Impact of Vineyard Practices on Grape and Wine Composition

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Outline

Assumption:
Managing wine composition in the vineyard is effective

- General thoughts to think about
- Berry structure
- Berry development
  - Compositionally, time is the primary driver
- Response of plants to environment
  - Upshot: complex
- Managing composition in the vineyard
  - Temperature/light/exposure
  - Thoughts wrt phenolics

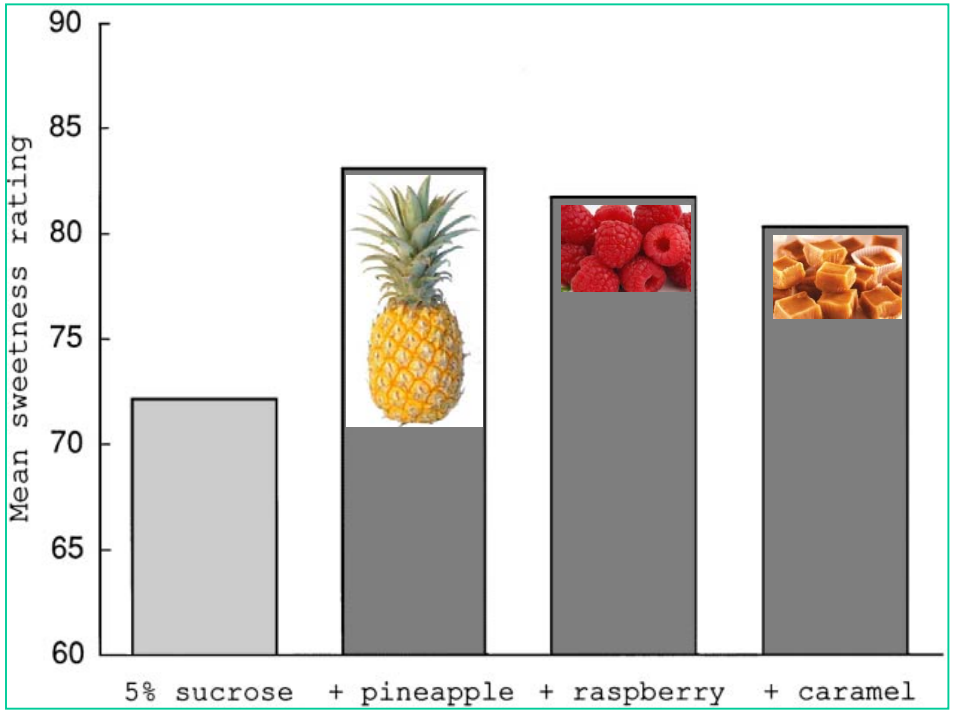
Wine composition and perception

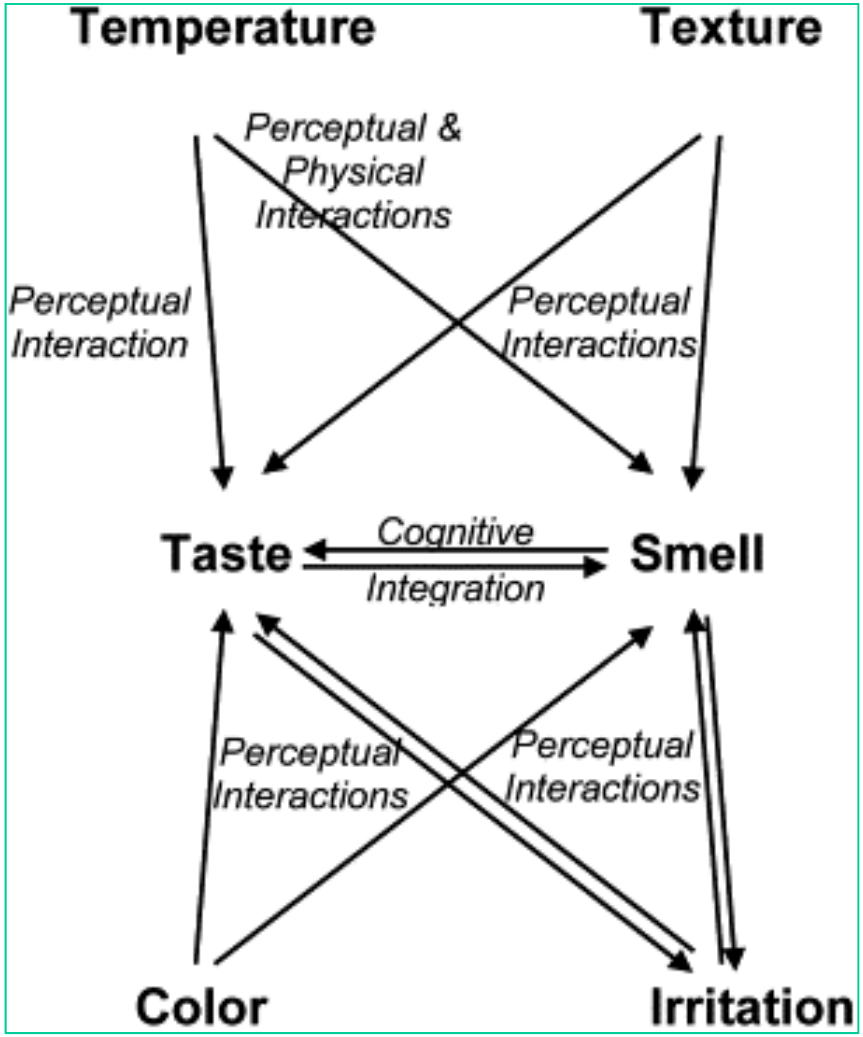
- Wine is complex
  - Over 1000 compounds identified
    - Sensory thresholds vary
    - Variable concentration
    - Interactions affect perception
  - Multiple sources of variation
    - Vineyard
    - Yeast and bacteria
    - Wood extraction
    - Compounds produced during storage
- Perception of wine is complex

Challenges: Perception is Complex

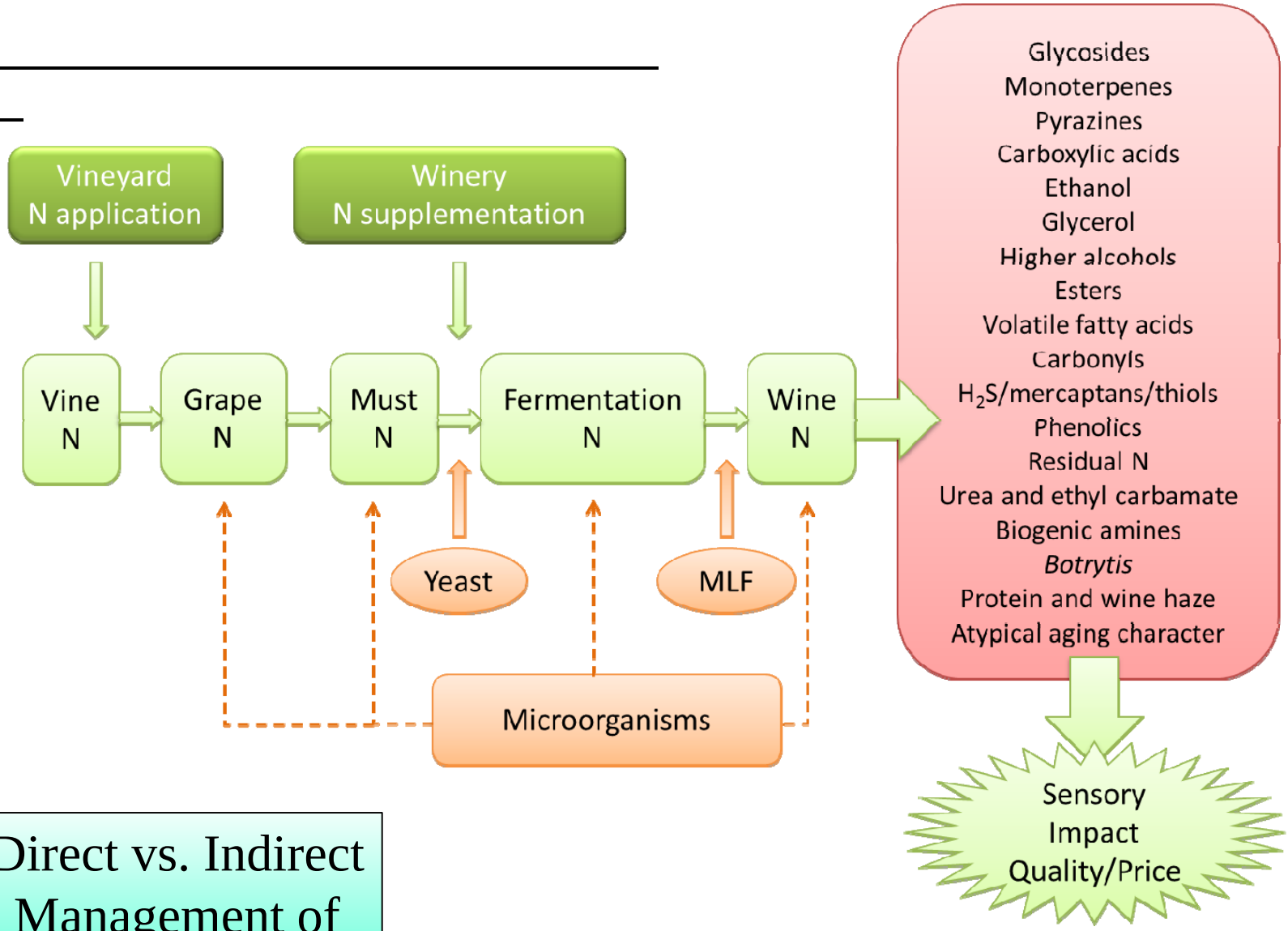
Prescott, Food Quality and Preference **10** 349-356 (1999)
Delwiche, Food Quality and Preference, 2004

Research has shown that human perception is complex and experience is generally influenced by multiple inputs



