Excerpts from a review by Brian Croser, TapaNappa Wines (Australia) of *Wine, Terroir and Climate Change* by John Gladstones (Wakefield Press, 2011). Printed in *Practical Winery and Vineyard* (Summer, 2012).

Water, roots and plant growth hormone effects on ripening:

Gladstones explains the ideal rainfall pattern and soil moisture response to achieve the best growth and ripening response from the root-derived hormones through the growing season (p. 29). The best quality depends on a "reliable enough wetting of the full soil profile in winter/spring, which allows the vine "to develop a fully comprehensive root system – which taps moisture to depth. The precarious moisture* balance of the post-veraison ripening period requires enough soil moisture stress to keep abscisic acid flowing from healthy roots and not so much stress that the roots lose activity and the canopy suffers desiccation as transpiration from the leaves exceeds water uptake by the roots.

Soil and wine:

The mineral composition of wine is a signature of its origin and, he speculates, must therefore relate to the unchanging base geology as opposed to the more dynamic mineral status of the soil. The hypothesis of the role of geology in determining the mineral composition of wine relies on the vine root system extending down to the parent rock material and the vine's xylem system becoming the main conduit for hormones and minerals after the phloem has closed down, from the roots to the ripening grapes late in the ripening process when the vine is dependent on deep moisture reserves. Some of these minerals are important as cofactors in the enzymes responsible for the synthesis of color and flavor compounds in the grape. This hypothesis explains the widely empirically observed but not scientifically proven assertion of soil and geology's major role in site terroir expression.

Hormones and ripening:

Hormone control of grape ripening is largely but not exclusively root-generated. In cool, humid soil, high latitude environments, the rapidly decreasing day length and temperature in the late autumn trigger abscisic acid production from the leaves which serves the same grape ripening stimulus as root-derived abscisic acid.

The developing seeds of the berries after flowering and fruit set contribute a hormone class called auxins. The main role of auxins is to delay the ripening effects of abscisic acid until the embryos in the seeds are fully developed, a logical result of natural selection.

The difference in the time of budburst between varieties is significant but the main difference in harvest time between maturity groups is created by the length of "phase 2 – lag phase" of berry development, the time between fruit set and veraison. This is the period when seed produced auxin is holding off the final ripening effects of abscisic acid. The differences between varieties in this phase are largely responsible for harvest date differences. Tannin synthesis in berries finishes at veraison so the later ripening varieties with longer lag phases have more time to build up tannin content, an observation supported by the generally higher tannins of late- maturing varieties.

* "*precarious" for dry climates where either dry-farming or irrigation are needed to sustain the vine through harvest*

Site selection:

Gladstones' hypotheses guide site selection only to higher latitudes or at lower latitudes in cool, foggy, low rainfall maritime environments, with narrow daily temperature range and low temperature variability (that's us!). The ideal vineyard would be on a moderately steep north-east slope (south-west in the northern hemisphere), with its back to the prevailing winds at an altitude of 200-300 meters. The soil would be dark or red in color to absorb sunlight heat and re-radiate it at night, with high incidence of rock at the surface and throughout the profile for the best heat transfer to the vine's deep roots. The soil could be a duplex soil with a deep reserve tank of tightly moisture-holding clay and a free-draining, moderate fertility top soil or alternatively a free-draining top soil over a deep layer of water-holding limestone. A fully charged soil would allow vines to deplete soil moisture by mid-summer and stop growth before veraison. Then, small supplements of summer rain, the deep subsoil and underlying geology must provide barely sufficient moisture to achieve ripening with mild stress on the roots but not so much as to cause leaf senescence.

There are obviously many fine terroirs around the world that do not fully answer these criteria and especially many that have large daily temperature ranges (e.g. Mendoza-Argentina and Maipo-Chile). Such sites work because of the total absence of rain in the late autumn allowing the grapes to fully ripen despite the night temperature inhibition of phenological development and ripening.

A key physiological response is the formation and retention of aroma and flavor compounds in grapes and their expression in wine, which is at the very core of wine quality. Gladstones attempts to explain those environmental and genetic factors at work in the biosynthesis of the tertiary compounds at the core of grape flavor. He examines the environmental influences involved in wine quality defining balance of the retention of these aroma and flavor compounds in the grape and their potential loss by vaporization and chemical degradation. He speculates about the role of these compounds in wine style and quality, and the circumstances of appreciation of different wine styles.

Gladstones focuses on grape flavor formation, and perhaps of equal importance to wine style and quality, the optimal environmental conditions required to retain those flavors in the berries and their transfer into wine.

