

TRELLISING + CANOPY MANAGEMENT

- canopy management techniques are aimed at:
  - achieving optimum leaf & fruit exposure to the sun
  - reducing the risk of disease → spray penetration + air circulation
  - ~~pushing~~ balancing the quality to yield ratio
- techniques include

long term: trellising
↳ can be used to increase canopy surface area + decrease canopy density.

short term (renewed annually): trimming, shoot thinning + leaf removal

↳ In particular, the use of high vertical shoot positioning (VSP) systems and divided canopies (such as Smart-Dyson + Scott Henry) have been effective means of getting highly vigorous vines into balance.

TRELLISING SYSTEMS

GOBELET

seen in S. Australia, Rioja, old vine Xin, S. France grenache.

- an old + simple technique. Spurs are arranged around the head of the trunk or short arms coming from the top of the trunk.
- only really used in **warm-dry** climates in low vigour situations.
- also known as bush vines, **alberello** (Italy) and **en vaso** (Spain)
- **no trellis, head-trained, spur-pruned**

GUYOT

- **head-trained, cane-pruned**
- one of the most popular cane-pruned systems, w/ a **single** or **double** cane layered horizontally from the head of the trunk.
- one of two renewal spurs are left
- suited to **Old World**, low **vigour** vineyards

CORDON DE ROYAT

- simple, **spur-pruned**, **cordon-trained** system, usually w/ a unilateral cordon spreading from a low trunk. Variations include a double cordon.

VERTICAL SHOOT POSITIONING

seen in **Bdx**, **Burgundy** + **Champagne** using a short trunk w/ close planting to increase vine stress. In **Alsace**, **Germany** + **New World**, it is employed using a higher trunk.

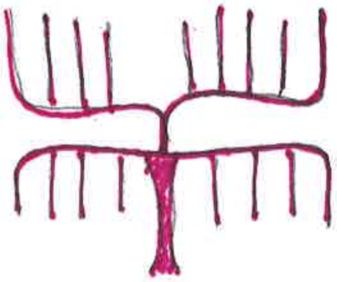
- widely adopted system where shoots are trained vertically upwards in summer, held in place by foliage wires.
- leads to relatively tall canopies and is suitable for mechanization
- may be **Spur** or **cane** pruned

TRELLISING SYSTEMS, CONT.

SCOTT HENRY - A **split-canopy** trellising system where the shoots are separated & divided into **upwards** + **downwards** growing systems, held in place by foliage wires. It is useful for **high vigour situations**.

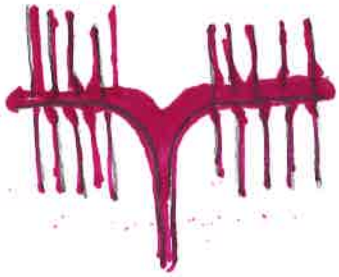
↑
Oregon winemaker + retired aerospace engineer

- can be **spur** or **cane** pruned (traditional cane)
- advantages include lower disease pressure, improved grape quality and higher yields.



SMART-DYSON - Developed by Richard Smart & John Dyson, this is a variant of the Scott-Henry trellis, w/ curtains trained up and down from **just one cordon**.

- **split-canopy** system

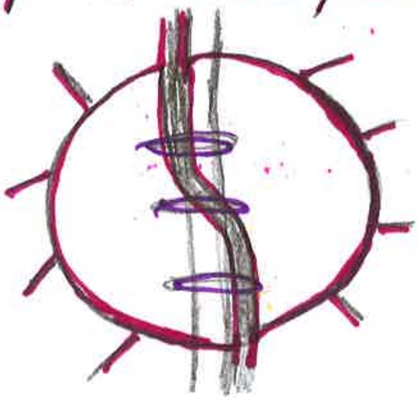


- always **cordon-trained**, **spur-pruned**
- more suitable for mechanical harvesting than most cordon-trained systems (and equally as suitable for mechanical pruning)

TRELLISING SYSTEMS, CONT.

DOPPELBOGEN - "**Double bow**" system for riesling vines common in the Mosel-Saar-Ruwer.

- Each vine is singly staked and two canes are bent round into a bow shape.
- **Single-staked** vines are common in areas w/ very **steep slopes** (also N. Rhône) where any sort of trellising is impractical.
- **Cane-pruned, head-trained**



EVENTAIL - French term for "fan"

- Cordon system w/ a number of arms arising from a short trunk, each bearing a short cane. Popular in Chablis + Champagne.

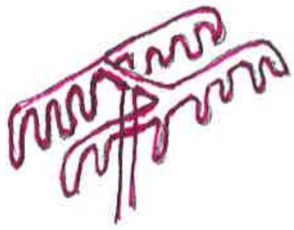
Spur!

Geneva, NY!

GENEVA DOUBLE CURTAIN - Split canopy system, w/ **cordons** grown high on two parallel horizontal trellising wires, w/ shoots bending down.

Spur-pruned

- aims to improve grape quality by reducing shade w/ a dense canopy, by dividing the mass of foliage in two.
- good for high vigour + New World



TRELLISING SYSTEMS, CONT.

LYRE - A variant on the Geneva Double Curtain. Was developed at Montpellier in the 1980s.
- Priciple advantages are improvement to the canopy microclimate resulting in less shading of foliage + fruit.
- **2 cordons**, like GDC, but fruiting canes are grown **upward** rather than downward (tends to be @ a lower height)
- preferred for medium vigor vines
- usually **spur-pruned**, but can be **cane-pruned**.