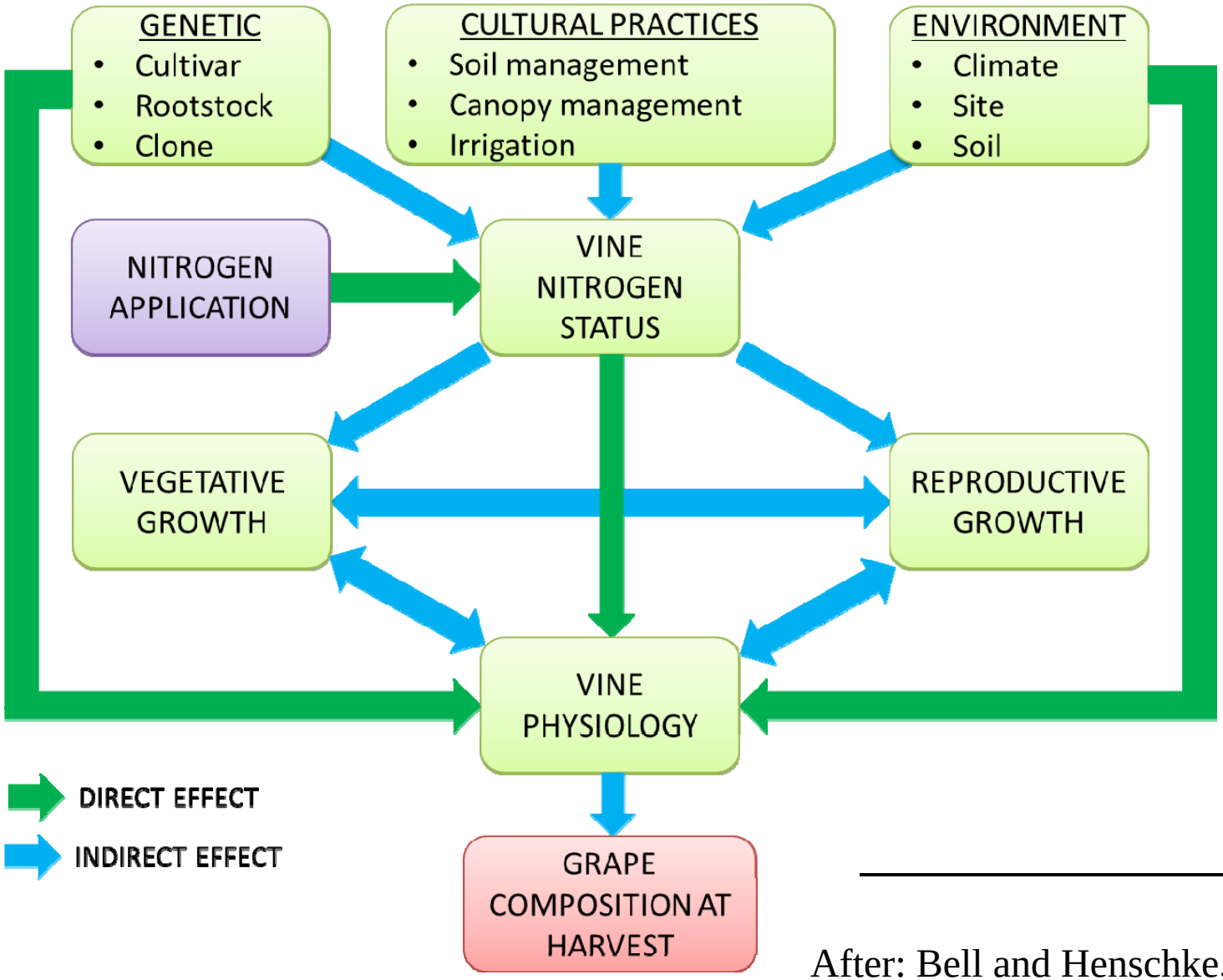


Nitrogen Inputs: Wine Composition



Direct vs. Indirect Management of Composition

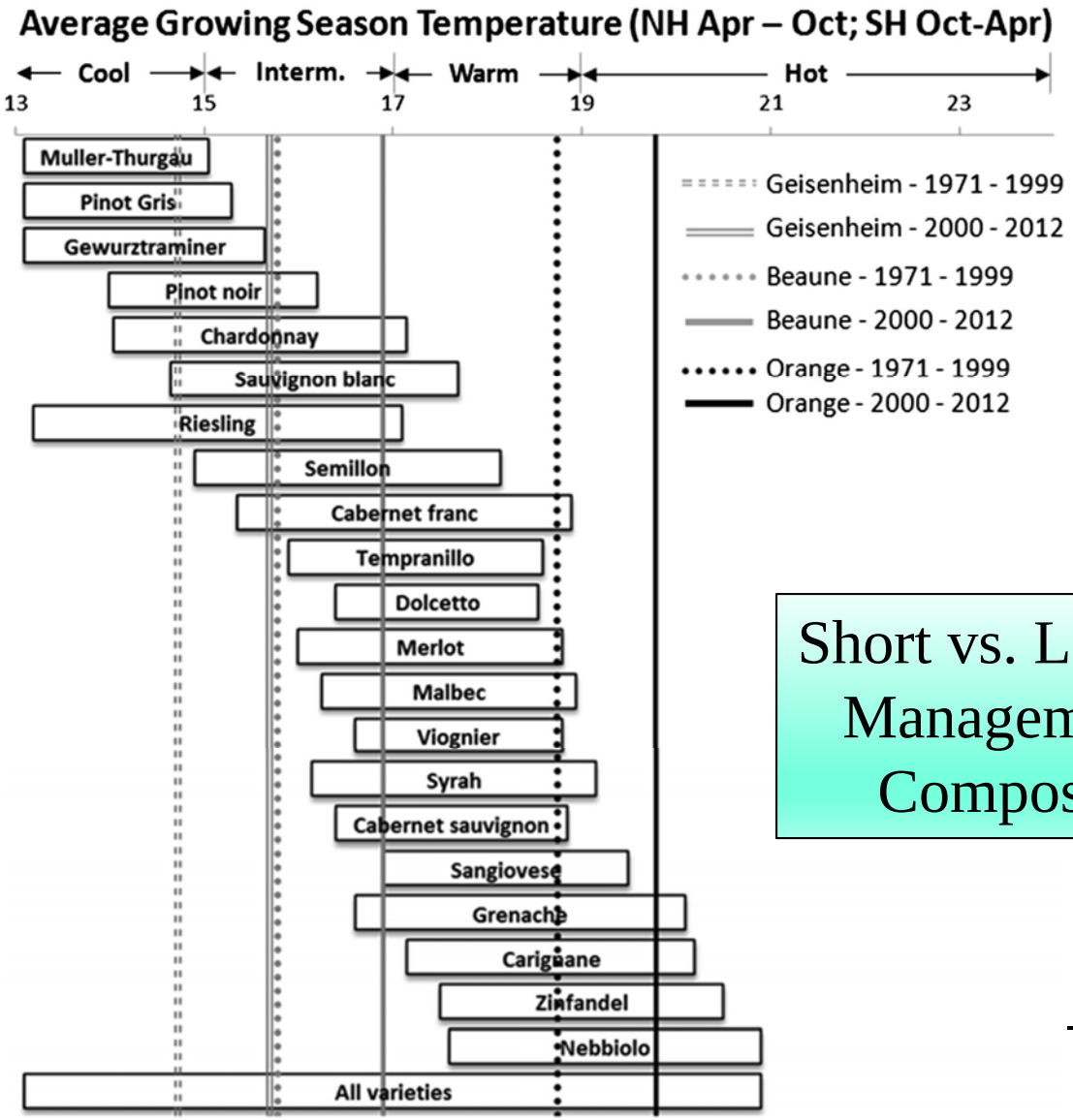
After: Bell and Henschke, 2005



After: Bell and Henschke, 2005

Growing Season Temperature: 1971-1999 and 2000-2012

Big Driver: Temperature

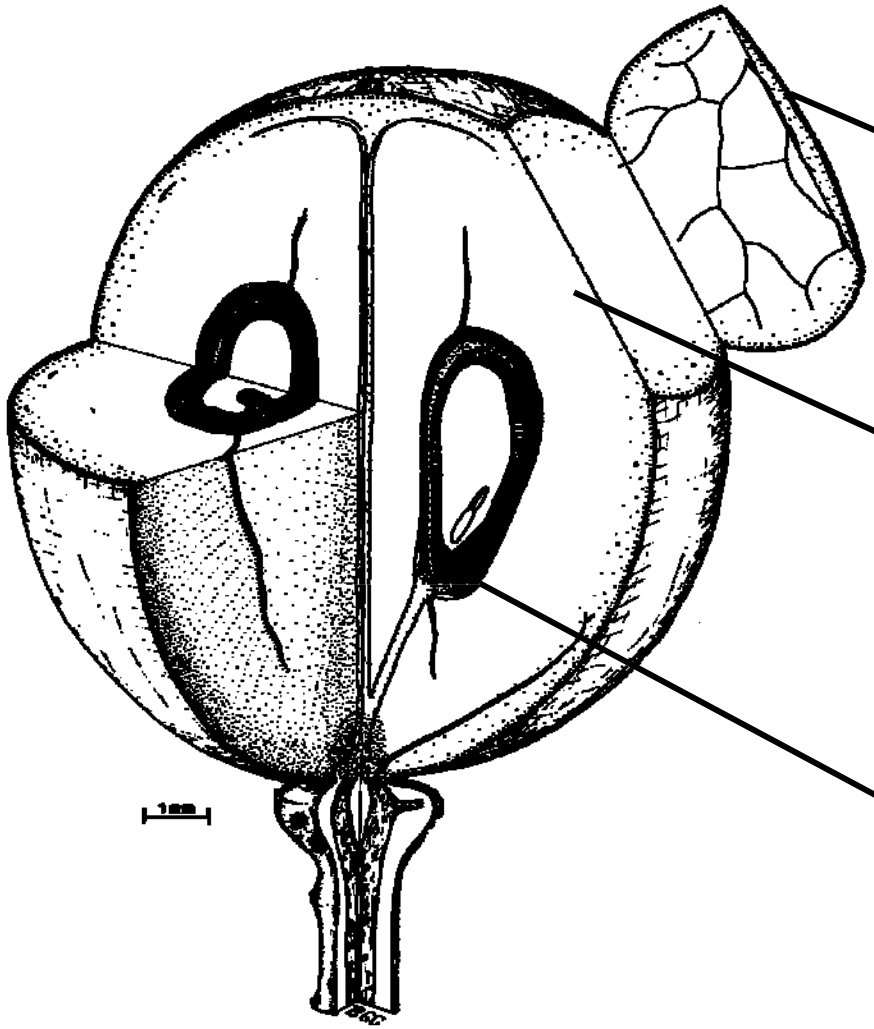


Short vs. Longterm Management of Composition

