To describe modern wine making as simply as fermenting sugars (from grape juice) and yeasts into ethyl alcohol would be akin to describing the human body as digesting food into energy in order to sustain life. The chemistry is significantly more complex with a multitude of reactions and influencers present. There is a direct correlation between the composition and quality of the grapes and the quality of the resulting wine. The chemical components present in grapes and their accompanying structures comprise a broad spectrum of compounds each with specific roles and influences in the wine making process. Some compounds are primarily used to support plant grown while others are used specifically in the wine making process either in their natural state or are transformed in some fashion and then employed in this process.

Grapes are comprised of 80% clear juice, 8% skins, 4.5% seeds, 4.5% pulp, and 3% stems and collectively are known as pomace. Grape juice is made up of 79% water, 20% carbohydrates, 1% organic acids and trace amounts of organic acids, phenolicz, vitamins, minerals and nitrogenous compounds. The main chemical compounds present in grapes and or wines are listed in the chart below:

<table>
<thead>
<tr>
<th>Component</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>H2O</td>
</tr>
<tr>
<td>Carbohydrates (sugars)</td>
<td>Fructose, Glucose, Pectin, Pentoses</td>
</tr>
<tr>
<td>Alcohols</td>
<td>Ethanol, Glycerol, Higher alcohols, Methanol</td>
</tr>
<tr>
<td>Aldehyde</td>
<td></td>
</tr>
<tr>
<td>Organic Acids</td>
<td>Acetic, Amino, Citric, Lactic, Malic, Succinic, Sulphurous, Tartaric</td>
</tr>
<tr>
<td>Phenolics</td>
<td>Simple, Hydrolysable tannins, Condensed tannins, Anthocyanins</td>
</tr>
<tr>
<td>Nitrogenous compounds</td>
<td>Amino Ammonium, Protein, Residual</td>
</tr>
<tr>
<td>Minerals (ash)</td>
<td>Calcium, Chloride, Magnesium, Phosphate, Potassium, Sodium, Sulphate</td>
</tr>
</tbody>
</table>

**CARBOHYDRATES (SUGARS)**

Grapes accumulate sugars during development through the translocation of sucrose molecules which are produced by photosynthesis from the leaves. As the fruit ripens, this sucrose is hydrolyzed by the enzyme invertase into the 6 carbon sugars Glucose and Fructose.

By the time the fruit is harvested the grapes are comprised of between 15-25% simple (3, 4, 5, 6, or 7 carbon) sugars. Not all of these sugars are fermentable and therefore do not play a role in fermentation. For this reason no wine is ever fermented completely “dry” without any residual sugar(s).

During fermentation, the 5 carbon sugars (Glucose and Fructose) in grape juice are attacked by the yeast cells turning them into ethanol (ethyl alcohol) and carbon dioxide. In an aerobic (oxygen rich) environment, this reaction can continue converting the newly formed ethanol into water and carbon dioxide. A blanket of carbon dioxide is added to the fermentation vessel prior to the addition of yeast cells to stop this process and also stop the oxidization of phenols which are present.
The final alcohol level of wine is directly related to the sugar levels present during fermentation. Sugar also plays an important role in the resulting wine’s body and mouthfeel.

Winemakers sometimes add sugar (usually sucrose) in a process known as chaptalization. The only exception to this rule is Champagne and other sparkling wines where a small amount of liqueur d’expédition (typically sucrose dissolved in still wine) is added after the second fermentation in the bottle, which is known as dosage.

**GLUCOSE**
Glucose and Fructose are the two primary sugars found in wine grapes. In wine Glucose tastes less sweet than Fructose. Initially grapes contain much more glucose than fructose (5 to 1) but as the fruit ripens more fructose is produced and this ratio evens out (1 to 1) by harvest.

Late harvest wines typically have much more fructose than glucose.

Glucose is the first sugar broken down in the fermentation process. Glucose molecules link with aglycone, in a process that creates glycosides, which play a role in the resulting flavor of the wine because of the relation and interactions with phenolic compounds like anthocyanins and terpenoids.