TENDONE - Italian term for the ~~tendone~~ **arbor** or **pergola** system — common in parts of Italy (Veneto), Portugal (Vinho Verde), Argentina, Chile
← known as **enforcado**
- can yield a lot of fruit, but fruit shading is a problem, and quality tends to be lower → fruit hangs below canopy and is shaded.

↑ tends to be called tendone when the canopy is horizontal (vs. inclined)

BASKET - often used for free-standing vines where **canes** are wound around one another for mutual support. **Head-trained**.
- common for Santorini Assyrtiko (b/c it is so windy)

↑ aka "wreath" or "kouloura"

XI. NATURALNESS IN WINE: HOW MUCH MANIPULATION IS ACCEPTABLE?

- SO_2 - Sulphur Dioxide
  - antioxidant
  - microbicide - prevents the growth of harmful bacteria & rogue yeasts at different stages.
  - produced naturally during fermentation

XII. MICRO - OXYGENATION

- also known as microbullage
- winemaking technique for adding very low levels of oxygen to a developing wine over an extended period via a ceramic device placed at the bottom of the fermentation tank.
  - ↳ designed to simulate the slow, control oxidation of barrel-ageing in wines that are kept in stainless steel.
- the technique was developed in the early 1990s by Madiran winemaker Patrick Ducournau.
- micro-oxygenation aims to:
  - build optimum structure
  - provide color stability
  - increase the suppleness/roundness
  - reduce herbaceous/vegetal notes
  - stabilize reductive qualities.
- main supporters include Chile + California, w/ France + Australia behind them.
- Three different stages of oxygen exposure:
  - Hyper-oxygenation (pre-ferment) - causes tannins to drop out of the must - commonly used in riesling + Champagne.
  - Macro-oxygenation (during-ferment) - boosts yeast health.
  - Micro-oxygenation (post-ferment): builds structure by encouraging the phenolic compounds to polymerize. Also oxidizes ethanol to acetaldehyde.

XIII. BARRELS + THE IMPACT OF OAK

- Four basic organisms that are crucial to wine production:

2 microbes + 2 woody plants

- yeast (Saccharomyces)
- lactic-acid bacterium (oenococcus)

- vitis vinifera
- **Quercus** (oak)

3 styles used to make barrels

Quercus Alba
from America!
Low phenol content, very high concentration of aromatic substances (lactones)

Quercus **Sessiliflora** (Quercus **Petraea**)
from french forests, particularly in the central + Vosges region
→ would include Nevers, Allier + Tronçais.
Contributes more aroma + less structure. this oak withstands weather better than Robur, and is thus much more planted now.

Quercus **Robur** (aka Quercus **Pedunculata**) + English oak
from french forrests, pricipally in Limousin, Burgundy + the South of france
Highly extractable polyphenol content; makes wines that are more structured & less aromatic. wider grained than Sessiliflora.

though certain oak is more common in certain forrests, both species grow in all six main forrests of france.

french oak tends to be rendered neutral by its 5th fill, while it takes 7-8 fills for American oak to be rendered neutral.

~~**~~ Coopers tend to not distinguish b/t the two species in their workshops → pay more attention to forrest + size of grain

1 style used to make cork
Quercus Suber

OAK

THE HISTORICAL IMPORTANCE

- everything used to be shipped in oak + oak was needed to build ships.
- 32% of france is forrest → only straight trees that grow fast are permitted to remain.
- trees are a minimum of 120 years old + 25 inches in diameter before they are cut.
- when they are cut down, first the canopy is trimmed off, then the tree is cut @ the base of the trunk, then the tree is divided into one meter sections.

COOPERAGE

- french oak must be cut along its vertical sap channels called medullary rays
  - ↳ Because American oak has ~~many~~ a higher amount of tylose - which are outgrowths from neighboring cells that block xylem vessels - they can be sawn in a number of planes + still be unpenatrable. Yields about 50% vs. 20% for french oak.
  - ↳ french oak creates staves of more uneven size, make cooperage more laborious.

Splitting (french) vs. Sawing (American)

- some coopers ignore provenance of oak and mix staves based on tightness and quality of grains (françois freres) while others would only include staves from a single forrest in the same barrels (Remond)
- before oak is used for barrel construction, it must be **seasoned**.
  - this is carried out to bring the humidity levels of the wood into line w/ the environment it will be used in ~~&~~ to allow some chemical modifications to take place.
  - 2-3 year process
  - takes place outdoors, normally → can be artificially simulated in ovens, but the chemical changes don't take place (to soften tannins + bitterness + increase aromatic compounds).

- After seasoning the barrels are shaped into place - the staves are shaped together w/ the assistance of metal rods + heat.
- toasting of the finished barrel happens next.
- standards for toasting vary considerably across ~~barrels~~ cooperages.
- merrandier = stave-maker