van Leeuwen C et al. PNAS 2013;110:E3051-E3052

The Grape Berry

The Grape Berry



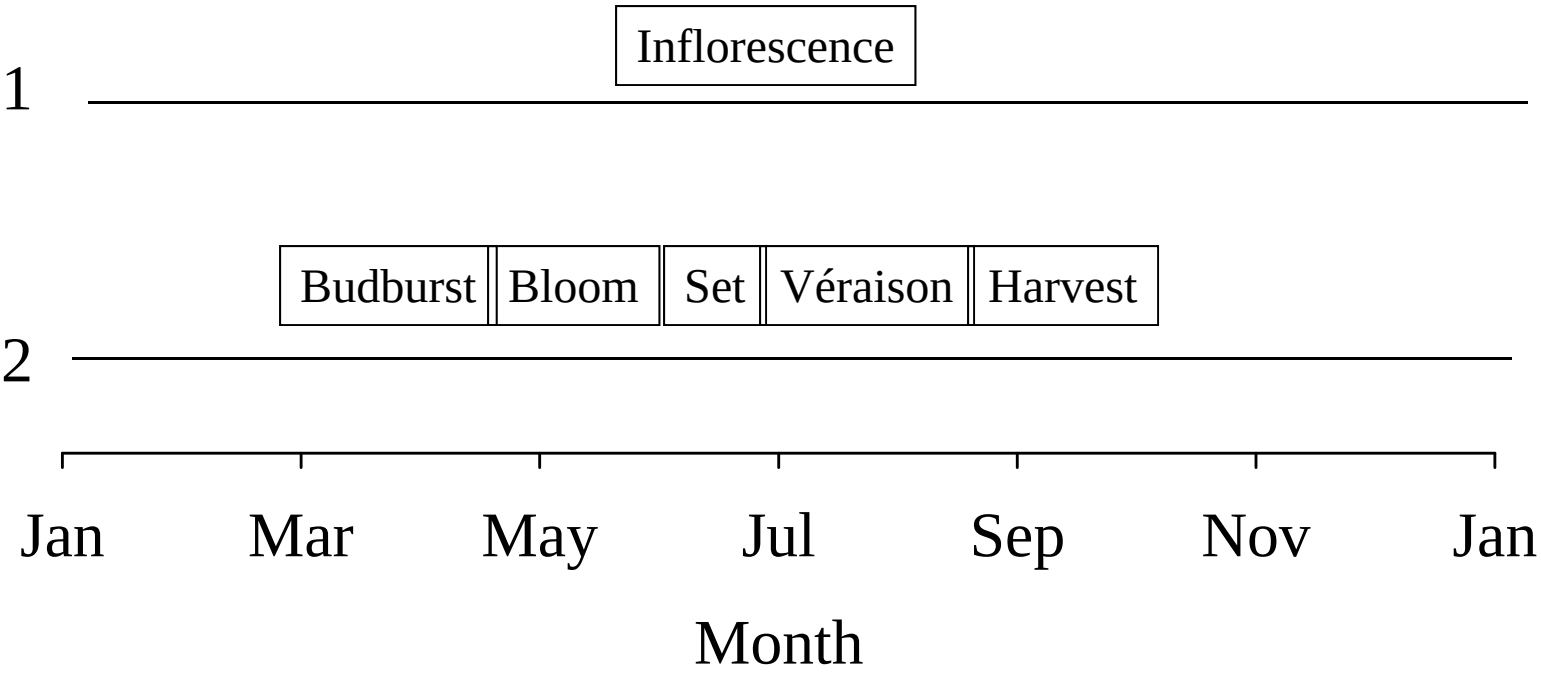
Skin
- Color
- Tannins
- Flavor

Pulp
- Water
- Acids
- Sugar
- Flavor

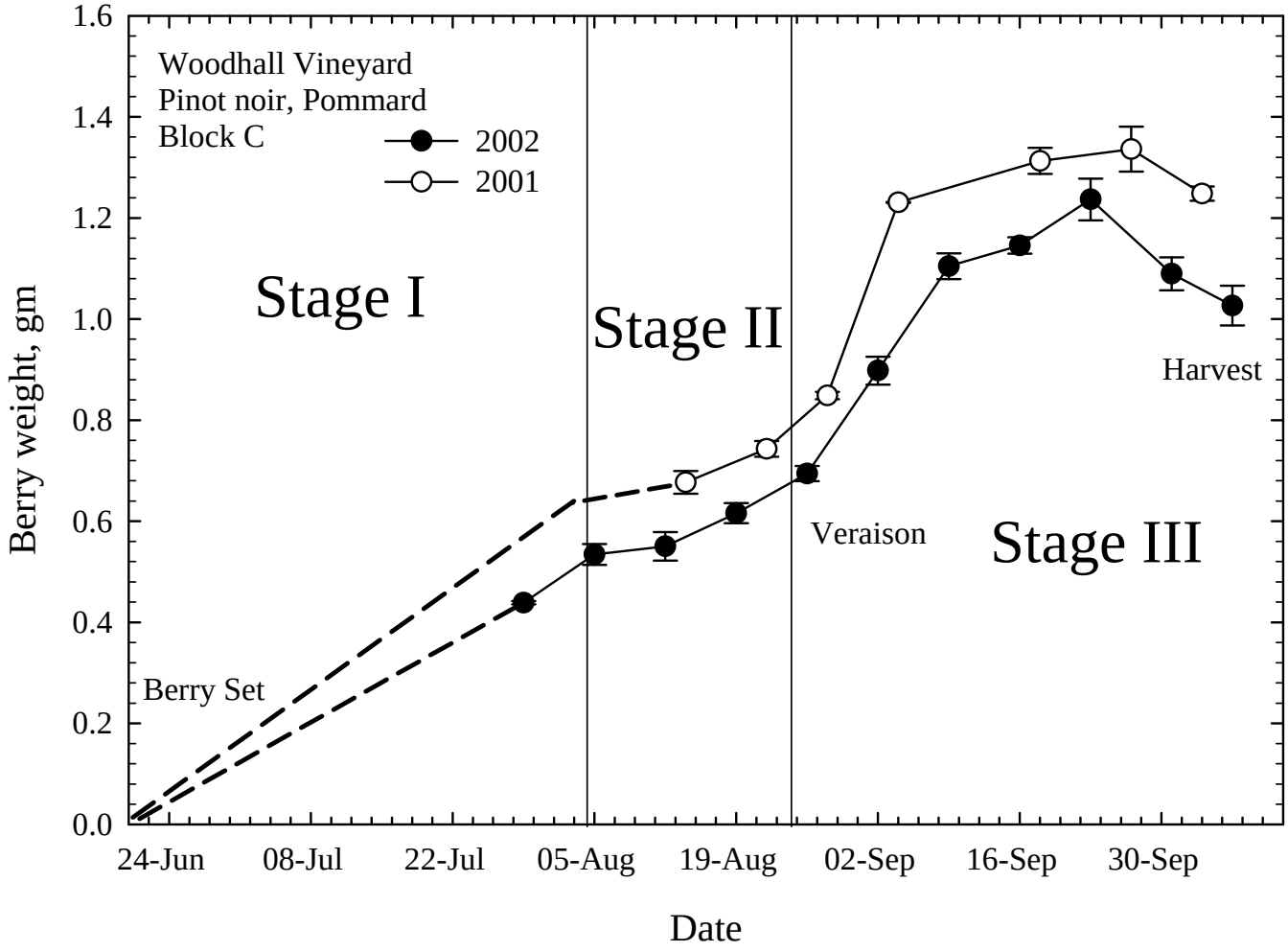
Seed
- Tannins

Coombe, AJEV,1987

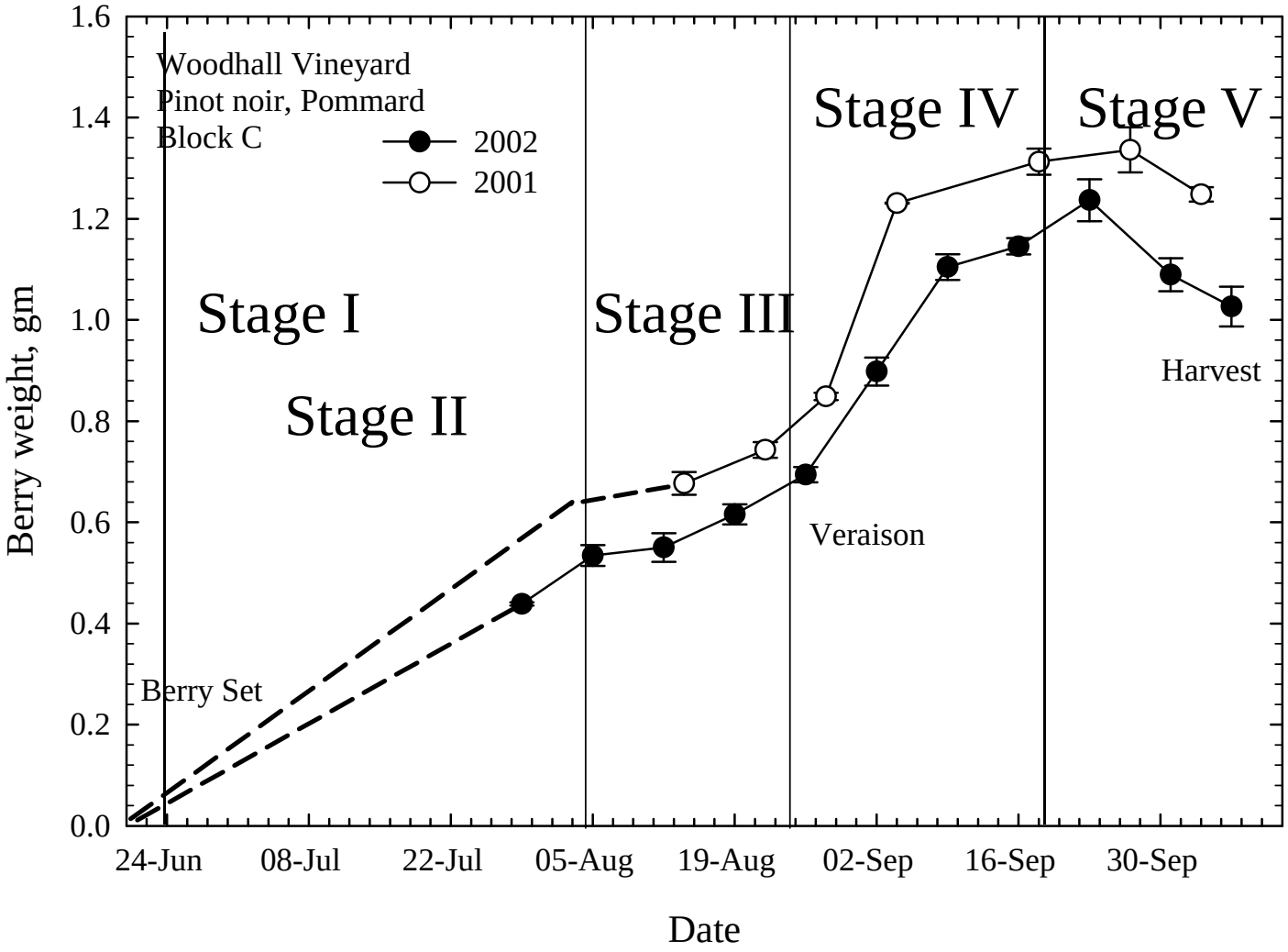
Grape Berry Development



Stages of Berry Development

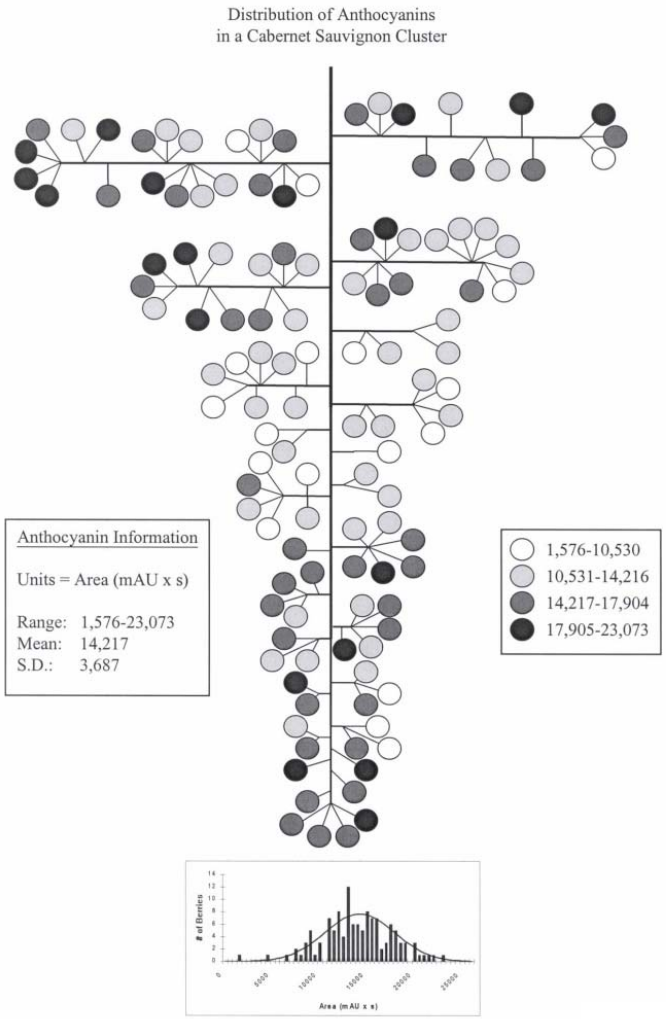


Alternatively . . . .