**FRUCTOSE**
Fructose can taste nearly twice as sweet as glucose which explains why fructose is so important in the production of dessert wines. During fermentation, glucose is the first sugar consumed by the yeast and converted into alcohol. At this point fermentation can be halted (either by temperature control or by adding brandy spirits in the process of fortification) resulting in a wine with higher fructose and residual sugars.

The technique of sussreserve, where unfermented grape must is added after fermentation is complete, will result in a wine that tastes less sweet than a wine whose fermentation was halted. This is because the unfermented grape must will still have roughly equal parts of fructose and the less sweet tasting glucose. This is also why during chaptalization where sucrose is added (which is 1 part glucose and 1 part fructose) will usually not increase the sweetness level of the wine.

**SUCROSE**
Sucrose will typically be found only in trace amounts because during the ripening process it is hydrolyzed into Glucose and Fructose. Any sucrose added during chaptalisation is typically consumed during fermentation.

Pectins have no great importance in grape juice but must be broken down as they can create haziness in the finished wine.

**ORGANIC ACIDS**
Malic, tartaric, and citric are the 3 main acids which occur in grapes. Acids give grape juice its acidity and act as a buffer to maintain the pH at around 3.2-3.3. Acids are also a major contributor to the flavor balance of the juice and wine, providing the sharp acidity. They also play a very important role in wine directly influencing color, balance, and taste. During fermentation, acids protect the wine from bacteria. In wine tasting, “acidity” refers to the fresh, tart and sour attributes of the wine which is evaluated in relation to how well the acidity balances out the sweetness and bitter components of the wine such as tannins.

**TARTARIC ACID**
Tartaric acid, along with malic and citric, is all present in grapes. Concentration varies by varietal (Palomino high, Malbec and Pinot noir generally low). Tartaric acid in high concentrations does not get completely metabolized like malic acid and can remain throughout the fruit ripening process. Less than half of the tartaric acid is free standing with the majority present as potassium acid salt. During fermentation these tartrates bind with the lees, pulp debris and precipitated tannins and pigments.
Malic acid is often associated with the green apples flavor it projects in wine and is involved in several processes which are essential for the health of the vine. Concentration varies by grape varietal, Barbera, Carignan and Sylvaner being typically high. During plant and fruit development, malic acids levels decline due to respiration and tend to have a higher depletion rate in warmer climates. When malic acid is depleted or used up the grape is considered over-ripe or senescent. Winemakers compensate for this absence by adding extraneous acid in a process known as acidification. This process enhances the effectiveness of sulfur dioxide to protect the wines from spoilage and bacteria. Acidification also helps to preserve and stabilize the color of the wine.

Excessive malic acid can be reduced during winemaking through malolactic fermentation or MLF. Bacteria convert the stronger malic acid into the softer lactic acid resulting in a wine with a higher pH (less acid) and a creamy mouthfeel. The bacteria required occur naturally in oak barrels or can be introduced via a cultured specimen.

Wines from cool climate regions, such as Riesling, will have more malic acid and green apple notes than wines from warmer growing regions.

Red wines in general (more often than whites) have higher concentrations of malic acid and are put through MLF. One white wine that is a notable exception is oaked Chardonnay.

Lactic acid is much milder than tartaric and malic and often associated with milky flavors. This acid is typically not present in grapes but instead is produced during winemaking by lactic acid bacteria (LAB) which includes three genera: Oenococcus, Pediococcus, and Lactobacillus. These bacteria convert both sugar and malic acid into lactic acid through MLF. Some strains of LAB can produce biogenic amines which may cause red wine headaches for some wine drinkers. Winemakers can prevent MLF by using sulfur dioxide to stun the bacteria or by racking the wine off the lees quickly since lees are the food source for them.

CITRIC ACID
This acid is very common in many citrus fruits but typically found in very small quantities in grapes. Although winemakers can use Citric acid during acidification, tartaric and malic acids are more commonly used. The European Union prohibits the use of Citric acid for this process. Another reason is yeasts tend to convert citric acid into acetic acid.

ACETIC ACID
Acetic acid is typically not found or in extremely low concentrations in grape juice. During fermentation, yeast cells naturally produce small amounts of acetic acid. If the wine is exposed to oxygen, Acetobacter bacteria will convert the ethanol (ethyl alcohol) into acetic acid. This reaction is the primary cause of wine degradation into vinegar or “corked” wine. An excessive amount of acetic acid is also considered a wine fault when concentrations reach or exceed 600mg/l. which are the human taste level threshold.

