IN THE NAME OF GOD

THE MERCIFUL THE COMPASSIONATE

SMALL FRUITS (ADVANCED)

M. Gholami

GRAPES

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History, Uses and production

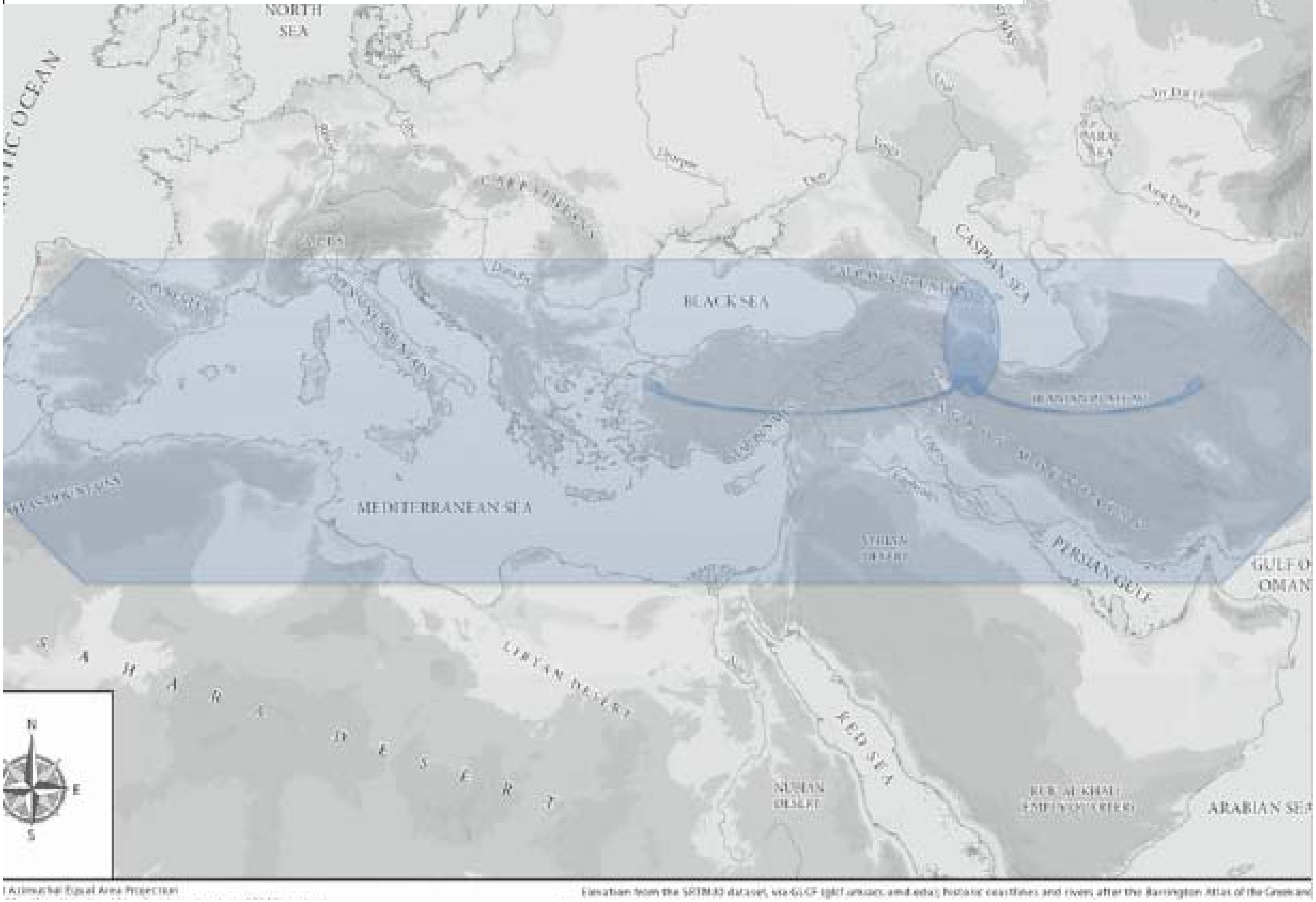
- کشت در تمام دنیا
- مصرف به شکلهای مختلف
- توسعه صنعت Viticulture
- سطح زیر کشت بیش از 7/9 میلیون هکتار
- شدیدا پر رشد (vigorously growing)
- علف هرز مزاحم !!! (crop *vs*. weed)
- گیاه بالا رونده (climbing plant)
- توانایی شکل گیری به فرم های مختلف

Geographical origin of grapevine species

- اهلی شدن *Vitis* spp در چند منطقه مختلف دنیا
- منشأ اهلی شدن *V. vinifera* به احتمال جنوب قفقاز (بین دریای خزر و دریای سیاه)، شمال غرب ترکیه، شمال عراق، آذربایجان و گرجستان

- گونه‌های بومی شمال آمریکا هم زیاد است (پلات 1). انگور V. labrusca بومی شمال شرق آمریکاست و در صنعت تولید آب میوه در بسیاری از ایالت‌های آمریکا اهمیت فوق العاده‌ای دارد. ولی سایر گونه‌ها کمتر برای تولید تجاری انگور استفاده می‌شوند.

Fig. 7.1 Natural range of the European grape, *Vitis vinifera* subsp. *sylvestris*. Domestication most likely occurred first in the region indicated by the oval area between the Black and Caspian Seas. Cultivated grapes spread to the east and west (arrows). Secondary domestication centers occurred at additional locations within the natural range of *V. vinifera* subsp. *sylvestris*. (Map Base © 2011, Ancient World Mapping Center (www.unc.edu/awmc))



- همبستگی و رابطه انگور با بلوط (grapes with oak)
- انگورها از درختان بلوط به عنوان قیم استفاده می کردند
- *Saccharomyces cerevisiae* (مخمر تهیه شراب) از درختان بلوط
- تجارت و مسافرت به فلسطین، سوریه، مصر، بین النهرین و سپس مناطق مدیترانه‌ای
- یونانی‌ها و رومی‌ها علاوه بر مصرف روش‌های کشت آن را نیز به سراسر اروپا و حتی مناطق شمال مثل بریتانیا گسترش دادند.
- V. vinifera از اروپا به شمال آمریکا، پرو و شیلی برده شد بعد به مناطق جنوب آفریقا، استرالیا و نیوزلند وارد شد.

Fig. 1.1. *Vitis riparia* smothering a tree in an upstate New York winter.

1

Plate 1. *Vitis riparia* grapes growing wild in the North East of the United States. The berries are densely coloured and strong of flavour.

- تاریخ اهلی شدن به حدود 6000 تا 10000 سال قبل
- تغییر صفات مورفولوژیکی و بیو شیمیایی با اهلی شدن *V. vinifera*

- *Complete flowers*
- *Uniformity in berry maturation in cluster*
- *More sugar content*
- *Wide range of colors*

Family, Genus, Species and Related Plants

- از نظر گیاه‌شناسی یک Liana (خزنده) یا یک Climbing vine (بیاره بالا رونده)
- فاقد تنه
- به صورت یک گیاه زیر رسته (understorey)
- پراکنش بذر به راحتی
- در برخی موارد انگورهای وحشی هم خوش طعم هستند

مثل *V. amurensis* یا انگور Amur grape که منشأ آن شمال شرق آسیاست. (cold hardiness) (disease resistance)

Family: Vitaceae

- mostly woody,
- tree-climbing vines, though a few have a shrubby growth habit.
- characterized by tendrils
- inflorescences opposite the leaves.
- There are 12 genera within the family including
- *Vitis*, *Ampelocissus*, *Clematicissus*, *Parthenocissus* (Virginia creeper), *Ampelopsis* and *Cissus* (kangaroo vine).

- <u>Genus: *Vitis*</u>

- consists of two subgenera, *Euvitis* and *Muscadinia*.
- flower petals separate from the bottom
- 38 کروموزوم برای Euvitis و 40 کروموزوم برای *Muscadinia*

- There are three named species in this group, the most important of which is *M. rotundifolia*

- Because of their different chromosome number, plants in this subgenus will not naturally interbreed with *Euvitis* species.

Vitis labrusca

Grapes

- Horticultural Classification

  (3 groups)
- Botanical Classification

  (2 groups)
- Classification according to usage

  (4 groups)

Grape Cultivar Types

American- selections from wild species found in North America (labrusca, aestivalis) and results of breeding

Ex. Concord, Catawba, Niagara, Delaware, Cynthiana/Norton

French-American Hybrids- Hybrids between V. vinifera and various North American species

Ex. Seyval, Vidal, Vignoles, Chambourcin, Foch, etc.

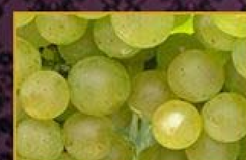
European- Vitis vinifera Ex. Chardonnay, Cabernet Sauvignon, Riesling, etc.

Meet the Grapes

Noble is the primary red muscadine used for juice and wines in much of the Southeast.

Cynthiana (a.k.a. Norton) - originated in Virginia and is currently very popular for use in making fine dry red wines.

Chambourcin is a black-fruited French hybrid grape used for producing a dry, deep-colored red wine.