Stage I of Development

- Period between bloom and set
- Duration provides feedback on crop uniformity
- Weather is important at this time
  - Warm and dry
  - Excessive heat damaging



Glynn and Boulton, 2001

Stage II of Development

- Approximately 2 months in duration
- Rapid cell division
  - Berry is formed
  - Seed is formed
- Compounds of significance
  - Organic acids (tartaric, malic, hydroxycinnamic)
  - Tannins
  - Flavor compounds (green characters)
- Reasonably resistant to heat damage
  - If acclimated

Stage III of Development

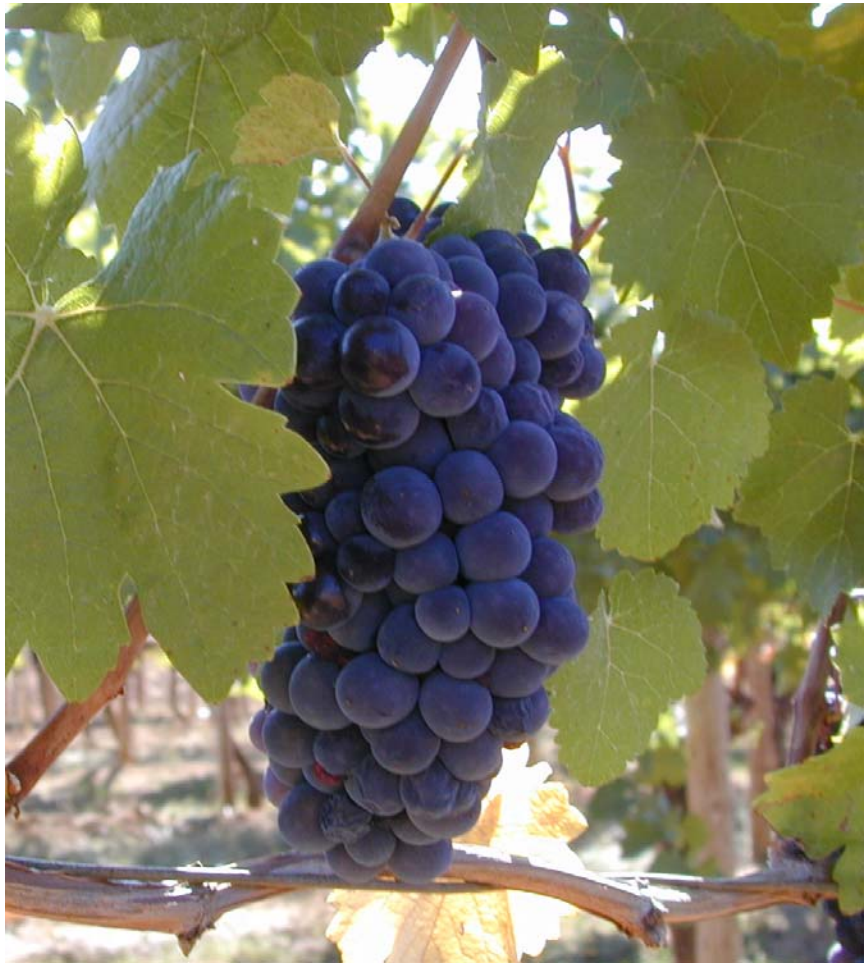
- Little growth in berry
- Final stages of seed development
- Berry weight at the end of this stage is approximately one-half of its final weight
- Susceptible to heat damage at veraison

Stage IV of Development

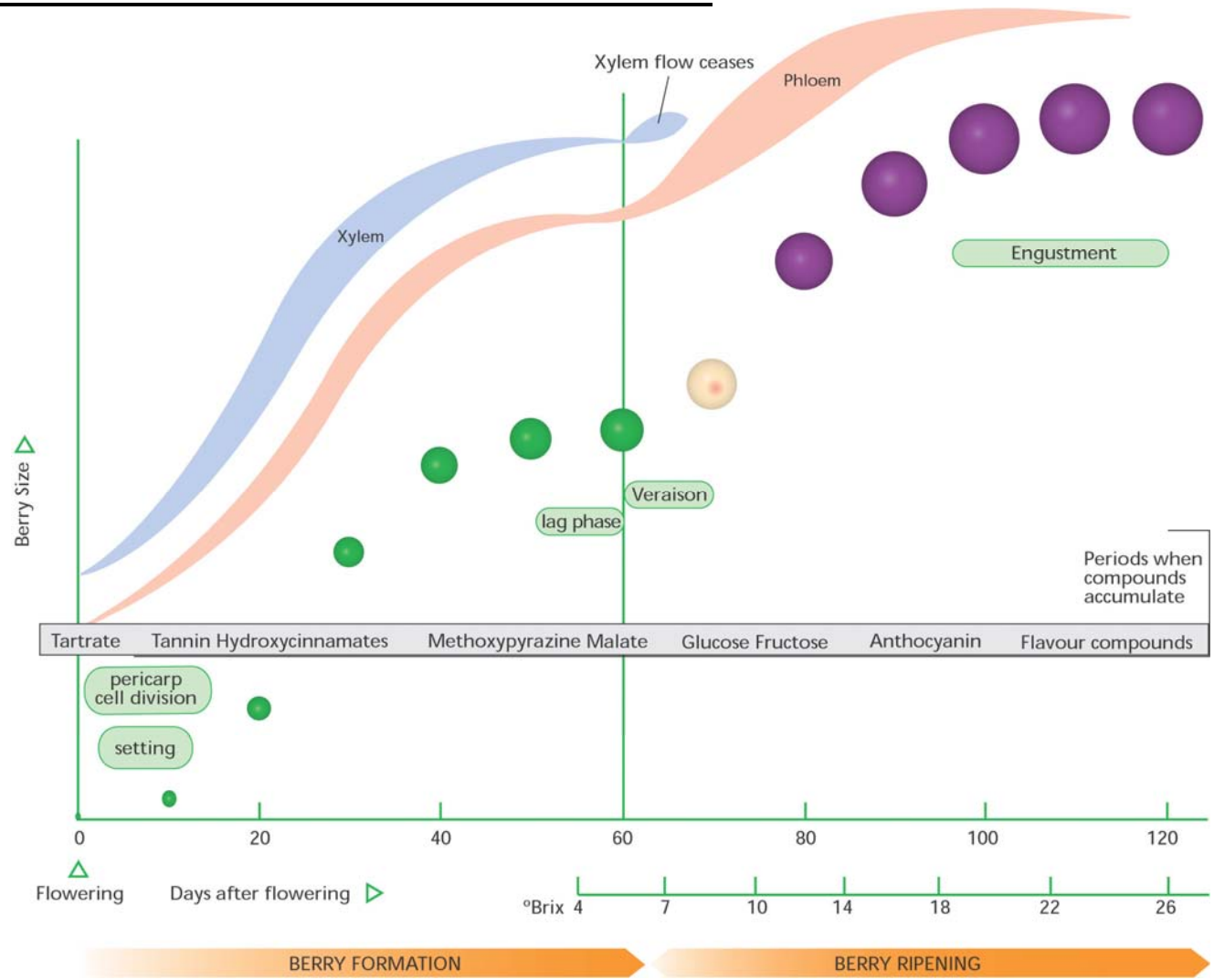
- Fruit ripening
- Compounds increase
  - Anthocyanins
  - Sugars
  - Flavors (fruity and floral aromas and precursors)
- Compounds decrease
  - Tannins
  - Organic acids
  - Flavors (green flavors)
- Reasonably resistant to heat damage
  - if acclimated

Stage V: Senescence

- Berry shrivel
- Cell breakdown
  - More easily extracted
- Concentration
- Flavor development

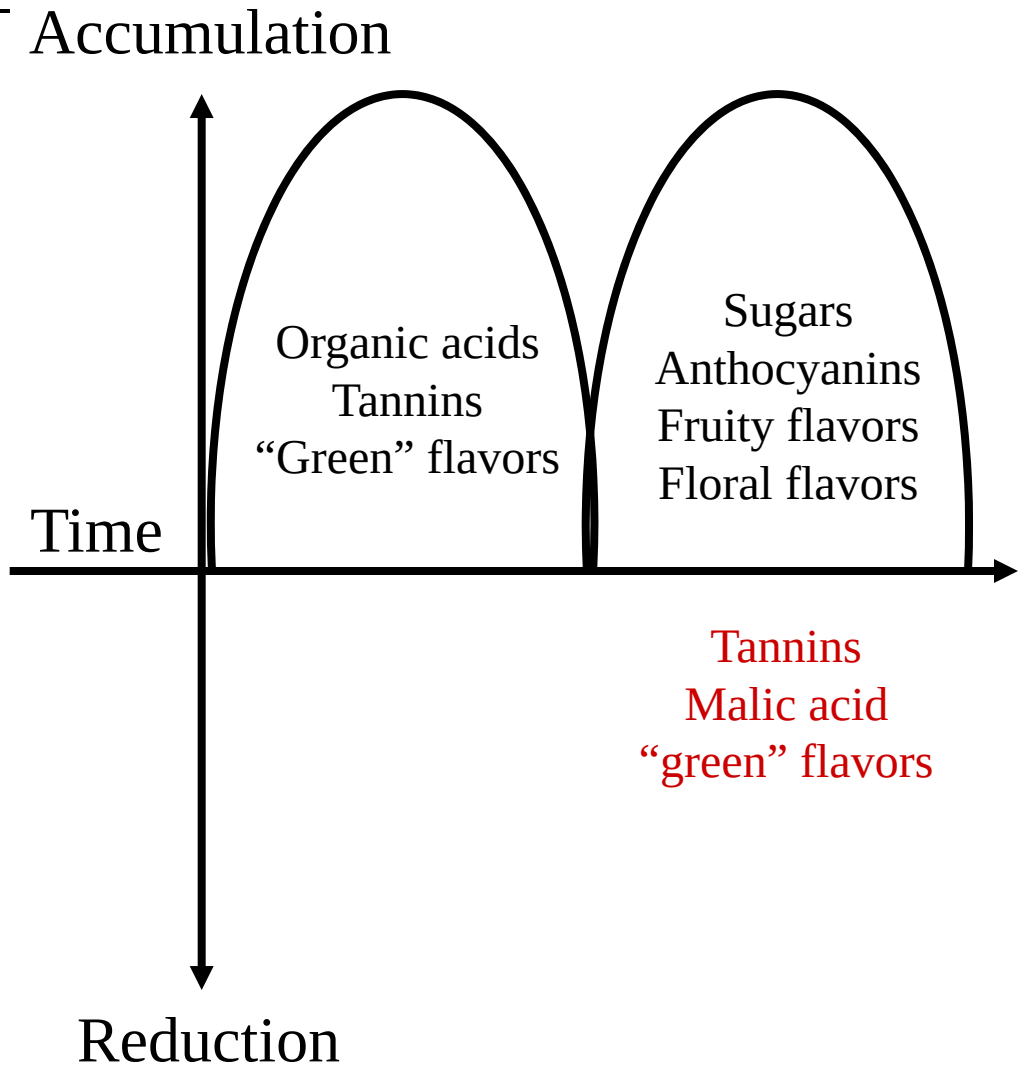


Berry Development - Summary



Australian Viticulture from text: "Ripening berries – a critical issue" by Dr. Bryan Coombe and Tony Clancy (Editor, *Australian Viticulture*), March/April 2001. Illustration by Jordan Koutroumanidis and provided by Don Neel *Practical Winery and Vineyard*

Solute Accumulation



Flavor Evolution

Riesling
Floral–perfumed–apple-pear–citrus-lime–passionfruit–tropical fruit

Sauvignon Blanc
Asparagus-capsicum-herbaceous-grassy-gooseberry-tropical fruit

Semillon
Herbaceous-straw-gooseberry-apple-quince-lemon-lime-passionfruit-tropical fruit

Chardonnay
Cucumber-grapefruit-gooseberry- apple-lime- melon-peach-rockmelon-fig-tropical fruit

Pinot Noir
Cherry-strawberry-violet-raspberry-plum-stewed plum

Grenache
Floral-boiled lolly-spicy-raspberry-pepper-plum-stewed plum-prunes-liquorice

Merlot
Herbaceous-leafy-perfumed-fruity-violet-cherry-raspberry-plum-fruitcake-blackcurrant