BUTYRIC ACID
This acid is bacteria induced and can cause a wine to smell of spoiled Camembert or rancid butter.
PHENOLICS

Phenols are present in several parts of the grape including stems, seeds, skins, and pulp. Specifically, phenolic acids are primarily found in the pulp, anthocyanins and stilbenoids in the skin, and other phenols (catechins, proanthocyanidins and flavonols) in the skin and seeds. The specific type and locations play significant roles in adding flavor to both white and red wines influenced by the maceration process, i.e., contact with each of these individual parts.

Phenolic acids (found in the pulp or juice) are commonly present in white wines which usually do not go through a maceration period. Red wines typically go through a more lengthy maceration period having longer contact with the skins, stems, and seeds. The amount of phenols leached out during this process is known as extraction. These compounds contribute to the astringency, color, and mouth feel of the wine. Phenols fall into two primary categories natural phenols and polyphenols and are comprised of several hundred chemical compounds. Among these are phenolic acids, stilbenoids, flavonols, dihydroflavonols, anthocyanins, flavanol monomers (catechins) and flavanol polymers.

Further natural phenols can be separated into two categories flavonoids and non-flavonoids.

Flavonoids include the anthocyanins (involved in the color of wine) and tannins (which influence the wines mouth feel)

Non-flavonoids include the stilbenoids such as resveratrol and phenolic acids such as benzoic, caffeic and cinnamic acids.

FLAVONOIDS

Up to 90% of wine’s phenolic content falls under this classification. Anthocyanins are responsible for the blue to red colors found in flowers, fruits, and leaves. In most grapes anthocyanins are found only in the outer cell layers of the skin, with the juice remaining colorless. This is the reason why white wine can be made from red grapes. In order to provide color to the wine, the fermenting must needs to have contact with the skins to extract the anthocyanins. The exception to this rule is a small class of grapes known as teinturiers, such as Alicante Bouschet, which has a small amount of anthcyanins in the pulp which produces pigmented juice.

As red wines age the anthocyanins react with other compounds in the wine causing a change in color to a more brick red. The resulting molecules link up to create polymers that eventually exceed their solubility and drop out of suspension and become sediment.

Tannins are a diverse group of chemical compounds that can affect not only color, but aging ability and texture of the wine. Tannins typically are described as the part of wine causing the drying sensation and bitterness in the mouth created by a reaction with the proteins in saliva.

Tannins are found in the skins, stems, and seeds of grapes or can be introduced through the use of oak barrels or the addition of chips or tannin powder. The amount of tannins extracted from these parts can be regulated by the length of contact with the fermenting must. An excess of tannins can also be remedied by the use of fining agents such as albumin, casein, or gelatin which bind to the tannin molecules and precipitate out as sediments. The amount of tannins found naturally in grapes varies by varietal with Cabernet Sauvignon, Nebbiolo, Syrah, and Tannat having the highest concentrations.

As wine ages, tannins form long polymerized chains which come across the palate as softer and less tannic. This process can be accelerated by exposing wine to oxygen which oxidizes tannins to quinone-like compounds that are polymerization-prone.

Micro-oxygenation and decanting wines are two additional techniques to mimic the effect of aging on tannins through the introduction of oxygen.

Studies have shown that tannins provide a beneficial vascular health effect by suppressing the production the peptide responsible for hardening arteries.
NON-FLAVONOIDS
The Stilbenoid Resveratrol has received lots of press most recently because of the perceived health benefits it can provide. The highest concentrations can be found in the skins of grapes which translate into higher levels found in red wines because of the longer skin contact given during the maceration of red wines versus white wines. Grape varietals grown in cool damp regions with higher risk of grape disease tend to produce more resveratrol versus grapes grown in warmer dryer regions.

Phenols can come from various other environments such as oak barrels used for aging or cork stoppers used in the bottling process. Vanillin is a phenolic aldehyde that provides the vanilla notes to wines that have been aged in newer oak barrels.

Guaiacol (found in natural cork) is one of these molecules responsible for the cork taint wine fault.