Chardonel, a cross between Seyval and Chardonnay, narrows the gap between French-American hybrids and V. viniferas by producing a fine dry white wine.

Vidal, a French hybrid developed in the 1930's, is a late ripening white grape that is used for wines ranging from sweet to dry, and even for "late harvest" wines.

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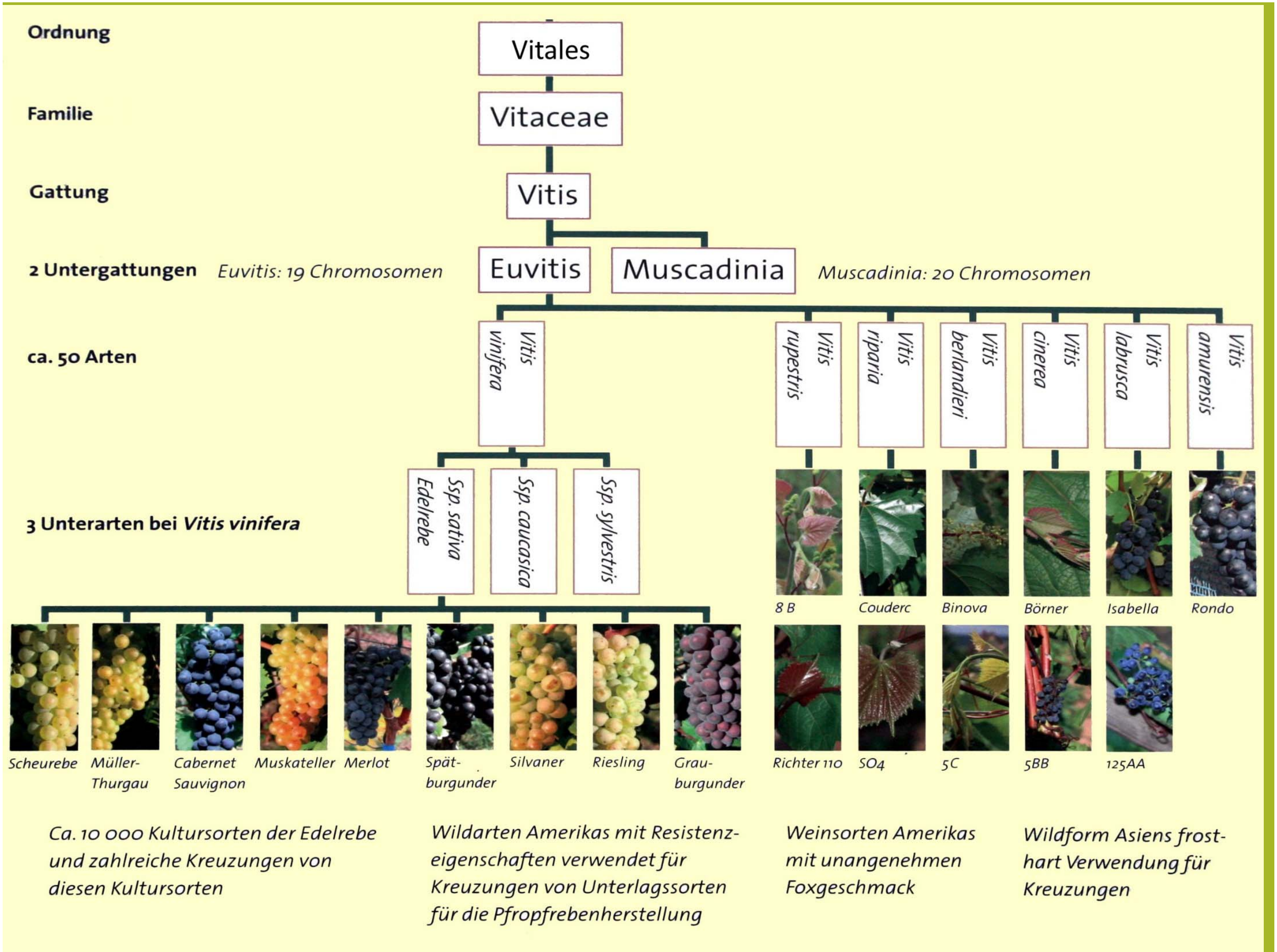
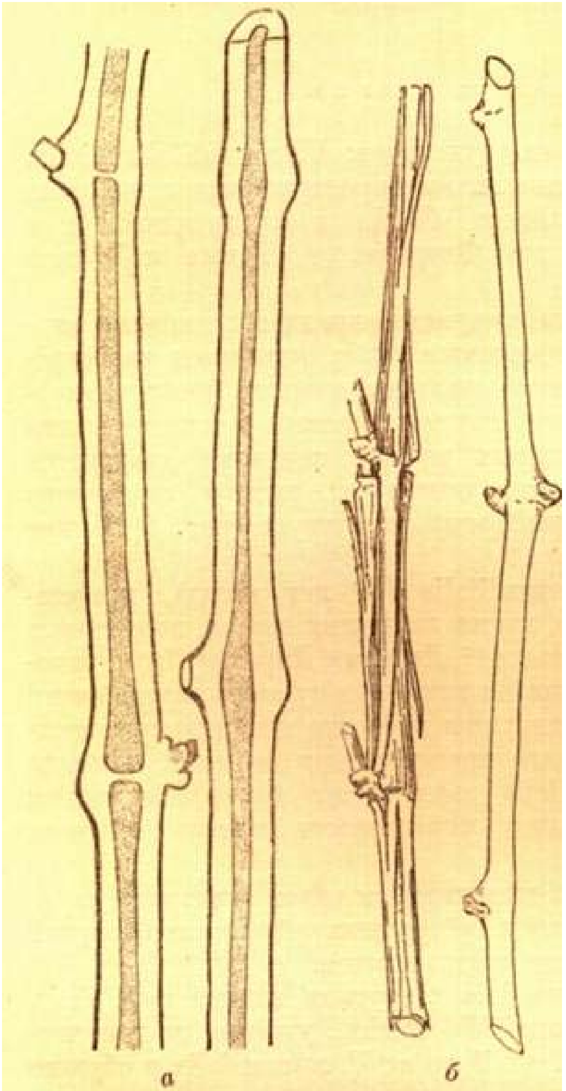


Ordnung
Vitales
Familie
Vitaceae
Gattung
Vitis
2 Untergattungen
Euvitis: 19 Chromosomen
Euvitis
Muscadinia
Muscadinia: 20 Chromosomen
ca. 50 Arten
Vitis vinifera
Vitis rupestris
Vitis riparia
Vitis berlandieri
Vitis cinerea
Vitis labrusca
Vitis amurensis
3 Unterarten bei Vitis vinifera
Ssp. sativa Edelrebe
Ssp. caucasica
Ssp. sylvestris
8 B
Couderc
Binova
Börner
Isabella
Rondo
Scheurebe
Müller-Thurgau
Cabernet Sauvignon
Muskateller
Merlot
Spätburgunder
Silvaner
Riesling
Grauburgunder
Richter 110
SO4
5C
5BB
125AA
Ca. 10 000 Kultursorten der Edelrebe und zahlreiche Kreuzungen von diesen Kultursorten
Wildarten Amerikas mit Resistenzeigenschaften verwendet für Kreuzungen von Unterlagssorten für die Pfropfrebenherstellung
Weinsorten Amerikas mit unangenehmen Foxgeschmack
Wildform Asiens frosthart Verwendung für Kreuzungen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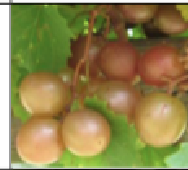
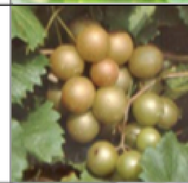
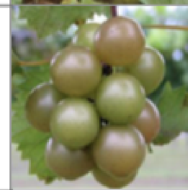
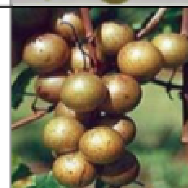
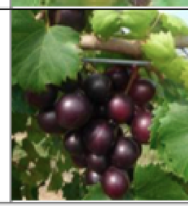
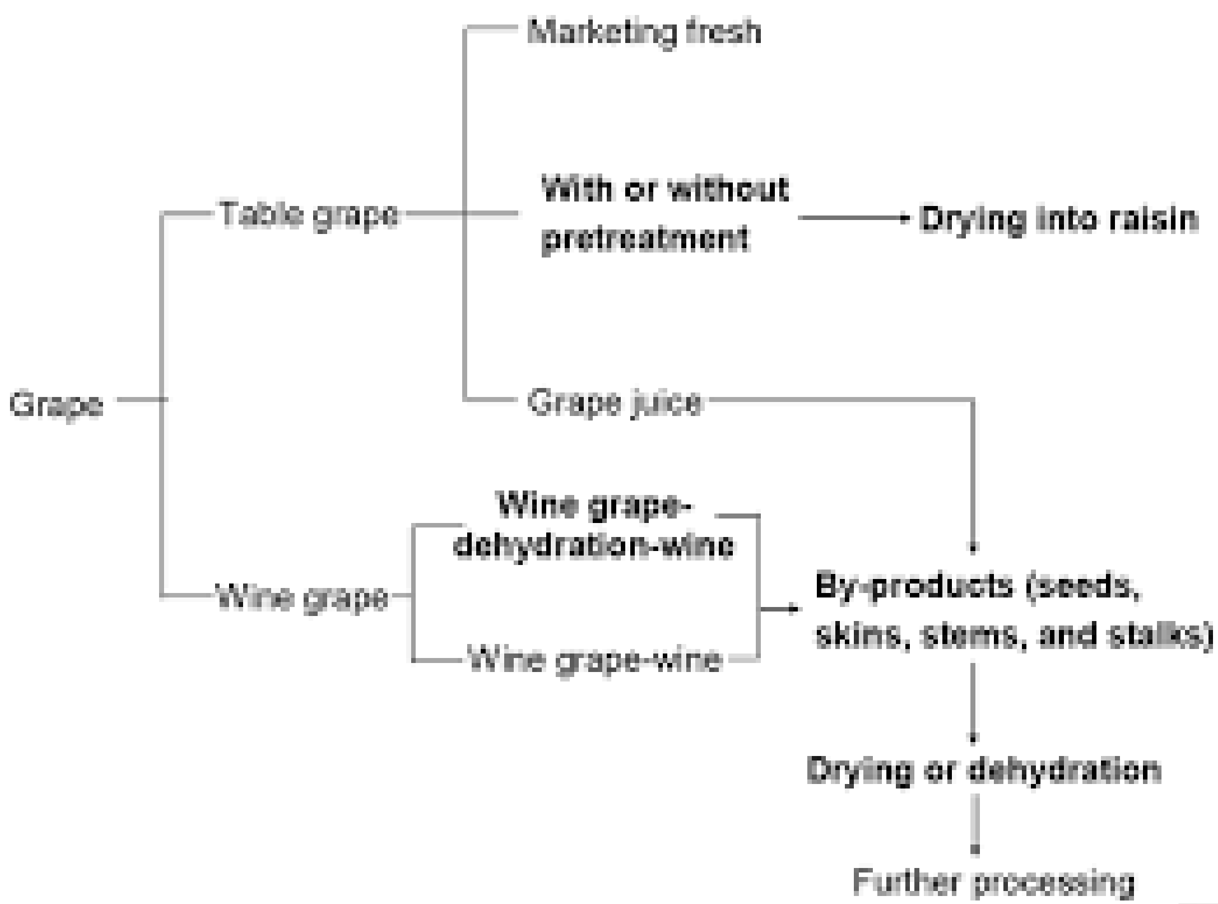
haracteristics of Muscadine Grape