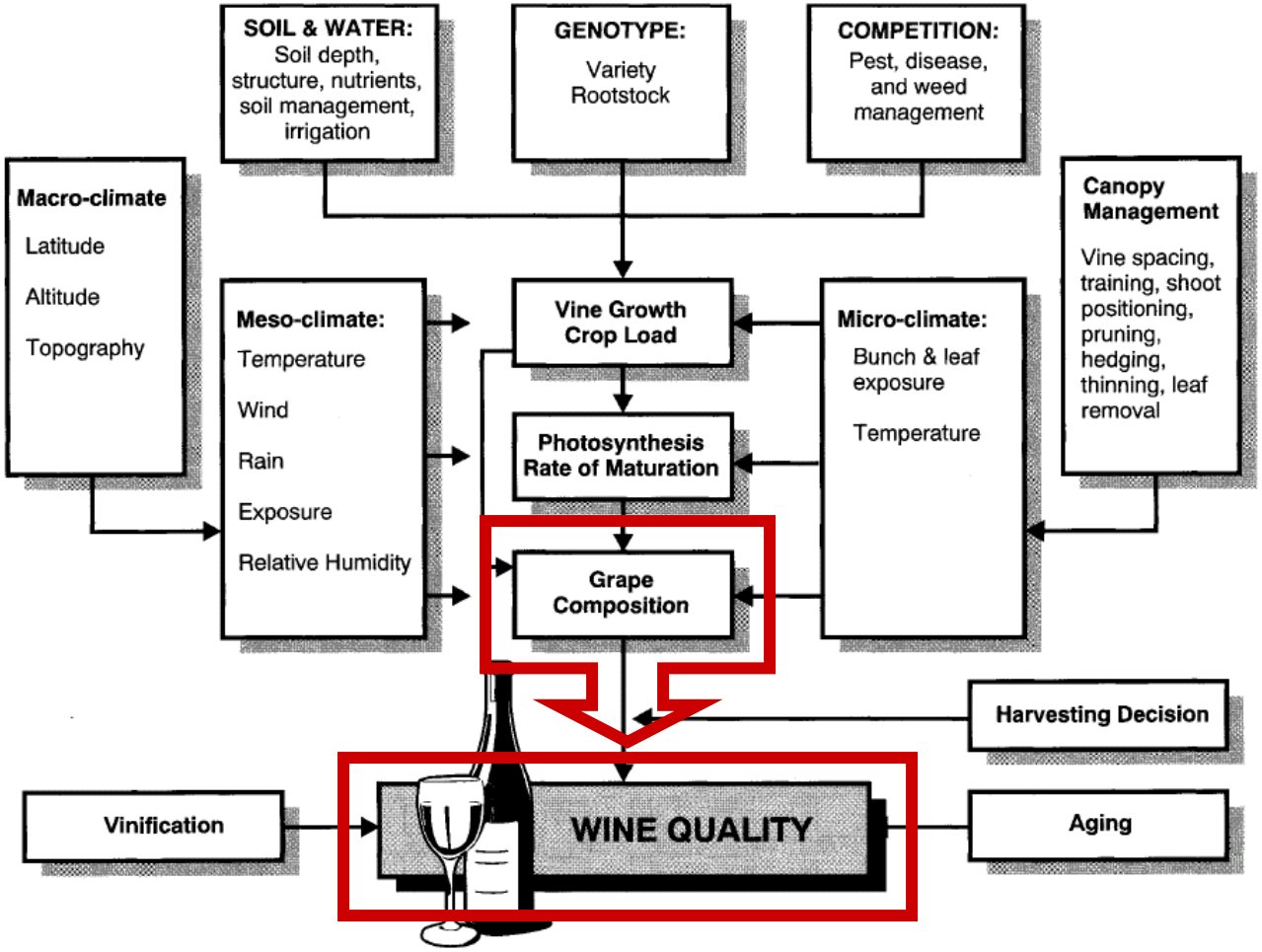
Cabernet Sauvignon
Herbaceous-capsicum-tomato bush-leafy-mint-dusty-black olive-blackcurrant

Shiraz
Herbaceous-spicy-raspberry-plum-pepper-blackberry-mulberry-liquorice-black olive-jam

Iland, P. and Gago, P. (2002). *Australian Wines, Styles and tastes*. Patrick Iland Wine Promotions, Adelaide.

Response of Plants to Environment

Inputs Responsible for Wine Quality



Jackson and Lombard, AJEV, 1993

Types of Stress

- Abiotic
  - Solar radiation
  - Temperature
    - Heat, freezing, chilling
  - Drought
  - Salinity
  - Ozone
  - Heavy metals
  - Herbicides
- Biotic
  - Insects
  - Viruses
  - Fungi
  - Bacteria
  - Wounds

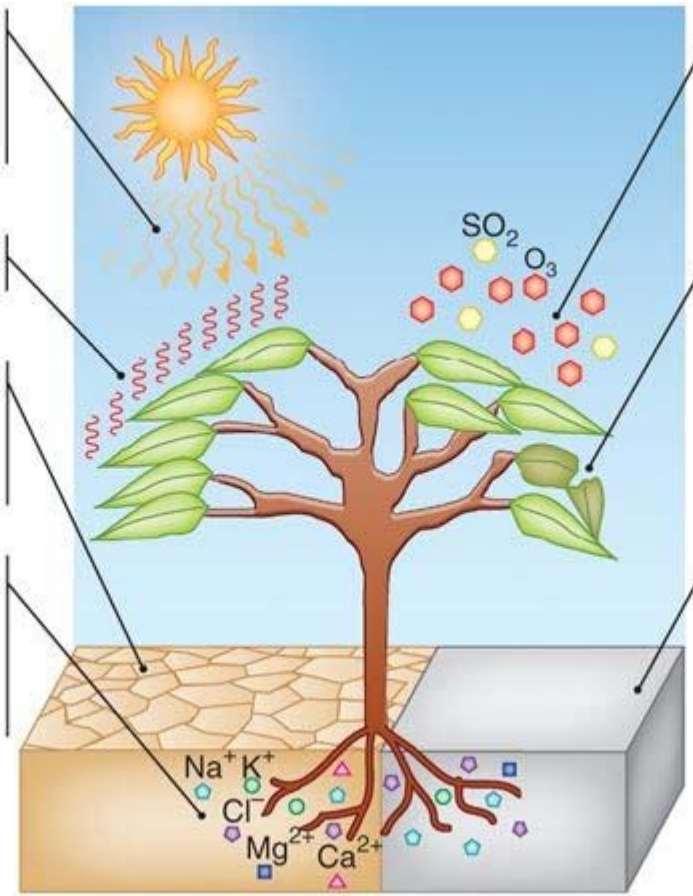
Response to Environmental Stress

High light causes production of excess excitation energy in the photosynthetic reaction centers, resulting in direct accumulation of a variety of reactive oxygen species.

High temperature stress denatures proteins and causes lipid peroxidation.

Water deficit, or drought, interferes with metabolism. ROS produced under drought conditions trigger signaling pathways that generate defense responses.

Soil salinity is usually caused by excess salts of chloride and sulfate. Salinity results in ion cytotoxicity and osmotic stress, and decreases uptake of nutrients. Resulting metabolic imbalances lead to oxidative stress.



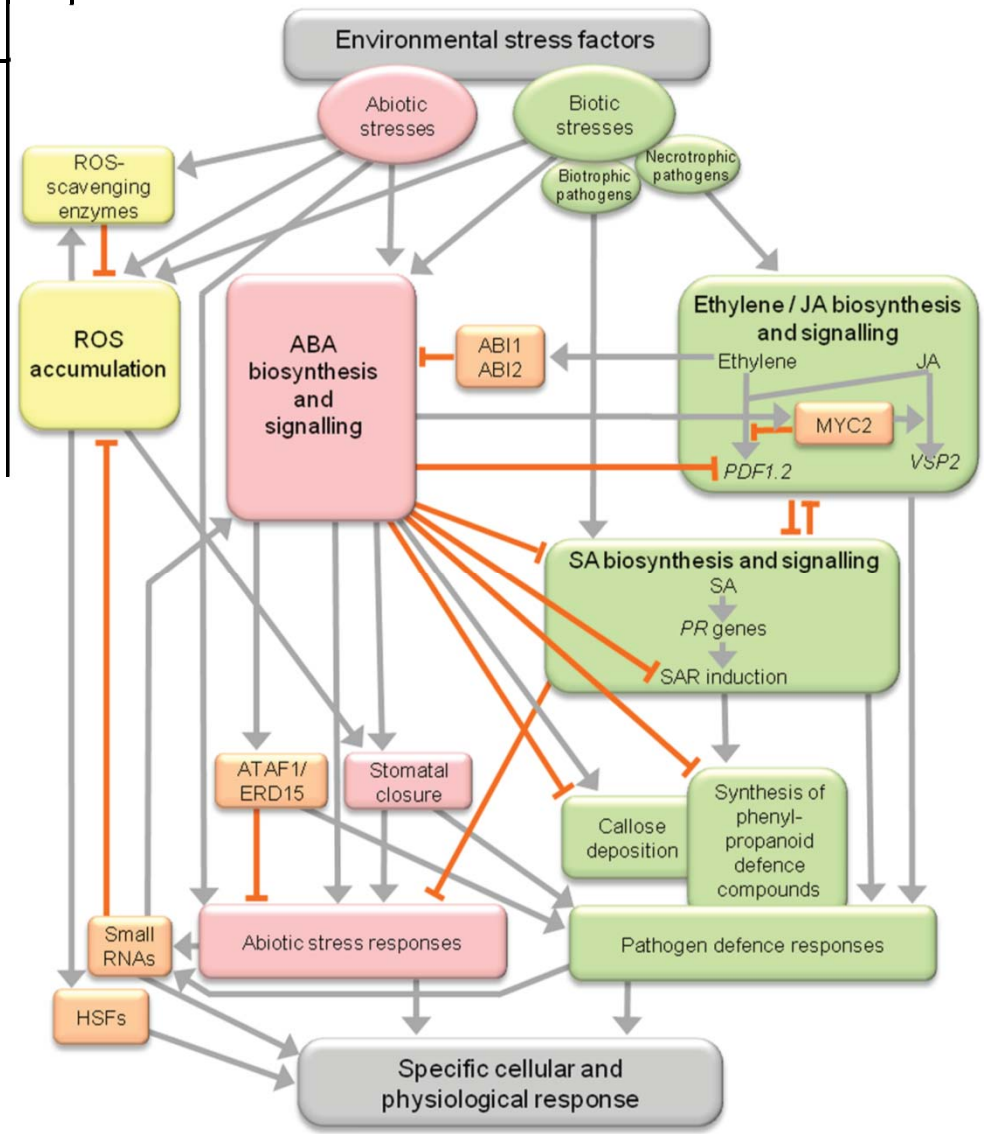
Air pollution with oxidizing species (including ozone and sulfuric acid) causes direct oxidative damage to tissues. Local and systemic signaling responses also occur.

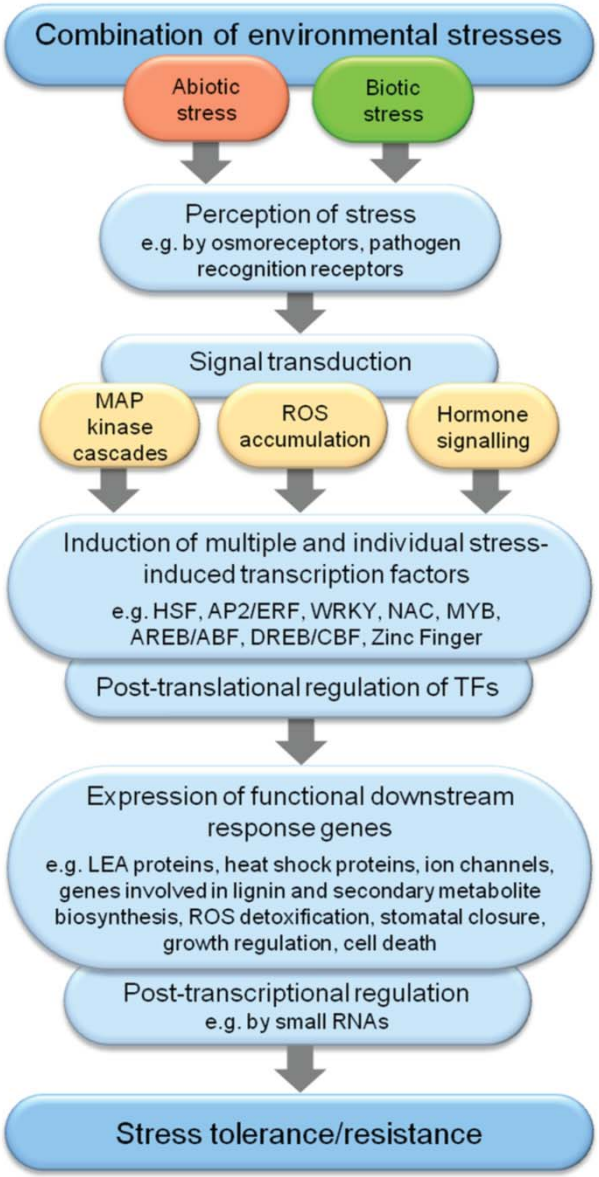
Mechanical damage—both biotic (e.g., from insect feeding) and abiotic (e.g., from wind damage)—triggers expression of defense-related genes.