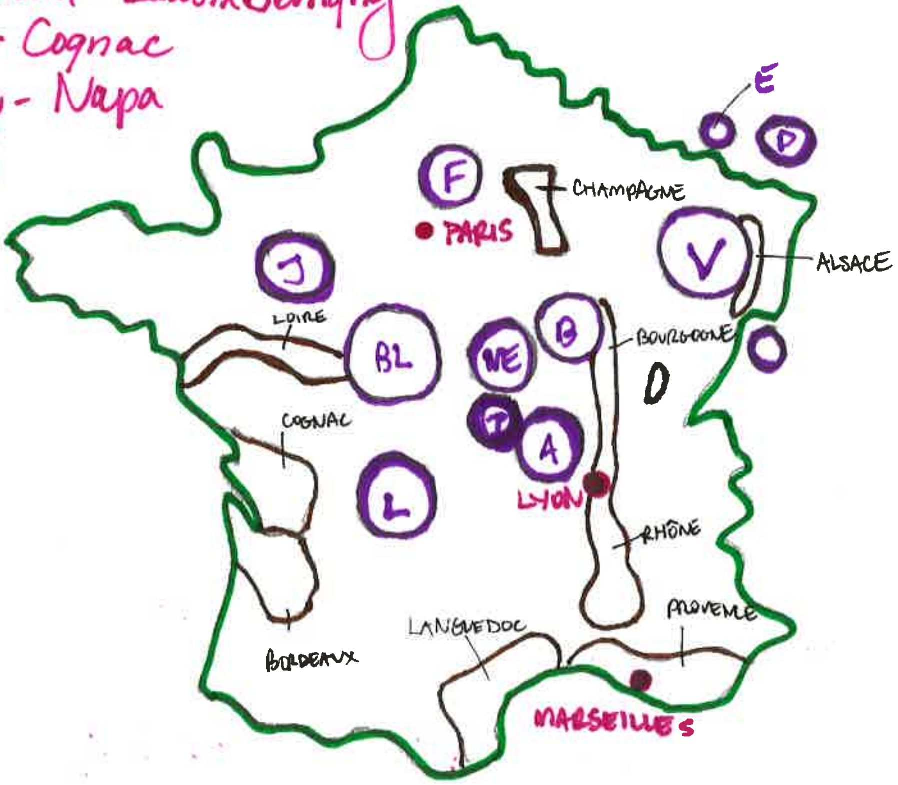
↳ a finished stave is a douelle or douve & is made after the merrains have aged.

THE BENEFICIAL EFFECTS OF BARRELS ON WINE

Flavor Compound	Characteristics	Influence of Manufacturing
Lactones	- coconut is the main one, w/ potential cedary, spicy, and herbal notes.	- toasting is thought to reduce overall lactone levels. - seasoning can affect the supporting characteristics to coconut.
Vanillin rare for red wines b/c they are fermented on their skins	- If wine is fermented in oak barrels, yeast metabolism reduces vanillin concentration - thus, barrel fermented wines have less overt oakiness than those fermented in steel & transferred.	- Levels can be increased by toasting, but decrease at high toasting levels.
Guaiacol	- char-like, smokey aroma.	- formed by degradation of wood lignin during toasting & thus increased at high toast levels.
Eugenol	- clove	- increased during toasting + seasoning.
Furfural	- caramel, butterscotch, almond.	- produced during toasting
Ellagitannins	- tannis absorbed by the wine from the wood → astringent.	- concentration decreases at high toasting levels.
Oxygen	- color is intensified b/c of reaction b/t tannins + anthocyanins + tannins are softened through polymerization.	- oxygen passes through the wood itself, the gaps in the staves + the bunghole.

FAMOUS COOPERS:

1. françois freres – St. Romain, Burgundy
2. Tonnellerie Remond - Ladoix Serrigny
3. Taransaud – Cognac
4. Seguin Moreau - Napa [french oak]



A = Alliers – similar to Nevers, but usually more tight-grained in structure.

B = Bourgogne (Bertranges) – just east of Nuits-St-George, Cateaux forrest. Similar to Limousin in high lactone/vanillin content (both Quercus Robur)

BL = Blois

E = Ettelbruck (Luxemburg)

F = Fontainebleau

J = Jupilles

L = Limousin – tough + course (apparently the result of poor growing conditions). Adds a vanillin note, but wines made in this oak tend to be more aggressive, simple + well suited to Cognac, where it is used most often.

N = Neuchatel (Switzerland)

NE = Nevers – medium to tight grained. Barrels made from Nevers oak are said to contribute a spicy, cinnamon-like flavor. If not toasted enough, they tend to contribute aggressive tannin.

P = Palatinat (Germany)

T = Troncais – a subsection of Allier. Trees of great size w/ the tightest grain → a favorite of winemakers looking for slower extraction & more finesse. Small + sought after.

V = Vosges – slightly wider grained than Allier + Nevers, though still on the tight side.

XIII. ALCOHOL REDUCTION + MUST CONCENTRATION

- the fundamental problem of:
  - grapes having an excess of sugars by the time they are phenolically ripe (warm regions)
  - grapes lacking the requisite sugar when they are phenolically ripe (cooler regions / dilution from rain (@ harvest)

REVERSE OSMOSIS

- if two liquids are seperated by a semi-permeable membrane, water flows across the membrane from the the more concentrated solution to the less concentrated solution. By increasing pressure, you can reverse
- Key uses for this technique:
  - removing water from grape must
  - removing alcohol or VA from a finished wine
  - removing a phenol that contributes to the negative flavor of brettanomyces.

Seperates the colorless, flavorless **permeate**: water, alcohol + acetic acid. The remaining wine is the **retentate** (phenolics + flavor compounds w/o alcohol). The alcohol is distilled off & water added back to create a lower alcohol wine.

ALTERNATE METHOD OF ALCOHOL REDUCTION: **Spinning cones**: seperates volatile fractions from the wine by means of centrifugal force and vacuum. These fractions are then blended back once the alcohol has been removed.

Legal in EU, but volume decrease cannot exceed 20% and a 2° max. potential alcohol increase.

The "traditional" technique of **Chaptalization** ignores any flavor dillution from rain & just addresses alcohol deficiency.

ALTERNATE METHODS of ~~Alcohol Reduction~~ MUST CONCENTRATION: **Vacuum distillation**: involves heat, which can damage the wine.

ALSO: **Saignée** (increases the ratio of juice to skins), **Cryo-extraction**, reverse osmosis of finished wine.

XV. SULPHUR DIOXIDE

FREE + BOUND FORMS

- bound forms have insignificant **antioxidant** + **antimicrobial** properties.