Variety			Size	Flavor	Notes
Tara			Large	Good, sweet flavor 14 - 17% sugar	Full-bodied flavor Color: Bronze Thick skinned
Early Fry			Very Large	Good Flavor 14 - 18% sugar	Color: Dull Bronze Traditional slip skin
Triumph			Medium Large	Very sweet 14 - 18% sugar	Color: Pinkish Bronze Traditional slip skin
Late Fry			Large	Very sweet 14 - 21% sugar	Color: Green-Bronze Traditional slip skin
Lane			Large	Very sweet 14 - 20% sugar	Color: Very dark, Purple-Black evenly colored grape Crisp skin
Nesbitt			Medium Large	Delicious, Concord flavor 14 - 18% sugar	Color: Purple-Black Traditional slip skin
Supreme			Very Large	Very sweet 14 - 22% sugar	Largest of the black variety. Color: Dark Purple-Red Crisp skin


Marketing fresh
Table grape
With or without pretreatment
Drying into raisin
Grape
Grape juice
Wine grape-dehydration-wine
Wine grape
Wine grape-wine
By-products (seeds, skins, stems, and stalks)
Drying or dehydration
Further processing

Classification of Grape Varieties

List of commercial and popular Grape varieties in India:

Category	Varieties
Table Grapes	Thompson Seedless, Sharad Seedless, Pusa Seedless, Sonaka.
Raisin Grapes	Thompson Seedless, Arkavati
Wine Grapes	Bangalore Blue, Thompson Seedless

THOMPSON SEEDLESS

Thompson Seedless is the dominant grape variety grown in California. Thompson Seedless grapes are usually sun-dried on paper trays for a period of between 17 to 21 days.

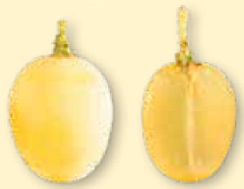
FIESTA & FLAME

Selma Pete, DOVine, and Fiesta are all Thompson Seedless varieties, while Flame Seedless is a cross between Thompson Seedless and other varieties including Muscat of Alexandria.

ZANTE CURRANT

Also known as Black Corinth, the Zante Currant is used to make small, seedless raisins. Because of its early ripening and quick drying time, Zante Currants can be dried both on paper trays and on the vine.

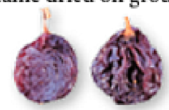
Thompson Seedless



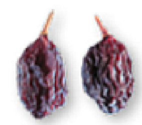
Thompson Seedless dried on ground

Fiesta **Flame Seedless**

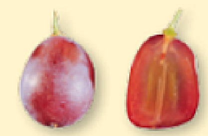
Flame dried on ground



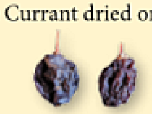
Flame dried on the vine



Zante Currant



Zante Currant dried on ground



Zante Currant dried on the vine

Grape

	2013	AreaName
1	11550024	China, mainland
2	8010364	Italy
3	7744997	United States of America
4	7480000	Spain
5	5518371	France
6	4011409	Turkey
7	3297981	Chile
8	2881346	Argentina
9	2483000	India
10	2046420	Iran (Islamic Republic of)
11	1850000	South Africa
12	1762572	Australia
13	1439535	Brazil
14	1389133	Egypt
15	1322090	Uzbekistan

Table 1.1. Estimated average annual grape production (2001–2003, in 100,000 kg) by country (from OIV, 2003).

Rank	Country	Production	Rank	Country	Production
1	Italy	78,436	22	Yugoslavia[a]	4,437
2	France	67,921	23	Bulgaria	4,253
3	USA	61,933	24	Mexico	4,184
4	Spain	59,896	25	Korea	4,173
5	China	44,450	26	Ukraine	4,000
6	Turkey	34,500	27	Afghanistan	3,650
7	Iran	26,736	28	Croatia	3,544
8	Argentina	23,353	29	Syria	3,461
9	Chile	19,459	30	Iraq	2,950
10	Australia	15,989	31	Morocco	2,739
11	South Africa	14,884	32	Russia	2,669
12	Germany	12,075	33	Austria	2,553
13	Greece	11,793	34	Algeria	2,362
14	India	11,400	35	Japan	2,260
15	Egypt	10,956	36	Macedonia	1,954
16	Romania	10,820	37	Turkmenistan	1,667
17	Brazil	10,794	38	Yemen	1,654
18	Portugal	9,988	39	Georgia	1,467
19	Hungary	6,789	40	Peru	1,364
20	Moldavia	6,036		All others	17,790
21	Usbekistan	4,970		Total	616,309

[a]Yugoslavia was not officially abolished as a political entity until 2003.

Table 1.2. Estimated area of land cultivated to grapes in 2005, by country. The percentage change in area since 1995 is also indicated (from FAO, 2006).

Country	Production area (ha)	Change from 1995 (%)
Spain	949,100	–18
France	851,615	–5
Italy	837,845	–7
Turkey	530,000	–6
China	453,200	+187
USA	380,000	+20
Iran	275,000	+18
Romania	217,006	–13
Portugal	210,000	–18
Argentina	208,000	+1
Chile	178,000	+57
Australia	153,204	+145
Moldova	145,000	–18
Greece	127,000	0
South Africa	123,190	+19
Bulgaria	113,334	+1
Uzbekistan	110,000	+16
Germany	98,000	–5
All others	1,387,118	+5
Of note:		
New Zealand	19,960	+227
Switzerland	15,000	+1
Canada	9,259	+29
Namibia	2000	+233

1.3 MORPHOLOGY AND ANATOMY

Many grapevine species are very vigorous, woody climbers named lianas, while others have a more brush-type growth habit (see Section 1.1). All are perennial (Latin *per* = through; *annus* = year), polycarpic (Greek *polus* = many, much; *karpos* = fruit, grain), and deciduous (Latin *decido* = to fall down). These terms are used to describe the vines' typical life form: they live longer than 2 years, they flower and reproduce repeatedly during their life, and they shed their leaves each year. With the aid of their tendrils and flexible trunks, wild vines climb on trees to a height of 30 m or more and spread out their foliage over the tree canopy (see Figure 1.2). As "structural parasites," vines can maximize their leaf area and shoot growth rate while minimizing their investment in a supporting stem structure (Ewers and Fisher, 1991; Wyka et al., 2013). Using the trees for support (i.e., seizing them as a natural trellis system), they can grow to tremendous size; the canopy of a single vine may cover a surface area of dozens of square meters. Grapevines can live to several hundred years of age: Famous examples include the "Great Vine" in London's Hampton Court Palace, which is thought to have been planted before 1770 and continues to produce 200–300 kg of fruit each year, and the "Old Vine" of Maribor (Slovenia), which is believed to be over 400 years old (Vršič et al., 2011). Vegetative propagation, whether naturally by layering or artificially from cuttings, bud grafts, tissue culture, and other means, extends a vine's life span virtually indefinitely. In fact, both rooted cuttings and grafted plants show clear signs of rejuvenation compared to their "mother" plants (Munné-Bosch, 2008). For instance, growth rates, leaf gas-exchange rates, and fruiting of recently propagated vines are like those of young plants and are independent of the age of the vines from which the propagation material was taken.