Cold stress interferes with metabolic processes (particularly enzyme activity) and alters membrane properties. Frosting can severely damage tissues when ice forms. Extracellular ice formation also causes intracellular water deficit.

Vickers et al., Nature Chem. Biol., 5: 283-291, 2009

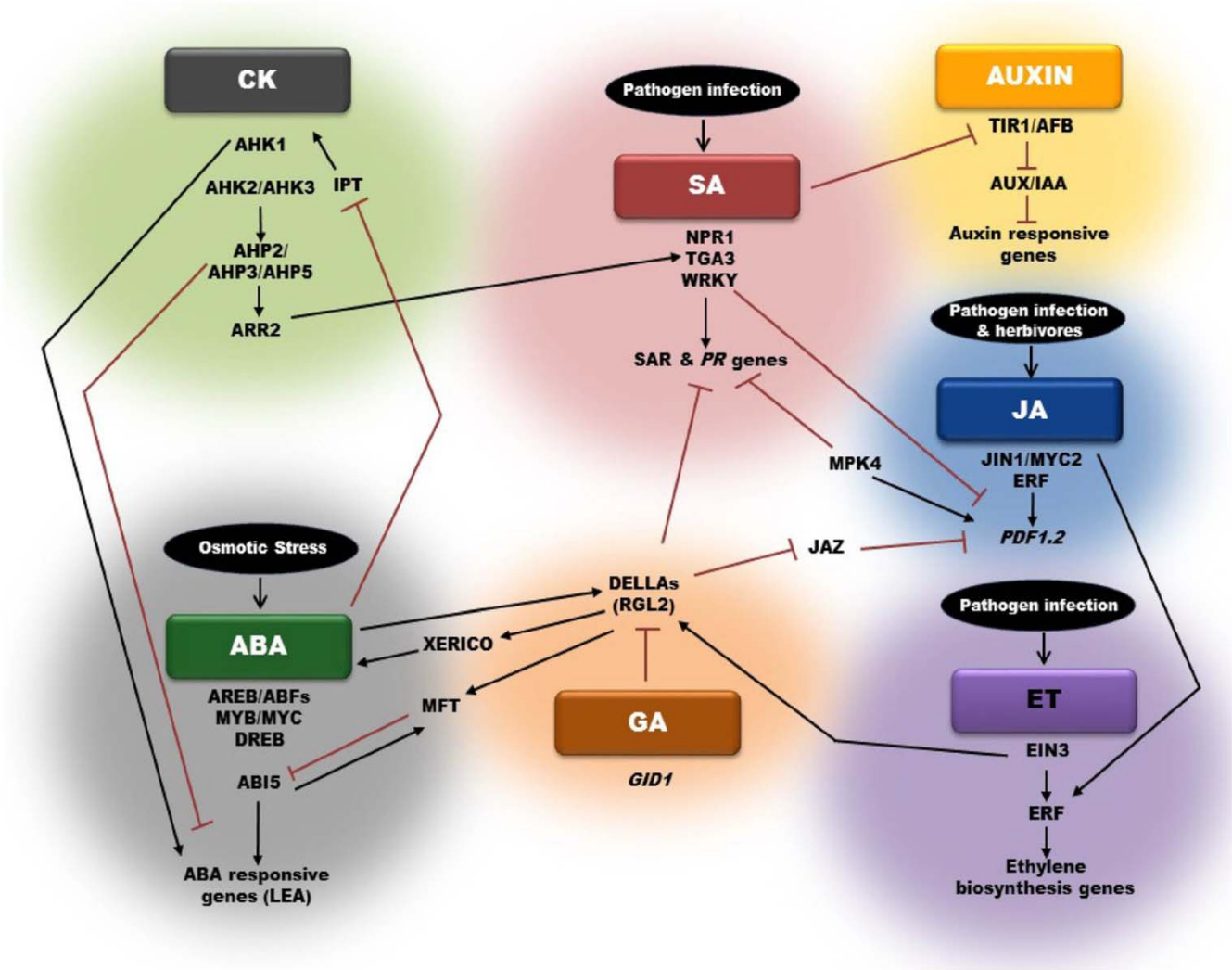
Response to Environmental Stress





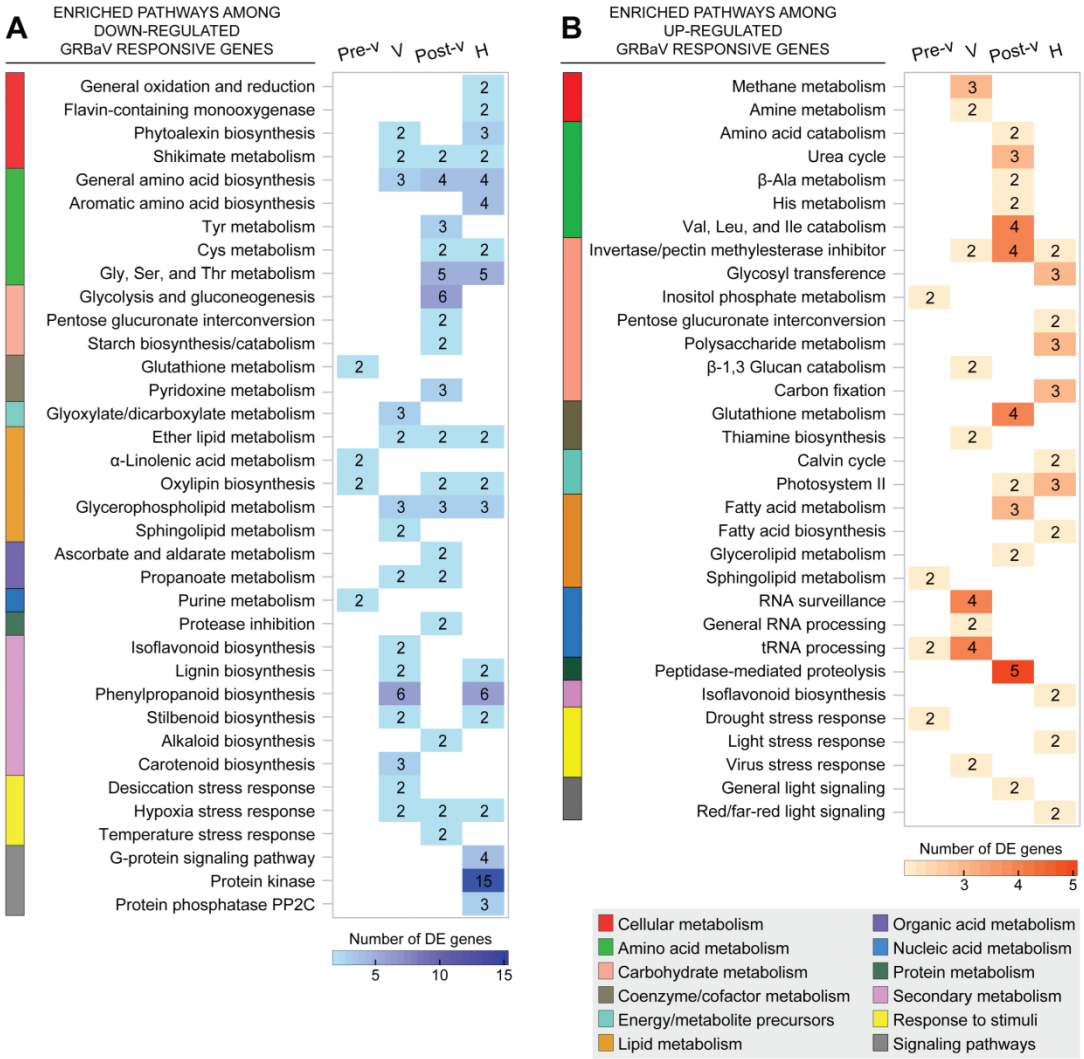
Atkinson and Urwin, J. Exp. Bot. 63: 3523-3544, 2012