Markets for non-sulphited wines:

- Jacques Néauport - consultant whose inspiration was the late Jules Chauvet
- Néauport has consulted for Pierre Overnoy & Marcel Lapierre among others
- one main technique is carbonic maceration under v. cold conditions.

THE IMPORTANCE OF PH

- at **higher pH** levels (lower acid), more total SO_2 is needed to get the same amount of free SO_2.
- SO_2 is more effective at a **lower pH** (higher acid)

→ double benefit of lower pH on sulphur effectiveness.

Keys for making successful low/no sulphite wine:

- good quality fruit
- cool temp. at every point in the supply chain
- employing an oxidative winemaking style
- keeping a spotless winery

HOW IT WORKS

- the most useful attribute is protecting wine against oxidation
  - ↳ does this by binding **aldehyde**, so we do not smell the oxidation.
- **botrytised grapes**
  - ↳ rich in an enzyme called oxidase, which is found often in damaged/fungal grapes
  - ↳ also high in compounds that bind free SO_2
  - ↳ Need LOTS of SO_2 to be effective.

EU, max SO_2:

- 160 ppm (mg/L) - dry red wine
- 300 - sweet wines
- 400 mg/L - botrytised wines

- **white wines** need more SO_2 to protect them from oxidation
  - ↳ **red wines** are rich in polyphenolic compounds, which give the wine a natural level of defense against oxidation.
  - ↳ white wines that have been handled reductively (stainless steel, inert gas) are especially vulnerable to oxidation.
- **antimicrobial** properties:
  - ↳ prevents the growth of & - at high levels - kills fungi (yeasts) and bacteria
  - ↳ sweet wines + unfiltered red wines are at most risk for bacterial problems.
- 3 stages where wine is likely to be exposed to considerable oxygen stress: [SO_2 additions are common at all three points]
  - at **crushing**
  - at the end of **malolactic** fermentation (or alcoholic if no MLF)
  - at **bottling**

XVI. REDUCTION: VOLATIVE SULPHUR COMPOUNDS

- **Reduction** + **oxidation** are opposites that depend on the relative absence of oxygen (reduction) and the relative presence of oxygen (oxidation).
  - ↳ the precise definition depends on measuring what is known as **redox potential**.
- Exposure to oxygen through winemaking practices such as racking, topping up, and filtering increases redox potential (lowering ability to display a reductive character).
- The effect of oxygen exposure is more severe in white wine → their redox state changes more easily.
- SO_2 lower redox potential
- ~~Lees stirring~~ / yeast **lees** scavenge oxygen, also lowering redox potential → stirring can help prevent reductive aromas (promotes some oxygen ingress)
- an excess of reduction can produce off flavors coming from an excess of volatile sulphur compounds.
- "reduced" = sulphidic
  "oxidized" = adelhydic
- **Screwcaps** encourage reduction → tightest seal possible.
- Sulphur-containing **mercaptans** (**volatile thiols**)
  - ↳ class of aroma compounds

XVII. MICROBES + WINES: YEAST + LACTIC ACID BACTERIA

- yeast = unicellular fungi
  - ↳ of the estimated 1000 volatile flavor compounds in wine, at least 400 are produced by yeast.
  - ↳ Saccharomyces cerevisiae is the main cultured wine yeast
- choice b/t native & cultured yeasts
- spontaneous fermentation
  - → things take a while to get going! → pied de cuve can move things along.
  - → risk of spoilage, particularly acetobacter (the acetic-acid bacterium that turns wine to vinegar).
  - → S. cerevisiae is the only yeast that survives past 5-6% alcohol.
  - → SO_2 on crushing also favors S. cerevisiae and can kill some weaker native yeast strains.
  - → Cooler temps favor wild yeasts, whereas higher temps shift in favor of S. cerevisiae.
- why spontaneously ferment?
  - → ideological
  - → can produce a slower, cooler ferment, burning off fewer aromatics.
  - → cheaper

MALOLACTIC FERMENTATION

Basic conditions necessary to conduct mlf: (also, tools to block mlf!)

1. pH - few mlf strains can initiate at pH's below 3.0.
2. Malolactic bacteria are inert below 15°C / 59°F
3. free SO_2 - high levels can inhibit!

- carried out by lactic-acid bacteria, it involves transforming malic into lactic acid → softens the wine's acidity.
- if wines do not undergo mlf, lactic-acid bacteria can cause secondary fermentation in the bottle, w/ the formation of small bubbles of CO_2.
- mlf stabilizes color in red wines ↱ can inoculate w/ lactic-acid bacteria to induce.
- mlf is often carried out in barrel to integrate the oak character.
- mlf also produces ethyl lactate, which enhances the sensation of body and diacetyl, which can smell buttery @ higher concentrations.
- Lactic-acid bacteria can cause off aromas itself, which can be controlled w/ temperature (lower) + free SO_2 (higher).

XVIII . BRETTANOMYCES

- Brett is a yeast - a unicellular type of fungus, not a bacterium.
- Dekkera = the ascospore forming form of the yeast, while Brett = the non-spore forming type.
  - ↳ 5 recognized species of Brett/Dekkera, w/ **B. Bruxellensis** being most relevant to wine.
- predominantly **a red wine problem**:
  - → red wines are far higher in **polyphenol content** & they generally have **higher pH**. Both factors encourage Brett development.
    - ↑ the compounds ~~for~~ are the precursors for volatile phenols responsible for bretty odors.
    - → potentially b/c SO2 is less effective w/ higher pH.

- Sugar + a nitrogen source are needed for Brett to grow.
- Controlling Brett:
  - ↳ maintaining high free-SO2 levels (lower pH is helpful here)
  - ↳ Velcorin / **DMDC** → works by deactivating enzymes in microbes

XIX. CORKS, SCREWCAPS + OTHERS

Cork!