Like other higher plants, grapevines comprise vegetative organs and generative or reproductive organs or fruiting structures. The vegetative organs include the roots, trunk, shoots, leaves, and tendrils (Figure 1.4), while the reproductive organs include the clusters with flowers or berries. A vine's vegetative part can be divided into a belowground portion (roots) and an aboveground portion (trunk and shoots). The aboveground portion together with the reproductive organs is termed the vine's canopy. The roots, the trunk, and its trained extension, the cordon, together form the permanent structure of the vine, which makes up 50–75% of the biomass (dry matter) of cultivated

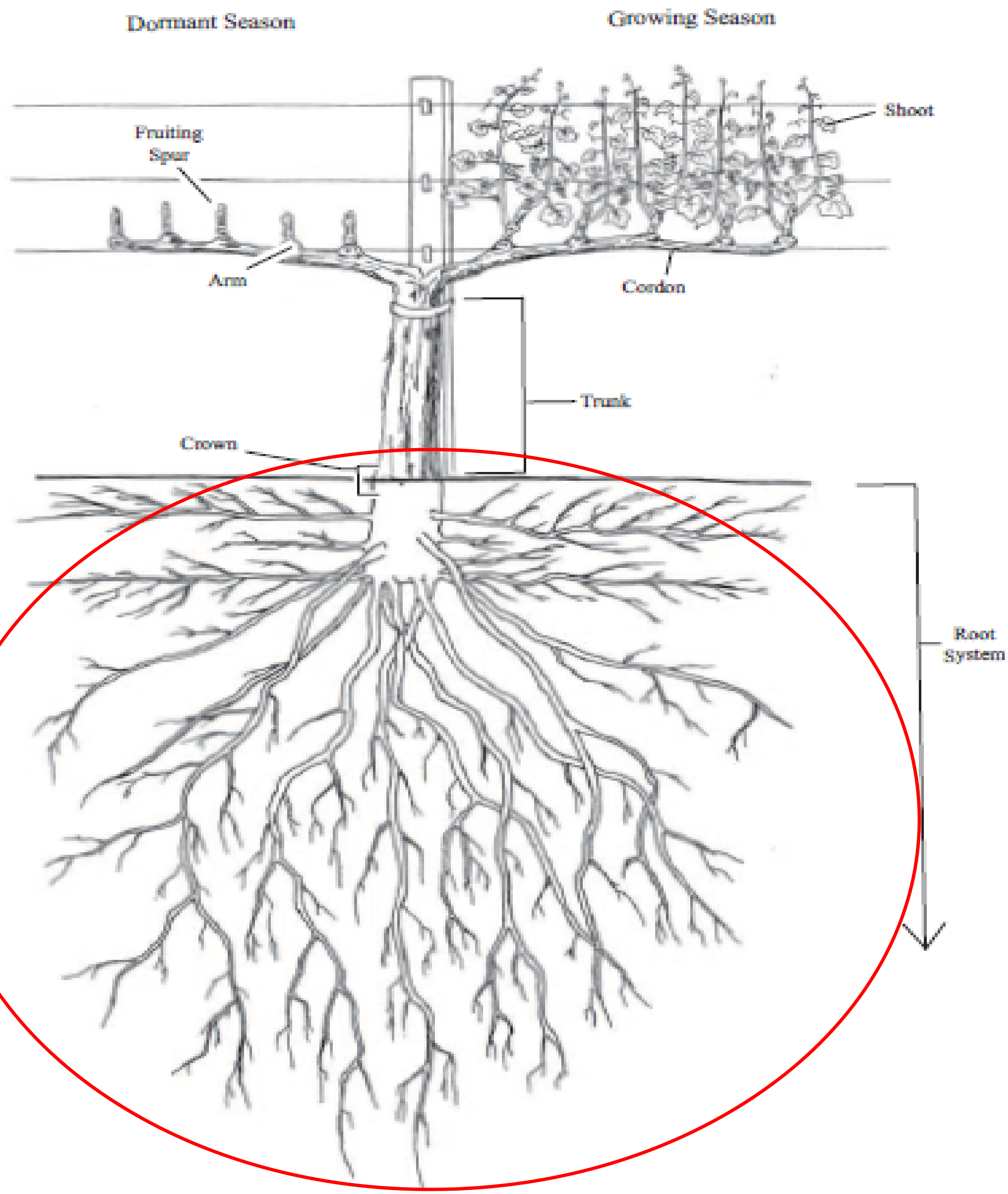


Figure 2. Grapevine structures and features: self-rooted vine. Drawing by Scott Snyder.

سیستم ریشه‌ای موهای بالغ از یک اسکلت چوبی متشکل از ریشه‌های پیرتر تشکیل شده است که از آنها ریشه‌های دائمی رشد می‌کنند (افقی یا عمودی). از این ریشه‌ها ریشه‌های جانبی زیادی تولید می‌شود. از این ریشه‌ها هم تعداد زیادی ریشه‌های جانبی کوتاه‌تر و نازک‌تر که نقش آن‌ها افزایش سطح تماس خاک است.

قسمت عمده سیستم ریشه‌ای انگور به طور معمول در ۱ متری خاک وجود دارد گرچه برخی ریشه‌ها در شرایط خاک‌های مساعدتر به عمق بیشتر نفوذ می‌کنند.

- Own-rooted/ self-rooted vines or grafted

- The crossing of *V. vinifera* and other species of grapevine was not widespread until the 19th century, when North American vine diseases and phylloxera (a plant louse) spread throughout Europe.

- *V. champini*, *V. berlandieri*, *V. rupestris*, *V. riparia*, etc.

- The root tip is the most important part of the root system, in that it is the part that will allow the plant to explore new areas of soil.

- Root hairs are the specialized organs that grow from the epidermal cells behind the tip and along for about 5 cm (zone of absorption).

- Root hairs have a very large surface area, they are the part of the root that perform most of the water and nutrient gathering, and also interact with the mycorrhizae.

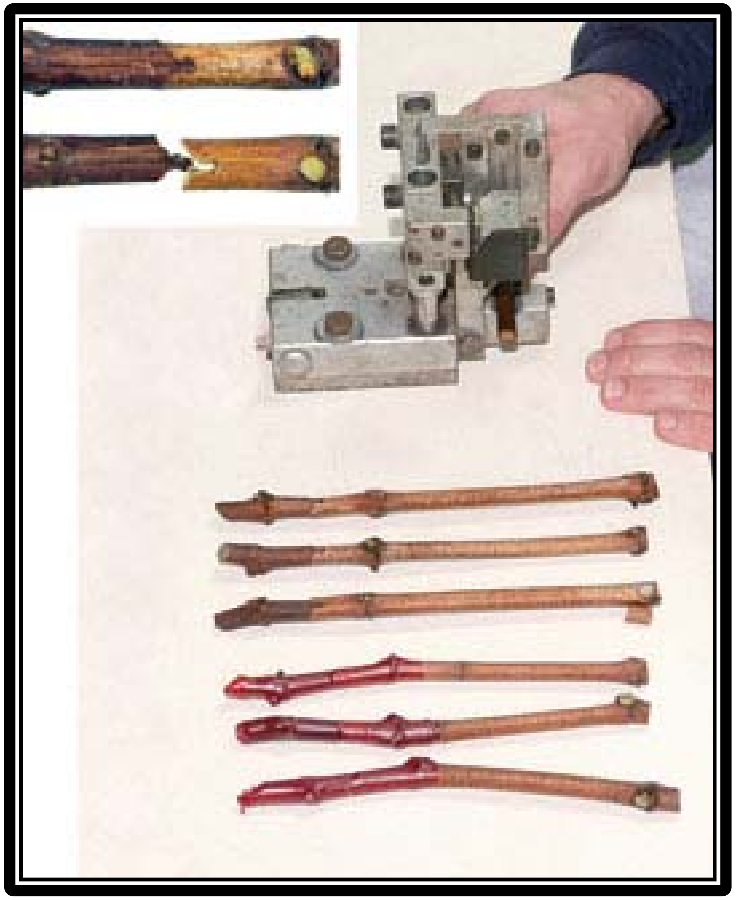


Table 5.1. Selected rootstocks and related information.[a]