Response to Environmental Stress



Verma et al., BMC Plant Biol., 16: 86, 2009

Response to Environment is Complex

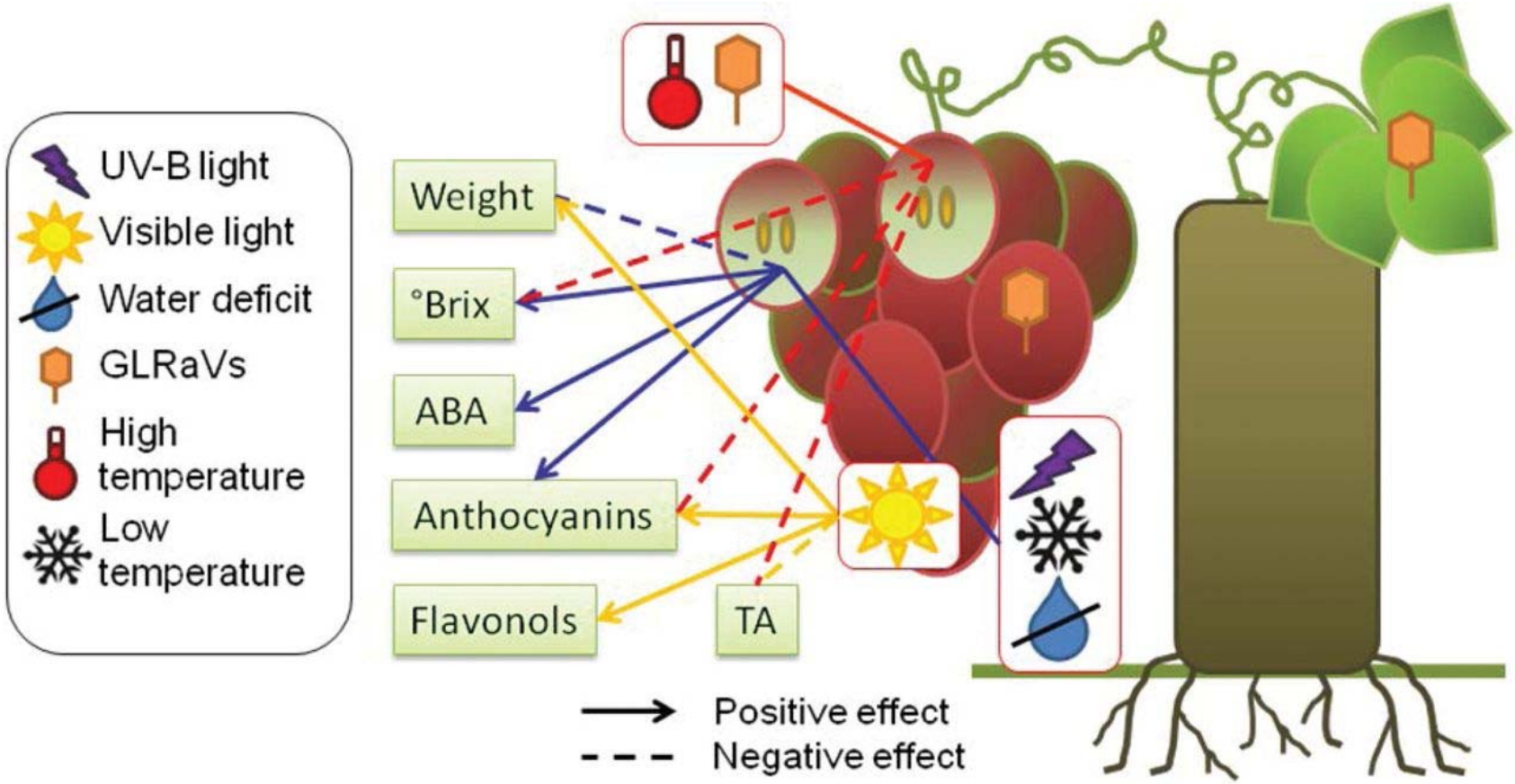


Response to GRBaV

cv. Zinfandel, Oakville/Sonoma, 2015

Blanco-Ulate et al., J. Exp. Bot. 68: 1225-1238, 2017

Environmental cues affecting berry ripening parameters



Nathalie Kuhn et al. J. Exp. Bot. 2014;65:4543-4559

JOURNAL OF Experimental Botany

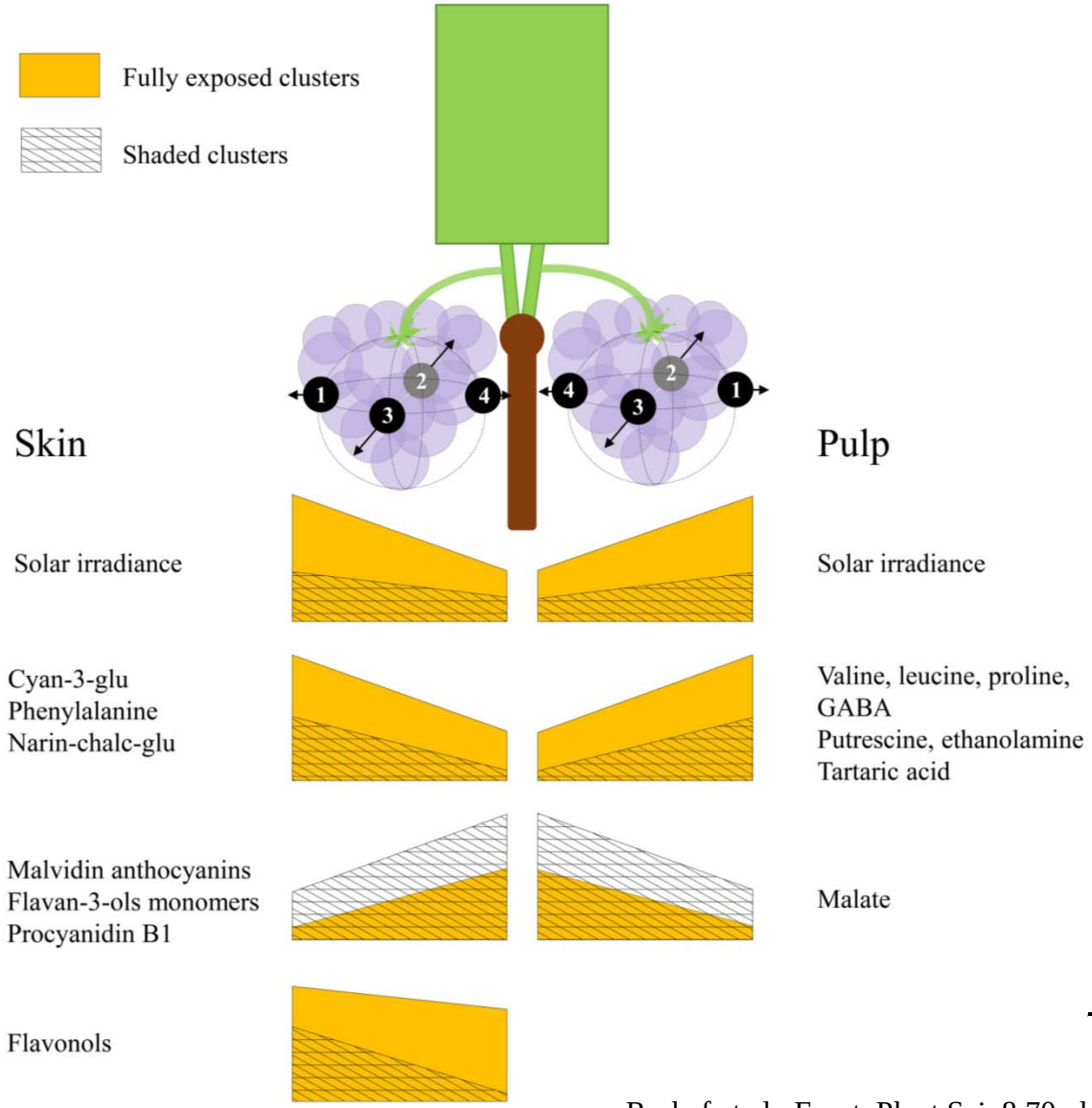
Influence of Temperature

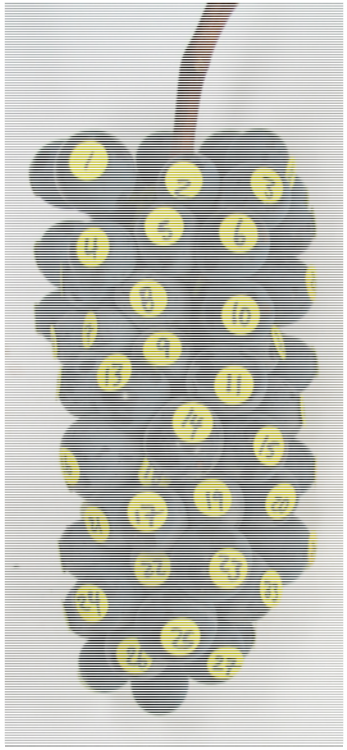
Cohen et al., J. Exp. Bot. 2012

Big Driver: Fruit Exposure

- Exposure improves flavor profile
  - Reduced veggie and more fruity/floral
    - Reducing veggie: exposure driven
- Exposure improves phenolics
- Exposure reduces disease pressure
- How much exposure is sufficient?
  - Depends on growing region
    - cooler – more exposure

Microclimate and Chemistry





Reshef et al., Front. Plant Sci. 8:70. doi:10.3389/fpls.2017.00070

Phenolic Development and Management

- High phenolics
  - High sun exposure
  - Lower levels N
  - Low soil moisture
  - Moderate canopy size
  - Moderate crop load
  - Low soil fertility
  - Small berry size

Moderate stress tends to increase phenolic quantity and quality.

Interest generally on color and tannins

Jackson and Lombard, 1993

Phenolics and Environment

- Anthocyanins
  - Temperature is important
  - Concentration increases up to 30 °C
- Tannins
  - Seed
    - Monomers decline with maturity
    - Less sensitive than skin tannin to change
  - Skin
    - Sensitive to exposure
    - Light is important
      - Quality is open question (UV-B)
    - Evidence for upregulation

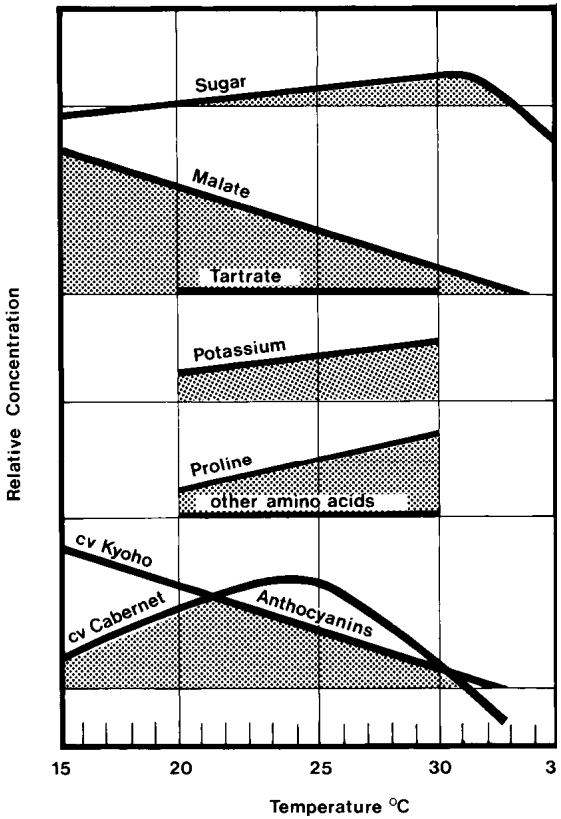


Figure 4.1 Tentative diagram of the generalized effects of temperature treatments on the concentration of some compounds in grape berries (from Coombe 1987).

Exposure Management

- Optimize exposure for your region
  - North Coast different than San Joaquin Valley
- If temperatures exceed 90 °F during growing season, sun protection in order.
  - N-S row orientation:
    - Avoid excessive shoot positioning/leaf removal on W-side of canopy
  - E-W oriented rows
    - Avoid excessive shoot positioning/leaf removal on S-side of canopy
- Adequate cover: 1-2 leaf layers