- comes from the bark of the cork tree, Quercus Suber.
  - most trees, if stripped of their bark, would die, b/c that's where the cells for new growth are located.
  - Quercus Suber has such a thick bark that it can be stripped of the mature trees w/o harming them.
  - cork can be compressed to about half its width w/o losing flexibility, and it has the remarkable property of being able to be compressed in one dimension w/o increasing in another.
- TCA!
  - 2,4,6-trichloroanisole
  - approximately 1/20 bottles is affected.
  - Seems to go noticed in white wines more than reds.
- Other issues relating to cork performance:
  - oxidation
  - is cork a neutral closure?
  - flavor scalping
- Three options for combating cork taint
  1. eradicate TCA from natural corks
     - **Sabaté**, the world's second largest cork manufacturer, has developed its "diamond" practice, which uses CO_2 to draw volatile compounds out of the cork.

       acquired and now known as ~~[illegible]~~ Oeneo, which counts Seguin Moreau as a subsidiary.
     - Amorim - the world's largest cork producer - has their own process called ROSA - a steam cleaning system for "technical" (composite) corks.
  2. Alternate closures
     - synthetic (plastic) - oxidizes easily
     - DIAM
       - users include Fèvre, Benoit Droin, Hugel, Bouchard, Jadot, Bindi
       - DIAM has two factories, one in Roussillon + one in Extremadura.
       - "MYTIK" is the brand of DIAM for sparkling wine.
       - objections include "too airtight", still some TCA, and a "gluey" note.

XIX. CLOSURES, CONT.

expands when heated to fill spaces b/t cork particles

② Alternate closures, cont.

- DIAM = original patent was established by Sabaté.
  (cont.) = DIAM is 95% processed cork, the rest is acrylate & polyurethane → the cork is processed w/ pressurized CO_2, which is able to nearly eradicate TCA.

  a binder

  = three different permeability levels
- Screwcaps = aka Stelvin or ROTE ("Roll-on Tamper Evident)
  = good for long-term aging - still the question?
  = born in 1959 when the French Company La Bouchage Mécanique introduced the Stelcap-vin & manufacturing rights were acquired by Australian Consolidated Industries in 1970.
  = 2000 → turning point for Aussie wine industry
  = 2001 → New Zealand Screwcap Initiative
  = two parts
    - the cap, made of alluminum alloy
    - the liner, made of expanded polyethylene wadding. This is typically covered w/ a tin foil layer that acts as a barrier to gas exchange, overlain by a PVDC film that provides a neutral surface for contact w/ the wine.
- Vino-Lok = glass stopper invented by German co. Alcoa in the early 2000s.
  = the seal is formed by a circular polymer disk that tastes neutral, is alcohol & acid resistant, and mimics the oxygen transmission of natural cork.
- Zork = plastic "peel & reseal"

XX. THE SCIENCE OF TASTING

WINE TEMPERATURE

- at higher temperatures, aromatic compounds (and ethanol) become more volatile. More expressive at first, but delicate nuances can be lost.
- lower temperatures suppress the perception of sugar.

VISUAL APPEARANCE

- can hint at grape variety, condition of fruit, and winemaking.
- red + white wines extract color from polyphenols in grape skins. Other factors that influence color:
  - oak usage
  - oxidation
  - age
  - botrytis
  - pH
  - reduction
- red wine color results from the presence of **anthocyanins**: the red/blue/black pigments in grapes, which are almost always found in the skins.
  - five different anthocyanin compounds are found in red wine, malvidin being the dominant.
  - these compounds are not stable in young wines, but react w/ tannins to form complex pigments, which gradually become larger as wine ages, to the point that they become insoluble & precipitate → **sediment**.
  - Oxygen has an important role in facilitating the process of phenolic polymerization.

post-fermentation sulphur dioxide additions bleach anthocyanins →

  - the color of pigments depends on the acidity of the grape must & the concentration of **sulphur dioxide**: they tend to be redder at a lower **pH** (more acid) and more purple at a higher pH.
- the accumulation of anthocyanins in red grapes during & after veraison is **enhanced by sunlight**, but actually **inhibited by heat** → cooler growing seasons may actually produce darker colored wines than hot ones.
- anthocyanins dissolve more readily in water than other polyphenols (eg. tannins) and thus are extracted first.
  - **pre-fermentation cold-soaks** build color
  - color will decrease w/ longer macerations (i.e. Barolo), but be more stable over time

XX. THE SCIENCE OF TASTING

VISUAL APPEARANCE, CONT.

- **oxidation** + **oak usage** are key components in wine color.
  - as various polyphenols oxidize, the wines undergo color change.
  - white wines darken as they oxidize, red wines lose color pigment.

- **botrytized wines** in general show a marked oxidative hue, courtesy of **laccase**, an enzyme produced by botrytis cinerea that oxidizes a wide range of phenols in the must + relatively unaffected by SO_2 additions.

- **oak tannins** - plentiful in new barrels, but not in neutral - stabilize & augment color.
  - ↳ compare a Gran Reserva Rioja in used American oak w/ a Ribera del Duero in new french oak for a short amount of time.
  - ↳ white wines aged in new oak barrels leach color + display a golden hue.

- **acylated anthocyanins** are anthocyanins that have undergone a chemical modification to make them more stable & increase their extraction.
  - ↳ Pinot Noir is the only grape that has been proven to lack acylated anthocyanins.