Rootstock	Parentage	Vigour	Drought resistance	Tolerance to lime	Tolerance to Phylloxera	Tolerance to nematodes	Tolerance to salinity
Freedom	1613C x *champini*	Moderate–high	Moderate–high	na	High	High	Moderate
Harmony	1613C x *champini*	Moderate–high	na	Moderate	Moderate–high	Moderate–high	Moderate
SO4	*berlandieri* x *riparia*	Moderate	Low	Moderate	Moderate–high	Moderate–high	Moderate–low
420A	*berlandieri* x *riparia*	Moderate–low	Low	Moderate	High	Moderate	Low
Ramsey	*champini*	High	Moderate–low	Moderate	Moderate–high	High	High
Riparia gloire	*riparia*	Low	Low	Low	High	Moderate–low	Moderate
44–53	*riparia* x (*cordifolia* x *rupestris*)	Moderate	High	Moderate	High	Moderate–high	na
101–14	*riparia* x *Rupestris*	Moderate–low	Moderate	Moderate	High	Moderate	High
Schwartzmann	*riparia* x *rupestris*	Moderate	Moderate–low	Moderate	High	Moderate	Moderate–high
3309	*riparia* x *rupestris*	Moderate–low	Moderate–low	Moderate	High	Moderate–low	Low
St George	*rupestris*	High	Poor	Moderate–high	Moderate–high	Moderate–low	Moderate
1616	*solonis* x *riparia*	Moderate	Moderate–low	Low	Moderate–high	High	na
AXR1	*vinifera* x *rupestris*	Moderate–high	Moderate	Moderate–high	Low	Low	na
99R	*berlandieri* x *rupestris*	High	Moderate–high	Moderate–high	High	Moderate–high	Moderate–low
5BB	*berlandieri* x *riparia*	Moderate	Moderate–low	High	High	Moderate–high	Moderate

[a]Sources of information: Anon (2007); Anon (2008); Arbabzadeh and Dutt (1987); Downton, 1985; Hardie and Cirami (1988); Hoskins *et al.* (2003); Lider (1958); McCarthy *et al.* (1997); Pouget and Delas (1989); Southy (1992); Stafne and Carroll (2006); Whiting and Buchanan (1992); Whiting *et al.* (1987).
na, not available.

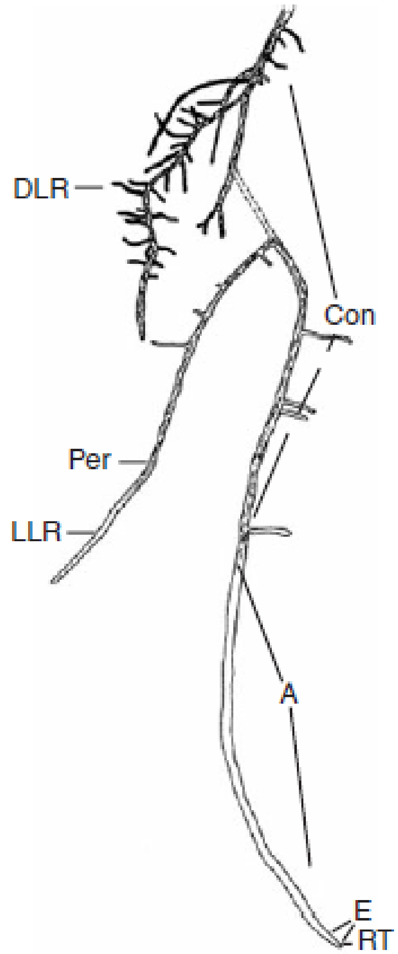


Fig. 2.2. Root of *Vitis vinifera* ('White Riesling') showing actively growing and inactive or dead portions. A, zone of absorption; Con, zone of conduction; DLR, dead lateral root; E, zone of cell elongation; LLR, living lateral root; Per, periderm; RT, root tip (reproduced with permission from Pratt, 1974).

The root system of established grapevines comprises a far-reaching, highly branched structure with a surface area far exceeding that of the leaf canopy it supports. A mature, cultivated grapevine can have more than 100 km of total root length with a surface area greater than 100 m^2, whereas its leaf area is usually less than 10 m^2. The woody roots, whose diameter rarely exceeds 3 or 4 cm, serve to anchor the vine and transport and store soil-derived nutrients, whereas the small absorbing roots ("fine roots," 0.1–1 mm in diameter) are responsible for acquisition of resources such as water and nutrients. The woody roots of mature vines are widely distributed, with horizontal roots exploring the soil for distances of up to approximately 10 m from the trunk (Huglin and Schneider, 1998; Smart et al., 2006; Figure 1.5). Although the majority of roots, especially the fine roots, are normally concentrated in the top 0.5–1 m, roots can grow to a depth of more than 30 m when they encounter no impermeable barriers (Galet, 2000; Lehnart et al., 2008; Morlat and Jacquet, 1993; Pourtchev, 2003; Viala and Vermorel, 1909). Indeed, grapevines are among the most deep-rooted plants, and their root biomass can range from 5 to 40 t ha^{-1}, which may be a reflection of the competition for water and nutrients during the vines' coevolution with their "trellis" trees (Huglin and Schneider, 1998; Smart et al., 2006).

- **Mycorrhizae**
- These are a group of fungi that form beneficial relationships with most species of plants, including grapevines.
- Vesicular arbuscular mycorrhizae (VAM) are the most common.
- VAM are usually most associated with plants in low-phosphorus soils, (as the hyphal network is more efficient), however, VAM associations are also known to occur in higher phosphorus soils.
- Grapevines normally have VAM infections, and this has been shown to have a beneficial effect on the growth of vines with improved root and shoot development.

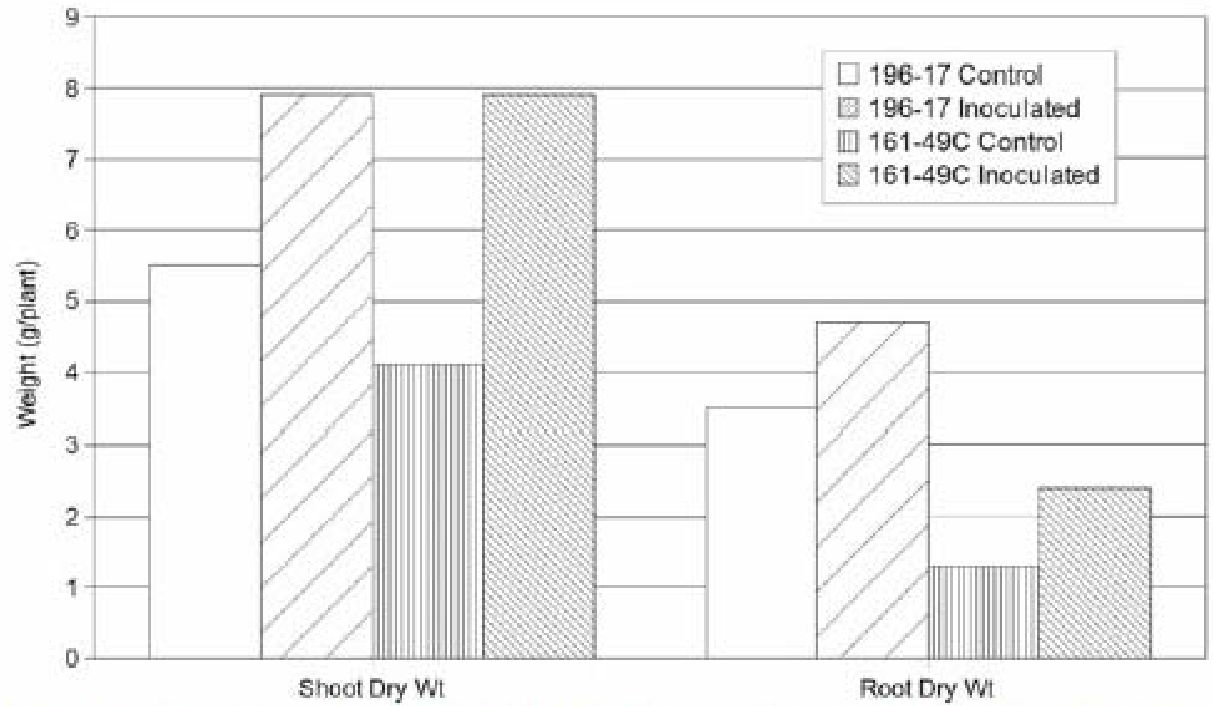


Fig. 2.3. The effect of inoculating two different rootstocks in grafted nursery vines with mycorrhizae. Both shoot dry weight and root dry weight were increased through the use of the mycorrhizal fungus *Glomus aggregatum* (reproduced with permission; redrawn from Aguín *et al*., 2004).