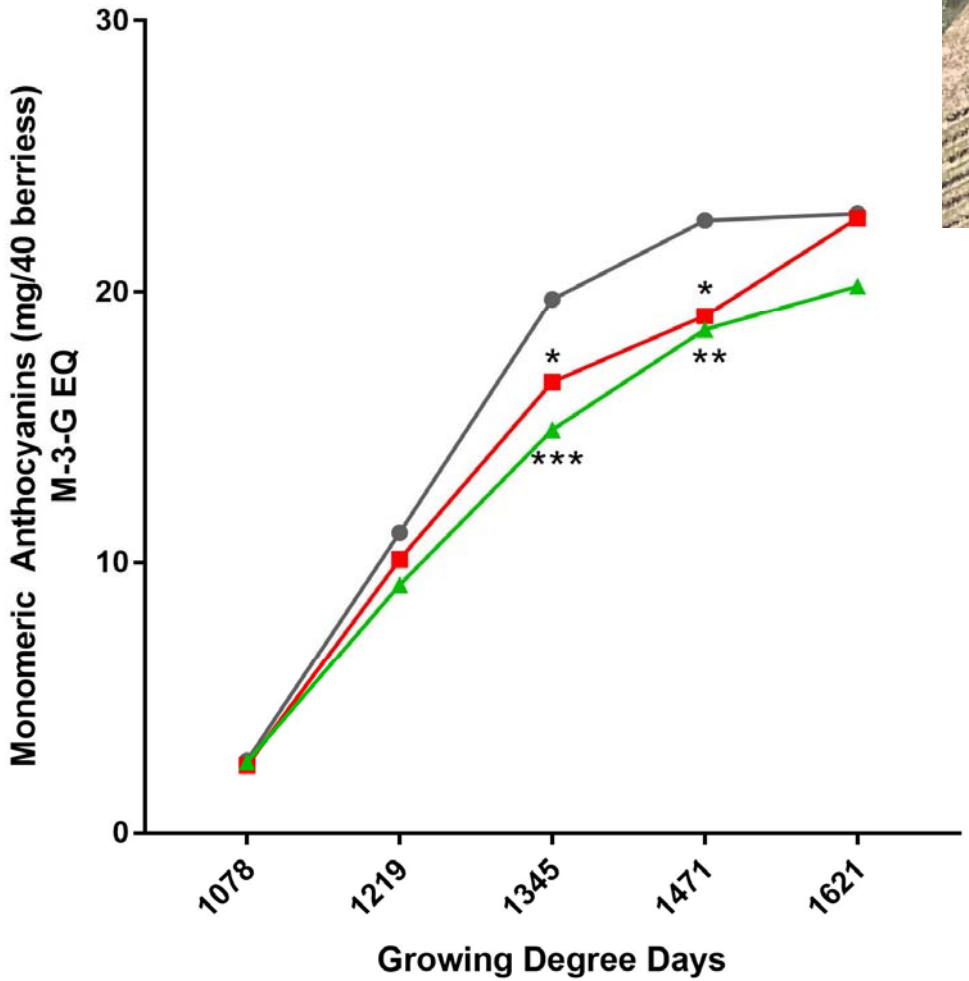
Shade Cloth Application

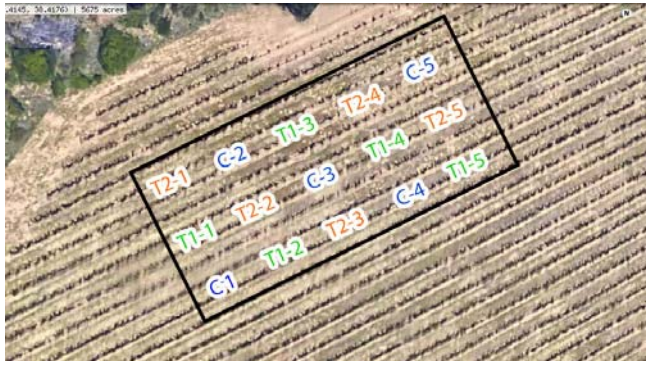
Mt Veeder – Napa Valley

cv. Cabernet Sauvignon, 5 reps, 2016

Campbell et al. In preparation

Monomeric Anthocyanins





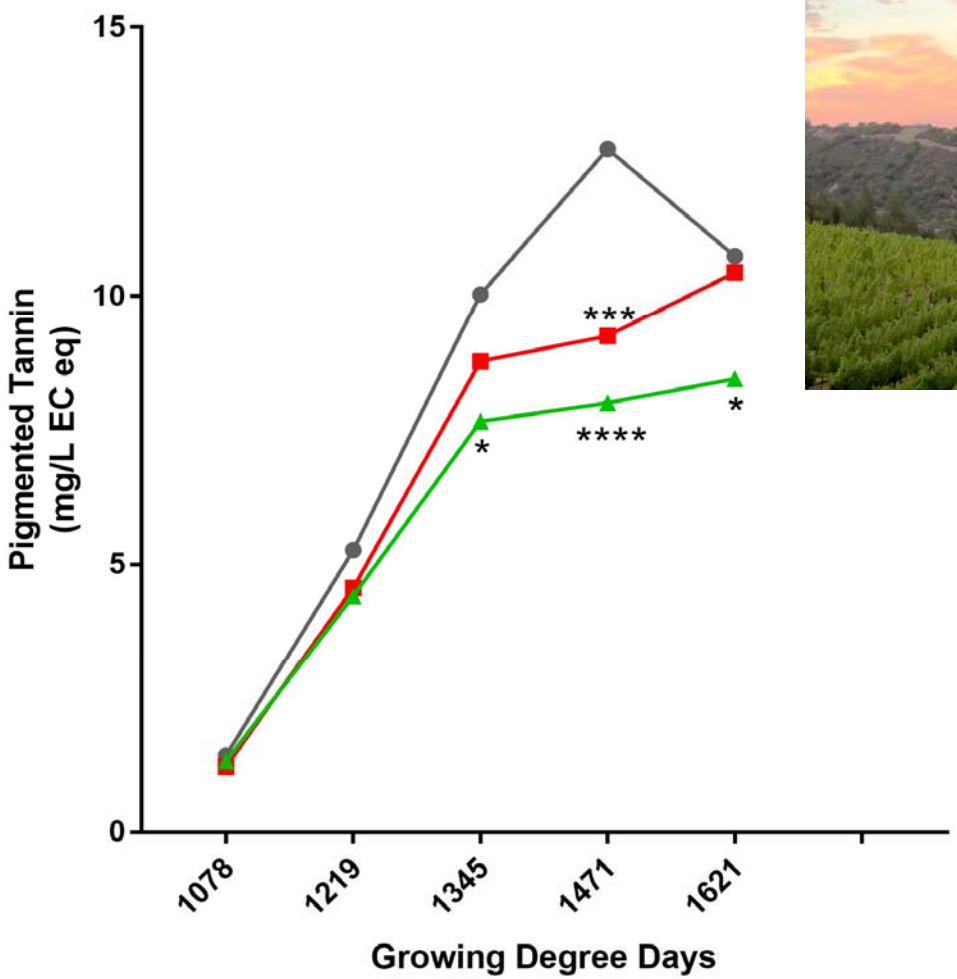
* = <0.05
** = <0.01
*** = <0.001
**** = <0.0001

Control
40% Shade
80% Shade

cv. Cabernet Sauvignon, 5 reps, 2016

Campbell et al. In preparation

Pigmented Tannin



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Control
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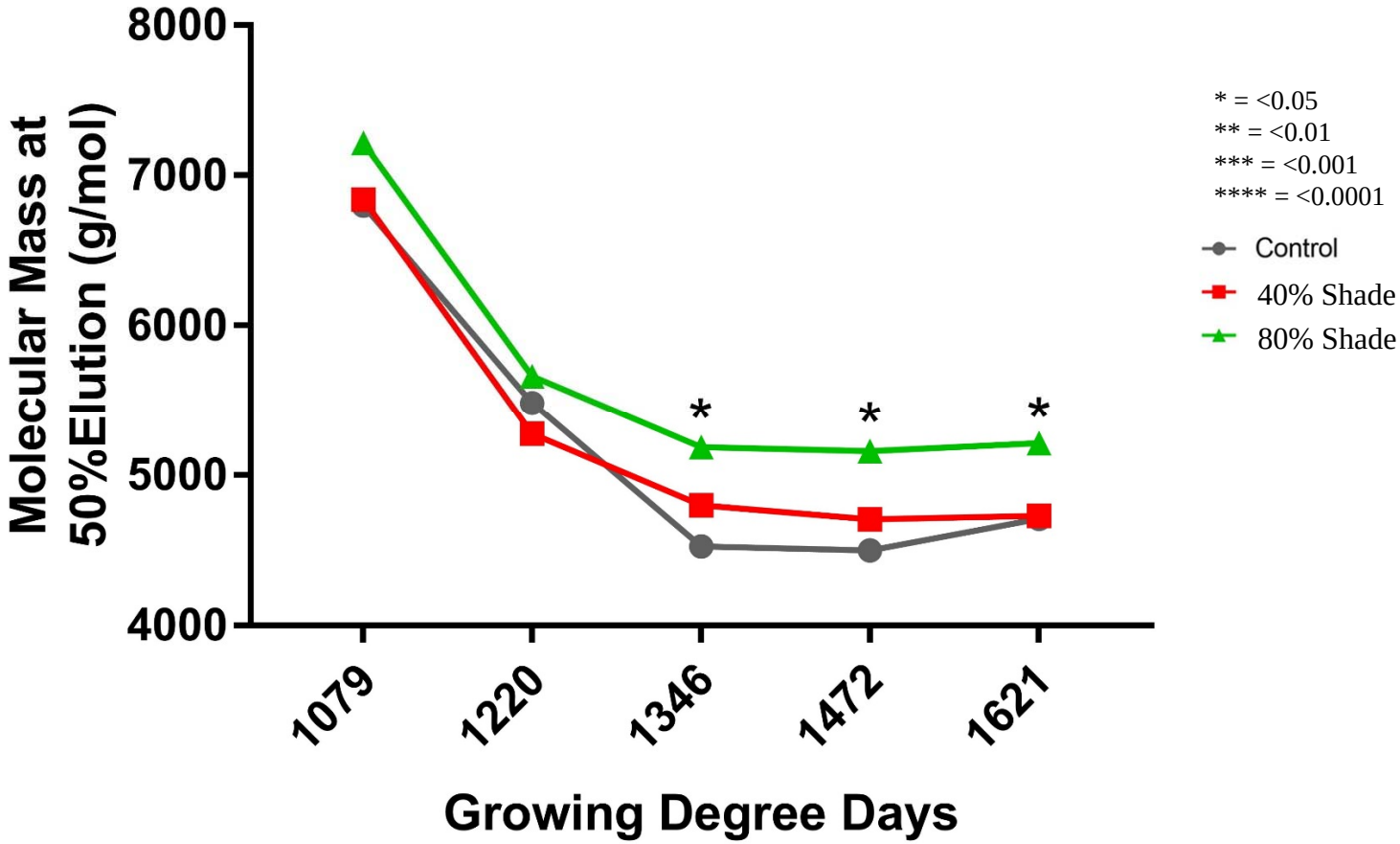
Campbell et al. In preparation

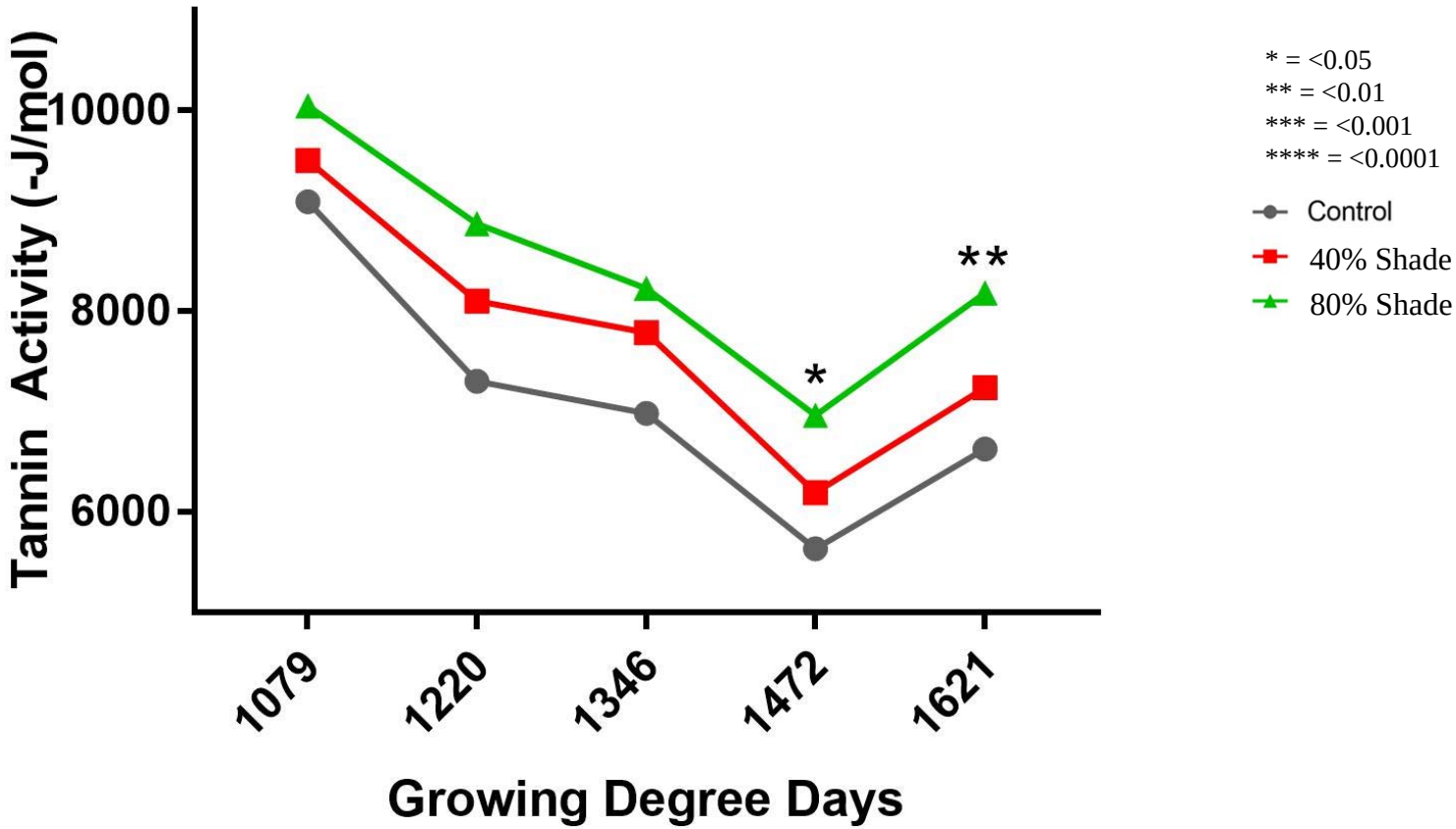
Tannin Molecular Mass



cv. Cabernet Sauvignon, 5 reps, 2016

Campbell et al. In preparation

Tannin Activity



cv. Cabernet Sauvignon, 5 reps, 2016

Campbell et al. In preparation