- **clarity** + **turbidity**:
  - the clarity of a wine is affected by density (concentration) of color + a liquid's turbidity.
    - → indicates a measurement of haziness caused by microscopic solid particles in suspension w/ in a liquid.
    - → can render a wine translucent rather than transparent b/c of the ability to refract light.
    - → can be caused by age & lack of fining/filtering in youthful wine.
  - **Opacity** + result of a highly concentrated, dark color.
    - ↳ an opaque wine may not show turbidity, but it is nonetheless **not clear**.
    - → Thus, lack of clarity can come from a highly concentrated, dark color or from turbidity.

XX. THE SCIENCE OF TASTING

VISUAL APPEARANCE, CONT.

- **rim variation:**
  - as wines age, the color at the rim of the glass will begin to show signs of oxidation before the color @ the wine's core.
  - a less obvious feature in white wines.
- **visible sediment:**
  - common is older red wines, consists of precipitated tannins, anthocyanins & other solids that fall out of suspension.
  - ~~tartaric~~ **tartrate crystals** - potassium bitartrate crystals + calcium tartrate crystals - may appear, signalling that the wine was not cold-stabilized.
  - young, unfiltered wines can throw sediment as well.
- **Spritz + effervesence:**
  - slight spritz can occur in young wines bottled early.
    - ↳ an excess of dissolved CO_2 becomes sealed in the bottle.
    - ↳ common in Spanish Albariño + Austrian GV.
    - ↳ especially common in screwcap-closed bottles.
    - ↳ Nouveau + young, carbonic red wines can display this.
  - intentional effervesence requires the presence of nucleation sites w/ minute air pockets trapped inside them.
- **tearing:**
  - tears/legs are small rivulets that appear along the film coating the inside of the glass after swirling the wine.
  - slow-forming, slow-moving, well-defined tears indicate high alcohol, but have no relationship w/ sugar, glycerol or viscosity.
  - **staining** merely reflects density of color + extraction.
  - tears occur b/c of the varying evaporation rates & levels of surface tension in water & alcohol (ethanol).
    - ↳ wines of higher alcohol content require more ethanol to evaporate prior to formation of tears than wines of lower alcohol content → "slow-forming tears" = higher alcohol...
- **viscosity** = the molecules in a liquid's ability to move within itself
  - ↳ high viscosity is caused by alcohol (mass) + sugar.

XX. THE SCIENCE OF TASTING

THE NOSE

FLAWS:

① TCA (trichloroanisole) + TBA (tribromoanisole) - **CORK TAINT!**

- caused by degradation of bacteria & fungi
- in the past, chlorine bleaching of corks exasperated the problem. Chlorine is a haleophenol, which is ~~the same class as TCA.~~ a precursor of TCA.

② **BRETT**

- Brettanomyces Bruxellensis - native to the Senne Valley of Belgium. → YEAST!
- prefers higher pH, polyphenols + lower SO_2
- Brett also produces acetic acid (sour ~~aroma~~ aromas of barnyard + bile)

③ **VOLATILE ACIDITY** → Acetobacter.

- [Acetic acid bacteria] converts both glucose + ethanol to **acetic acid**.
- Unlike the fixed tartaric + malic acids, acetic acid is volatile, it vaporizes + gives off vinegary aromas.
- Acetic acid bacteria requires oxygen to grow, and populations spike w/ open-top fermentations, racking & other oxidative procedures. [barrels that are infrequently topped off]
- the US govt. enforces max. acetic acid levels in wine:
  - RED WINE: 1.4 g/L (1.7 g/L if brix at harvest is > 28°)
  - WHITE + DESSERT: 1.2 g/L (1.5 g/L if brix at harvest is >28°)
- Dessert wines produced from botrysized grapes often have higher levels of acetic acid → the botrytis mold breaks open the grape skins, allowing the co-infection of the grapes w/ yeast or bacteria that produce acetic acid.

④ **ETHYL ACETATE**

- Ethyl acetate is an ester of acetic acid and ethanol - smells like nail polish remover.
- Acetic acid bacteria generate ethyl acetate, but other microorganisms may synthesize it as well → it often appears hand-in-hand w/ VA, but the causes can be distinct.

XX. THE SCIENCE OF TASTING

THE NOSE, CONT.

FLAWS, cont:

⑤ **OXIDATION**

- Some winemakers prefer to allow deliberate oxidation for whites during crushing & pressing: the juice browns as phenolics in the must oxidize but freshness returns during fermentation as these polymers drop out → widely practiced for Chardonnay + barrel fermented whites + protects against in-bottle oxidation.
- techniques that lead to more pronounced oxidation in wines + sans soufre, long barrel aging, regular battonage + frequent racking.
- acetaldehyde + sotolon → first & second generation products of oxidation of ethanol, respectively.

⑥ **MADERIZATION**

- heat exposure → speeds up the process of oxidation & leaves wines w/ a cooked flavor.

⑦ **SUFUR**

- Hydrogen sulfide can be generated in the fermenting must by yeast. Highly volatile hydrogen sulfide is encouraged through low levels of nitrogen in the must, elemental sulfur residue on recently sprayed grapes, SO_2 additions + certain yeast strains → ROTTEN EGG
  - ↳ this can be corrected through aeration, or through the addition of the yeast nutrient diammonium phosphate (DAP).
- lees contact creates an environment favorable to reduction
  - ↳ battonage & racking can diminish it.
- when conditions for hydrogen sulfide production are favorable, a wine is said to have low redox potential → volatile sulfur compounds like thiols & thioethers are more likely to appear.
  - ↳ burnt match, cabbage, rubber
  - ↳ don't dissapate as readily as hydrogen-sulfide odors

XX. THE SCIENCE OF TASTING

IMPACT AROMAS

- Wine aromatics result from numerous volatile flavor compounds; some are present in grapes and some are byproducts of fermentation and other winemaking processes. Historically split into two categories

IMPACT AROMAS (create distinct varietal character)

↓

now adapted to include not just varietal character, but winemaking (i.e. oak), fermentation (i.e. VA) + viticultural (i.e. botrytis) factors.