The Trunk

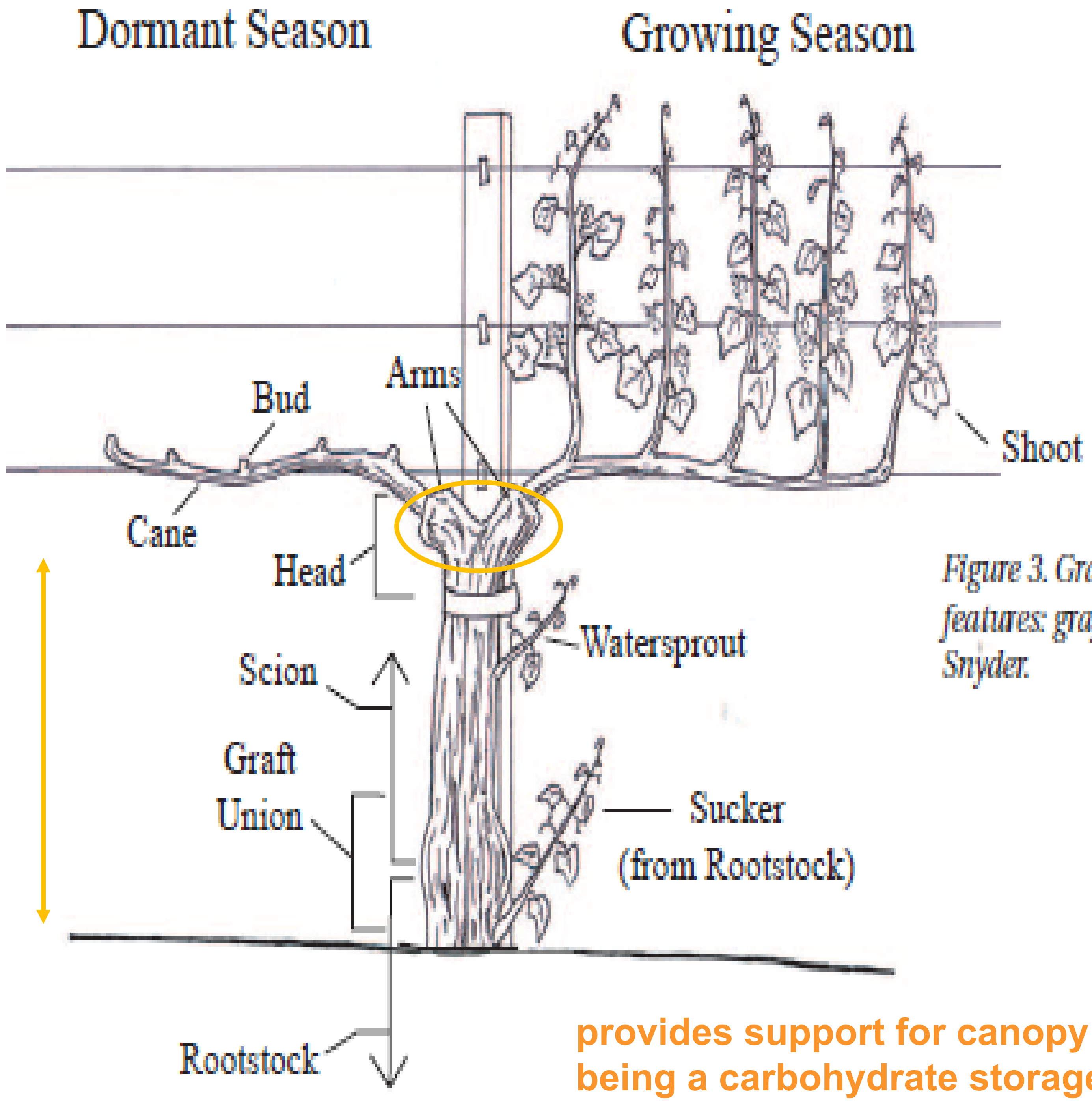
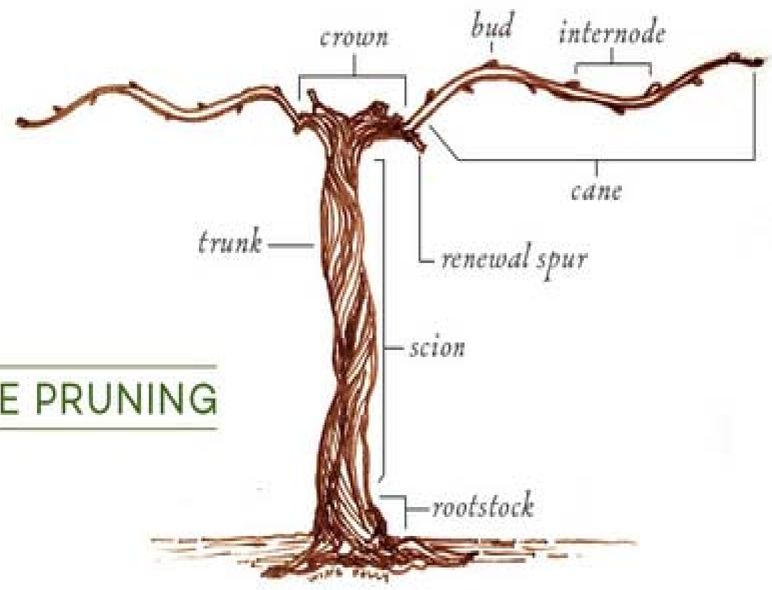


Figure 3. Grapevine structures and features: grafted vine. Drawing by Scott Snyder.

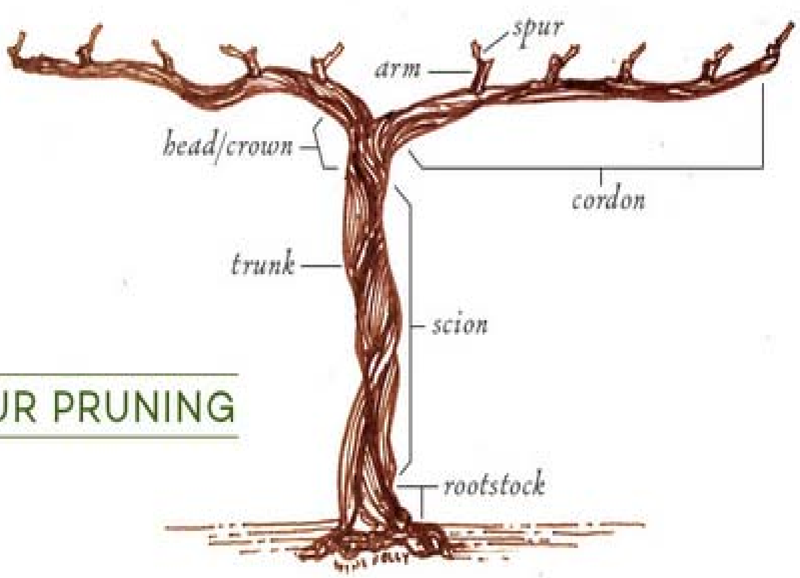
provides support for canopy growth as well as being a carbohydrate storage site

In mature vines, trunk has short arms in which canes or spurs are produced.

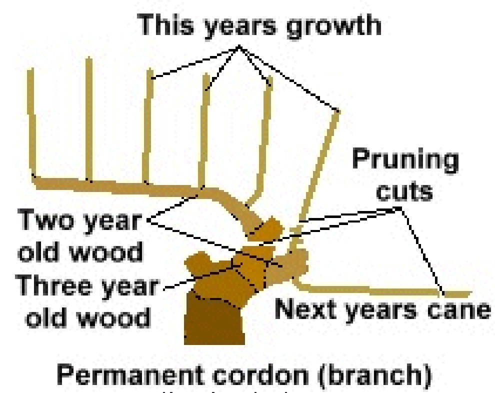
CANE PRUNING



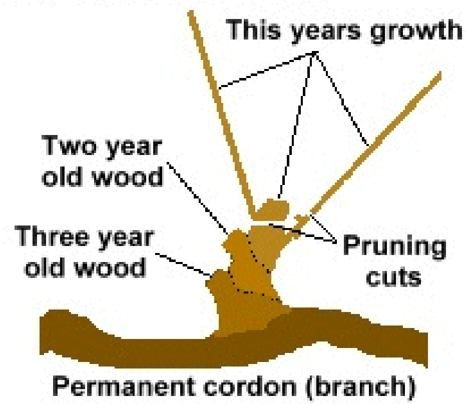
SPUR PRUNING



CANE PRUNING



SPUR PRUNING



Home Garden

Shoots and Canes

- Primary unit of vine growth
- Primary shoots arise from primary buds and are fruit- producing shoots on the vine.
- The shoot has many points of growth, but the extension growth of the shoot occurs from the shoot tip.
- Arranged along the shoot in regular patterns are leaves, tendrils, flower or fruit clusters and buds.

> Growth rate of the shoot varies during the season. Grapevine shoots do not stop expanding by forming a terminal bud as some plants do; they may continue to grow if there is sufficient heat, soil moisture, and nutrients.