Gladstones refers to the "non sugar ripening process" which he defines as "the biosynthesis and the storage of aroma and flavor compounds (engustment), loss of malic acid and other acids; continued skin anthocyanin synthesis in red varieties; loss of herbaceous aromas and flavors and, very important, the maturation of tannins in seeds, skins, and cluster stems."

Regional/site differences in heat summation and temperature equalbility largely define site suitability for varieties of different maturation groups. He identifies the climate regime of the last 30 days of ripening period as the most influential for the production and retention of aroma and flavor compounds and the polymerization and extractability of the phenols of the skins and seeds.

Climate is not the only terroir attribute at play in the last 30 days of ripening. The role of abscisic acid is essential to the continuity of the ripening process and the synthesis of tertiary aroma and flavor compounds. Responding directly to soil environmental conditions, the roots are the main source of abscisic acid.

The quantum and quality of the tertiary aroma and flavor compounds synthesized is profoundly influenced by atmospheric temperature. Gladstones identifies the optimal mean temperature of the last 30 days of ripening for the synthesis of flavor and pigment in red varieties as 18^o to 22^oC and for the best attributes of delicate white and sparkling wines the mean can be as low as 12^o to 15^oC. (In Table 3.1 on page 36) the ideal temperature regime, sunshine hours, rainfall, and afternoon humidity for the final 30 days of ripening for different wine styles ranging from sparkling wines, through light, medium, and full bodied table wines are defined.

The synthesis of volatile aroma and flavor compounds is optimized when the abscisic acid ripening signal is strong, the light is diffused by clouds or the low sun angle at high latitude to maximize photosynthesis without harmful radiation hearing, the day temperature is cool, the night temperature is warm, and the afternoon humidity is moderate to high to restrict transpiration. He argues these narrow daily temperature range attributes are characteristic of great terroirs.

The importance of the temperature equability (narrow daily temperature range) of a site, feeds into the aroma and flavor story. Low day temperatures at moderate humidity favor the direct synthesis of aroma and flavor compounds and the accumulation of sugars as starch during the day. At night, the surplus assimilate is translocated to the berries as sugar, the substrate for aroma and flavor volatilized from the berries at elevated temperatures and in the case of very high berry temperatures they are chemically degraded. Aroma and flavor evaporation is an important concept.

The importance of moderate-cool bunch temperature to the retention of volatile aromas is contrasted with the evaporative loss of berry aromatics and the "dead fruit" character of berry shrivel which is caused by abnormal heat stress during final engustment.

The incidence of strong sunlight directly onto clusters creates an accumulative heating effect because of cluster geometry and the low number of transpiring stomates on berries which can raise berry temperatures 12^o to 15^oC above ambient temperature. This effect is especially accentuated in the black-skin grapes and results in the loss of volatile aromas.

Phenolic development:

The maximum amount of phenol has formed in the berry by the end of the lag phase of berry development. The lag phase is the period before veraison in which seed development is completed under the control of auxin. The length of the lag phase largely defines whether a variety is early or late ripening. In late ripening varieties the long lag phase allows the accumulation of more tannin and color (anthocyanin) than in early maturing varieties. This fits with the universal observation that later ripening Cabernet Sauvignon has more color and tannin than early ripening Pinot Noir. The short, cool ripening season of early maturing varieties allows for maximum retention of the low boiling point aromas and flavors and restricts the development of tannin astringency and bitterness. The prolonged lag phase and ripening season of late ripening varieties in warm climates allows the volatilization of the low boiling point aromatics and the accumulation of higher boiling point aromatics and astringent tannins. Achieving tannin maturity is a result of a reduction in the total amount of tannin which can be extracted from the berry <u>after</u> veraison. There is a larger reduction of the extractability of the smaller molecular weight tannins (catechins) in the seeds due to seed hardening than the larger molecular weight polymers (flavonols) from the skins. The catechins are responsible for bitterness and the flavonols for astringency, so the overall organoleptic effect is a softening of the total tannin astringency and the disappearance of bitterness. Early ripening varieties have less of all tannins but especially those causing bitterness.

The ecology of winemaking and drinking:

Wines made from early ripening varieties in cool regions are aromatic, relatively high in acid and low in tannins. Grape composition is responsible for these wine characteristics but also the low fermentation temperature in the cool autumn/winter of cool regions preserves and enhances these aromatic qualities. The Northern European people and cultures naturally value the cool climate wine styles as the best terror expressions of their regions. By contrast, the room temperature consumption of the natural wines of late-maturing varieties and warmer areas, to the need to "bring up the high boiling point aromatics that have survived warm ripening and fermentation and soften the perception of high tannins."