CONTRIBUTING COMPOUNDS (add to complexity, but not varietal character)

- **PYRAZINE**
  - pyrazines steadily decrease in the weeks following veraison.
  - not only Bdx. grapes contain pyrazines, and many others can display these notes, especially if harvested underripe.
  - the orange Asian ladybug, when they get into aging or fermentation vessels can also secrete pyrazines → 2004 (and, to a lesser extent, 2011) in Burgundy
    → 2001 in Ontario.

- **MONOTERPENES**
  - family of related compounds responsible for the highly aromatic, floral + sweet citrus notes of: Muscat Blanc à Petits Grains, Gewürztraminer, Torrontes, Viognier and (to a less extent), Riesling & Albariño.
  - → monoterpenes accumulate during ripening. Remain relatively unchanged by fermentation. Can degrade quickly w/ bottle aging.
  - Botrytis can also reduce monoterpene content — why Muscat is not a good candidate for noble rot.

- **ROTUNDONE**
  - responsible for the peppery aroma of Syrah, Gr. Mourvedre and the Italian grapes Schioppettino + Vespolina (also Mondeuse?, Pineau d'Aunis?)
  - accumulates in the grape skin & increases during the period from veraison to harvest.
  - a portion of the population is unable to detect Rotundone.

XX. THE SCIENCE OF TASTING

IMPACT AROMAS, cont.

- **THIOLS**
  - These sulfur-containing compounds are present as odorless precursors in ripe grapes → no discernable flavors in the unfermented fruit (unlike monoterpenes) b/c they are chemically bound to non-volatile substances like sugars or amino acids.
    - ↳ during fermentation, yeasts metabolize sugars + amino acids, making thiols volatile.
  - Rising hydrogen sulfide levels, light exposure + high levels of heat can also generate thiols.
  - aka **mercaptans**
  - can produce
    - DISTINCTIVE VARIETAL AROMAS: grapefruit, black currant, passion fruit, lemon grass + guava + "cat pee"
    - OFF AROMAS: garlic, rubber, cabbage, onion
  - can also be associated w/ a roasted coffee note, that tends to be created during the barrel toasting process. Can also develop in Champagne aging, both before & after disgorgement.

- **NORISOPRENOIDS**
  - accumulate in the fruit's pulp, not skin. More common, volatiley, in red grapes. Sunlight intensifies development. Types:

1) Beta-damascenone: stewed apple, rose + honey → concentrated in Riesling + Chardonnay.

2) Beta-ionone + Alpha-ionone: violets + raspberries in red wine

3) Vitispirane: chrysanthemums, eucalyptus + camphor → accumulates in bottle aging. Tawny Port.

4) **TDN**: trimethyl-dihydronaphthalene → petrol/kerosene. TDN attains higher concentrations in warm, sunny climates and can develop w/ age. Other factors that influence: water stress, nitrogen deficiency, and selection of yeast strain.

XX. THE SCIENCE OF TASTING

Impact Aromas, cont.

- **ISOAMYL ACETATE**
  - an ester produced by yeasts during fermentation
  - at low levels, enhances fruitiness, but at higher levels creates a distinct banana / pear drop note.
  - cold fermentation temperatures (59-68°F) enhance the synthesis + retention of isoamyl acetate.
  - dissipates w/ bottle age
  - associated w/ pinotage, German wheat beers, bubblegum.
  - carbonic maceration is linked to it, as the process augments ester production, but many producers in Beaujolais believe the banana note in wines of the region was created by a popular commercial yeast.
- **DIACETYL**
  - produced in perceptable amounts @ the conclusion of MLF → butter, nuttiness.
- **LACTONES**
  - lactones are present in grapes as a type of ester, but most impact aromas are caused by fermentation of aging.
    - **Sotolon** = results from the reaction b/t acetaldehyde + glutamic acid – a second generation product of the oxidation of ethanol → curry, maple syrup, walnut, fenugreek.
      = plays a role in the oxidative styles of Sherry, Vin Jaune & Madeira.
      = is synthesized by the botrytis cinerea fungus.
    - **Whisky Lactone** = American barrels contain larger concentrations of whisky lactones than French → sweet, woody, coconutty fragrance.
- **DIMETHYL SULFIDE**
  - a thioether → commonly considered a fault → cooked cabbage + shrimp
  - at low levels → corn, black olive, truffle → older Champagne + Chardonnay

XX. SCIENCE OF TASTING

{ Goode groups wine-flavor compounds into 5 groups: acids, alcohols, sugars, polyphenols + volatile compounds }

THE PALATE

• SWEETNESS

- True sweetness reveals itself instantly on the palate.
- V. vinifera accumulates two main sugars – glucose + fructose.
  - ↳ twice as sweet & ferments more slowly.
- as sweet wines age, the impression of sugar diminishes, though the actual amount of sugar remains constant.
  - → sugar carmelization + Maillard reactions may be responsible for this altered perception.

• BODY

- primarily a function of the wine's viscosity (alcohol, sugar) + level of dry extract (sum of all dissolved solids: residual sugar, tannin and other polyphenols, fixed acids, glycerol + traces of minerals & other substances)
  - → can also be bolstered by oak aging + battonage.