Fixed growth *vs.* free growth

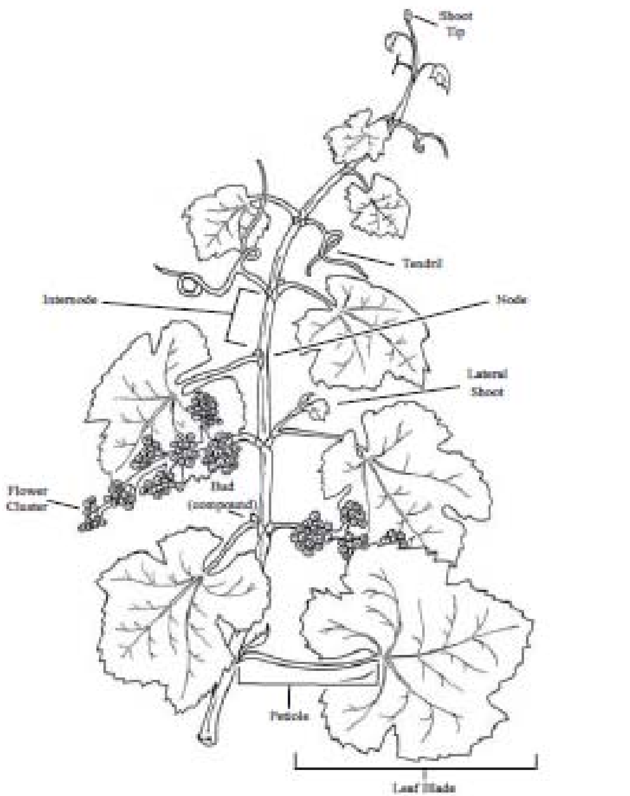
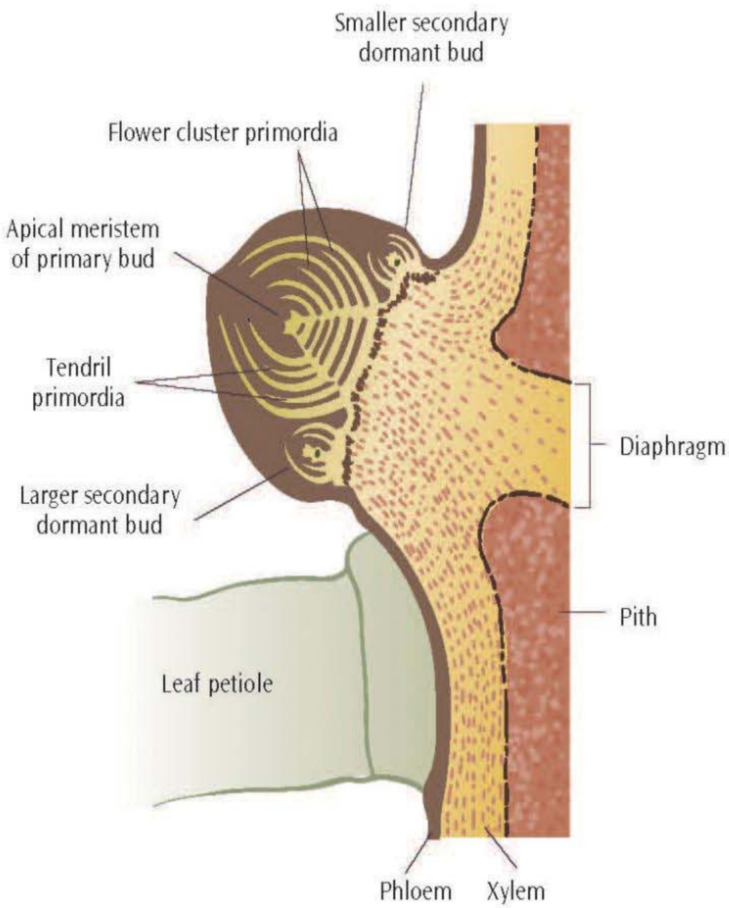


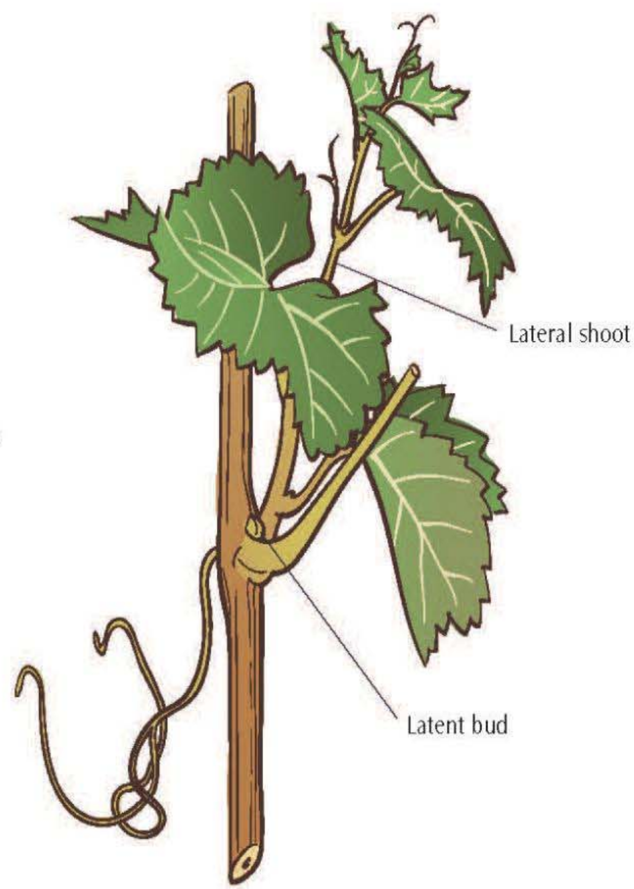
Figure 4. Principal features of a grapevine shoot prior to bloom. Drawing by Scott Snyder.

- The early-season shoot development is called fixed growth.
- It is the growth of the pre-formed nodes and leaves and results in the early appearance of leaves and flower clusters.
- A pattern to tendril and leaf appearance emerges: every third node lacks a tendril but this pattern …

At each internode and at the base of the leaf petiole there forms another **compound bud** and an **axillary (or lateral) bud**

The axillary bud will develop into a noticeable lateral shoot if conditions are favourable during the season,
The compound bud is the one that will overwinter and be the source of shoots for the following season





Further elongation of the shoot beyond the fixed growth is called the **free growth**.

It is the result solely of the environmental conditions of the current season and the shoot tip meristem.

Grapevines will grow as long as conditions (primarily temperature) permit, so their growth is called **indeterminate**.

The outer layer of meristem growth is old phloem,

as the cane grows it becomes what we see as the bark of the vine,

covers the older canes and vine trunks.

A cross-section of a cane shows the relative positions of the phloem and xylem on either side of the cambial layer, as well as the way in which the inner cortical cells (pith) break down to leave the center open.

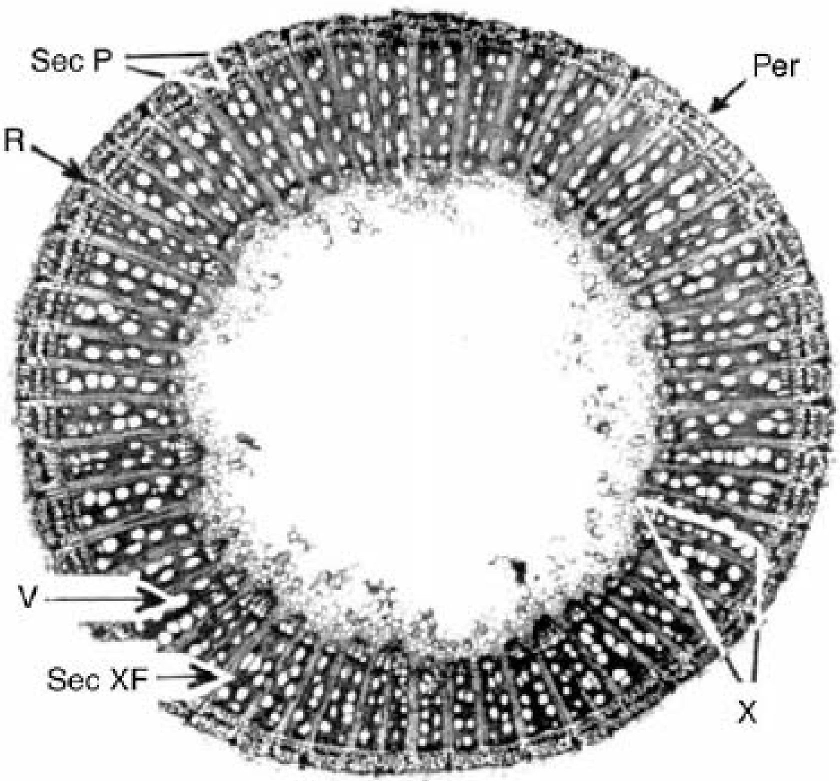
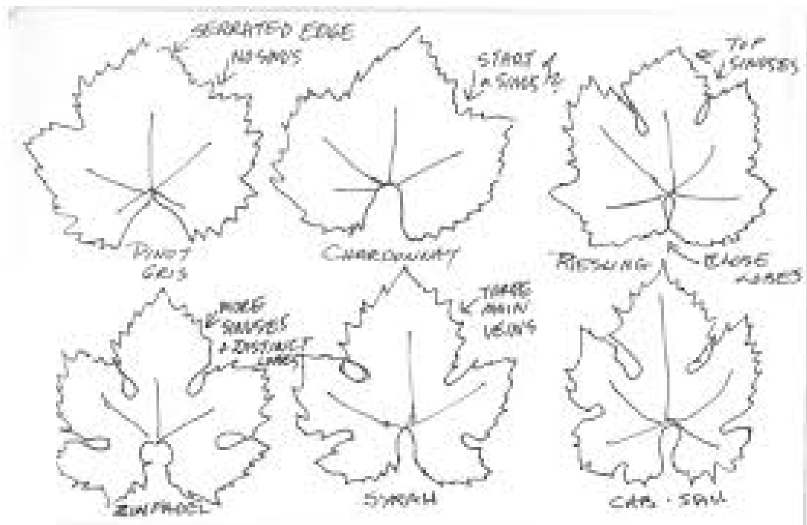
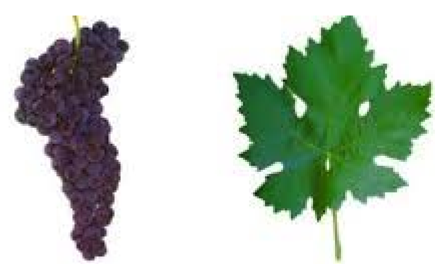