• ACIDITY

- tartaric acid is the most important acid
- tartaric, malic + citric acids are the most common fixed (non-volatile) acids in grapes.
- tartaric + malic = 90% of a grape's acidity → they increase prior to veraison.
  - ↳ after veraison, tartaric acid will remain relatively stable, while malic acid will decrease.
  - ↳ particularly in warmer climates, very little malic acid remains at harvest.
- malic = apple, lactic = sour cream, tartaric = hard/vinous
- 3 measurements:
  - ① total acidity - the sum of a wine's organic acids, chiefly tartaric, malic + citric. Typically wines fall b/t 4.5 g/L (the EU minimum) and 9 g/L.
  - ② titratable acidity - similar sum, but easier to measure, and usually smaller values. measurement of titration is affected by cations, such as potassium, which can buffer acidity.

Both can be abbraviated to "TA"

XX. SCIENCE OF TASTING

THE PALATE, CONT.

- **ACIDITY, CONT.**
  - 3 measurements, cont.:
    - ③ pH - while ① + ② measure the quantity of acid in a wine, pH determines an acid's strength.
      - pH is a logarithmic scale, so a liquid w/ a pH of 5 is ten times more acidic than a liquid w/ a pH of 6.
      - white wines typically range from 2.9-3.5 pH; reds typically range from 3.3-3.8 pH
      - different types of acids have different pH values: tartaric is stronger than malic (lower pH), and malic is stronger than lactic.
      - does not directly corelate w/ quantity of acidity.

* TA tends to be a better predictor for the taste of acid.

- **MECHANISM** for acid accumulation
  - after veraison, grapes store sugar + malic acid decreases → respiration
  - ~~heighten~~ higher temperatures increase respiration, while cooler climates curtail it.
    - ↳ argument of the diurnal swing: malic acid respiration (loss) slows at night & when it is cool, but this doesn't slow sugar accumulation.
  - somewhat equally, warm regions w/ low nighttime temperatures (Ribera del Duero, Napa) and cooler regions w/ sunny growing seasons (Alsace, Pfalz) can retain acidity while still accumulating sugar.
  - harvest date → huge factor (think: Hunter Semillon)
  - Potassium rich soils tend to reduce acidity
  - Skins + stems can absorb tartaric acid ↳ longer macerations can lessen acidity.
  - aging in bottle can decrease acidity → tartaric acids react w/ ethanol to form ethyl acid tartrates → the sensation of acidity is rounded + diminished.

XX. SCIENCE OF TASTING

THE PALATE, CONT.

- **TANNIN + PHENOLIC BITTERNESS**
  - tannin = phenolic compounds that can tan (precipitate proteins) in leather; in wine, they contribute to bitter + astringent sensations, promote color stability + are potent antioxidants.
  - tannins can enter a wine through maceration w/ grape skins, seeds + stems, or from aging in oak barrels.
  - tannins are a sensation, while bitterness is a taste + back of the palate, appears after sweetness + sourness.
  - oak tannins & grape tannins are different types of compounds deriving from different parts of the plant.
    - ↳ oak tannins tend to be less astringent
    - ↳ grape tannins show a higher degree of bitterness.
    - ↳ oak tannins pervade the palate & are more striking on the finish.
    - ↳ grape tannins live in the front of the mouth.
- phenolic bitterness in white wines: created by pressing, crushing, maceration + skin contact
  - ↳ whole bunch pressing (i.e. no crushing) minimizes extraction of phenolics.
- white wines characterized by lower levels of acid often have increased levels of phenolics → these bitter compounds balance + preserve the wine.
  - ↳ high concentrations: Marsanne, Viognier + Gewurz
  - ↳ low concentrations: Albariño, PG, Grüner Veltliner + Fiano.

XX. SCIENCE OF TASTING

THE PALATE, CONT.

- **ALCOHOL**
  - ethanol, ethyl alcohol, a byproduct of fermentation, is the dominant alcohol in wine.
  - S. Cervisiae may produce up to 15% ethanol - above that, most yeast strains die.
  - Other alcohols - methanol, fusel alcohols, glycerol - play a small part.
  - higher levels of alcohol in a wine enhance sweetness & bitterness, but suppress acid + astringency.

- **GLYCEROL**
  - after ethanol + CO_2, the most abundant by-product of fermentation is glycerol
    - ↳ a non-aromatic sugar alcohol that typically appears in a range from 4-15 g/L in dry wines, w/ red's showing higher concentrations than whites.
  - can imbue a slightly sweet taste, but does not affect viscosity or weight.
  - botrytis leads to increased glycerol production.

ESTERS - formed by the reaction of organic acids w/ alcohols (during aging or fermentation)
- ethyl acetate is the most common ester in wine
  - ↳ acetic acid + ethanol

GLOSSARY

SHOOTS - new green growths w/ leaves, tendrils, and often flower clusters, developing from a bud of a cane or spur.

TENDRILS - twisting, clinging, slender stem-like structure on vines. (Tendrils) attach themselves to a trellis or post to provide support for the plant. They exhibit thigmotropism, a growth response to touch.

BUDS - an organ on a plant stem consisting of overlapping immature leaves or petals w/o protective scales. In viticulture, a dormant bud contains a larger primary bud & two smaller secondary buds
↳ can form leaves, flowers, or tendrils.

"undeveloped, primordial grape shoot"

CANE - a mature shoot after leaf-fall.

SPUR - a cane pruned back to one, two, or three buds.

CORDON - the woody framework of the vine, extending from the top of the trunk. A cordon-trained vine has a trunk terminating in one or more cordons, which are then spur-pruned (usually).

TRELLIS - a man-made structure, consisting of wood + wires.

TRAINING - the actions of pruning in winter & summer, and shoot & cane placement, so that the vine's trunk, arms, cordons & buds are appropriately located on the trellis system.