Fig. 2.6. Cross-section of a 1-year-old grapevine shoot of *V. vinifera*. Per, periderm; Sec P, secondary phloem; X, primary xylem; Sec XF, secondary xylem fusiform cell; R, ray; V, xylem vessel. Note that the centre of the shoot is open – the cortical cells have collapsed (reproduced with permission from Pratt, 1974).

شکل و اندازه بسته به رقم متفاوت است و یک ویژگی انگور است. موسکادین برگهای کوچک عرض ۵ تا ۷ونیم سانت. گرد و بدون لوب با حاشیه دندانه ای وینیفرا برگهای بزرگ ۲۰ تا ۲۵ سانت. به شکل قلب یا دایره ممکن است لوب داشته باشد. عمق و شکل لوبها و فاصله بین آنها که سینوس نامیده میشود به نوع رقم بستگی دارد. حاشیه برگها دندانه دار





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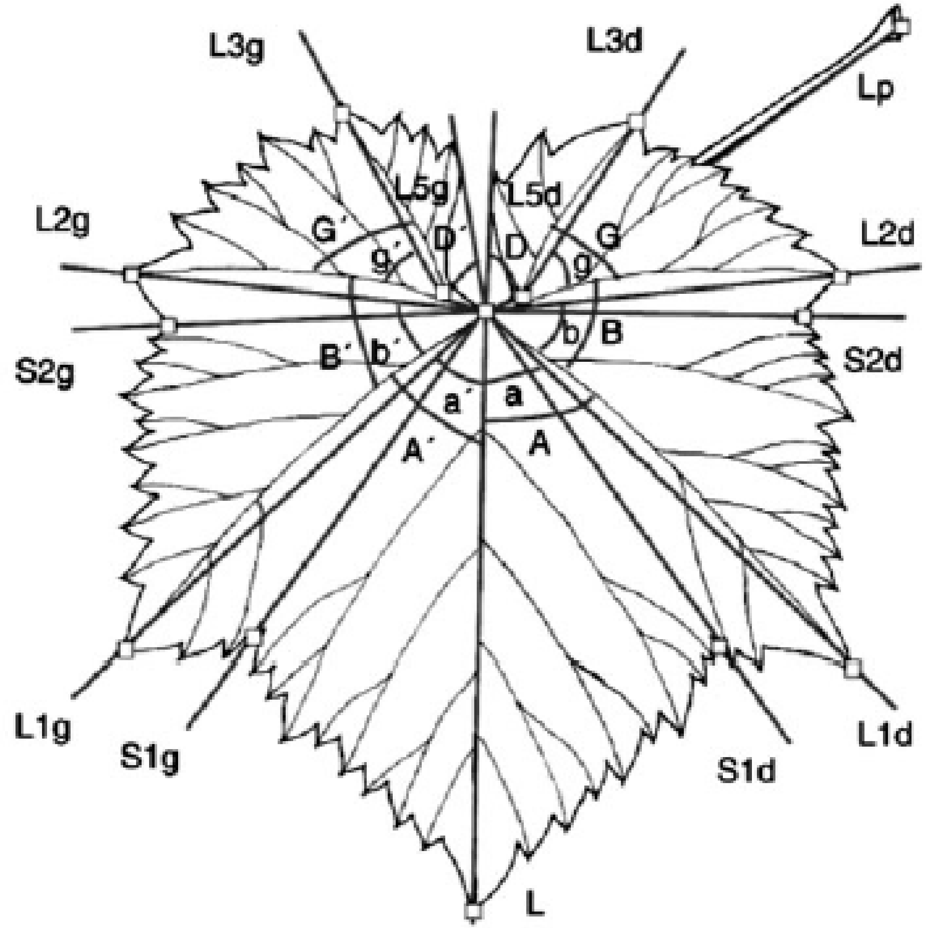
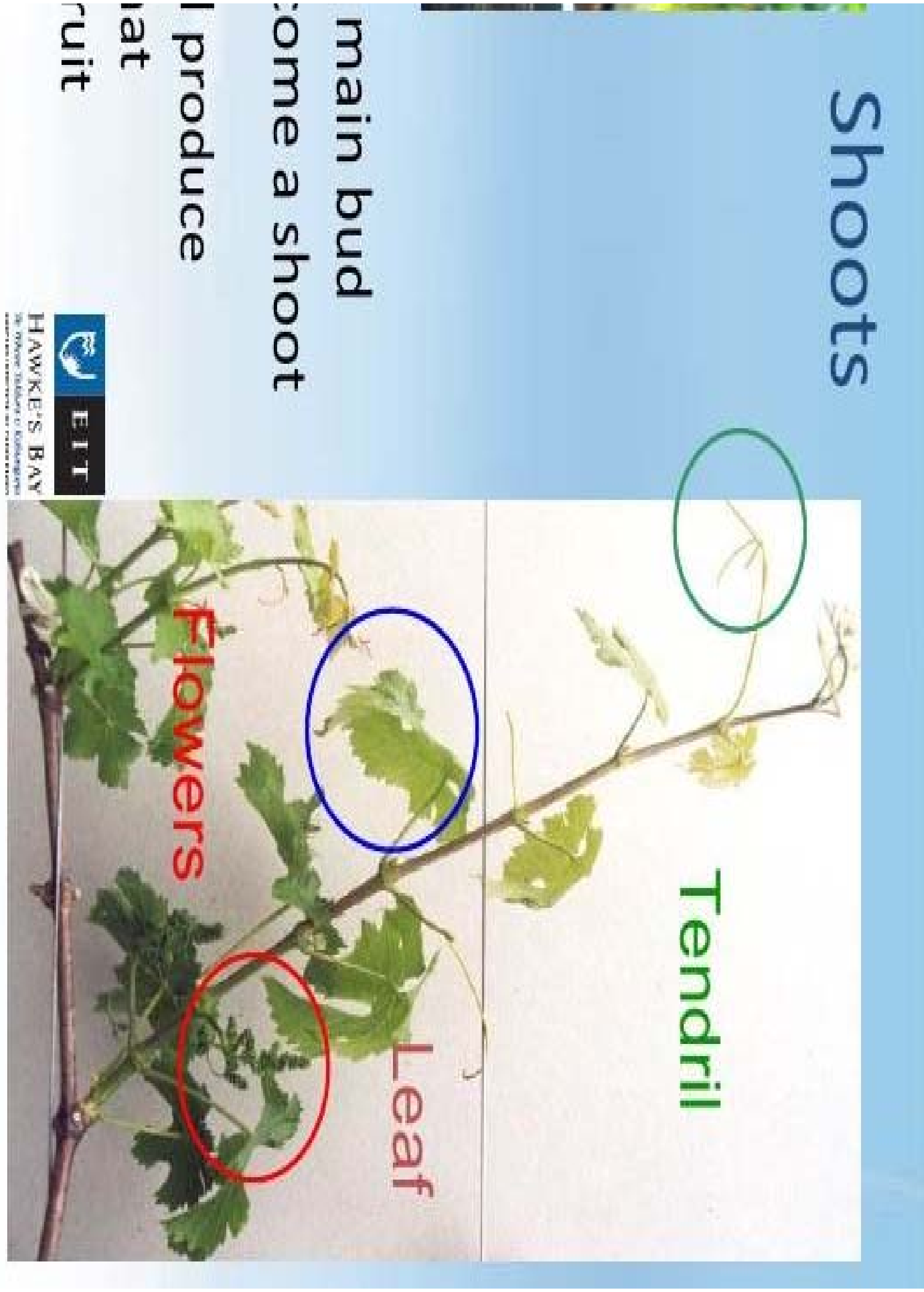


Fig. 2.9. An example of ampelographic measurements that can be made on mature grape leaves. Abbreviations correspond to parameters as set out by the OIV (Office International de la Vigne et du Vin (OIV, 1983)) (reproduced with permission from Santiago *et al.*, 2005).

A fruitful shoot usually prod



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The number of flower clusters on a shoot is dependent upon the grape variety and the conditions of the previous season under which the dormant bud (that produced the primary shoot) developed.

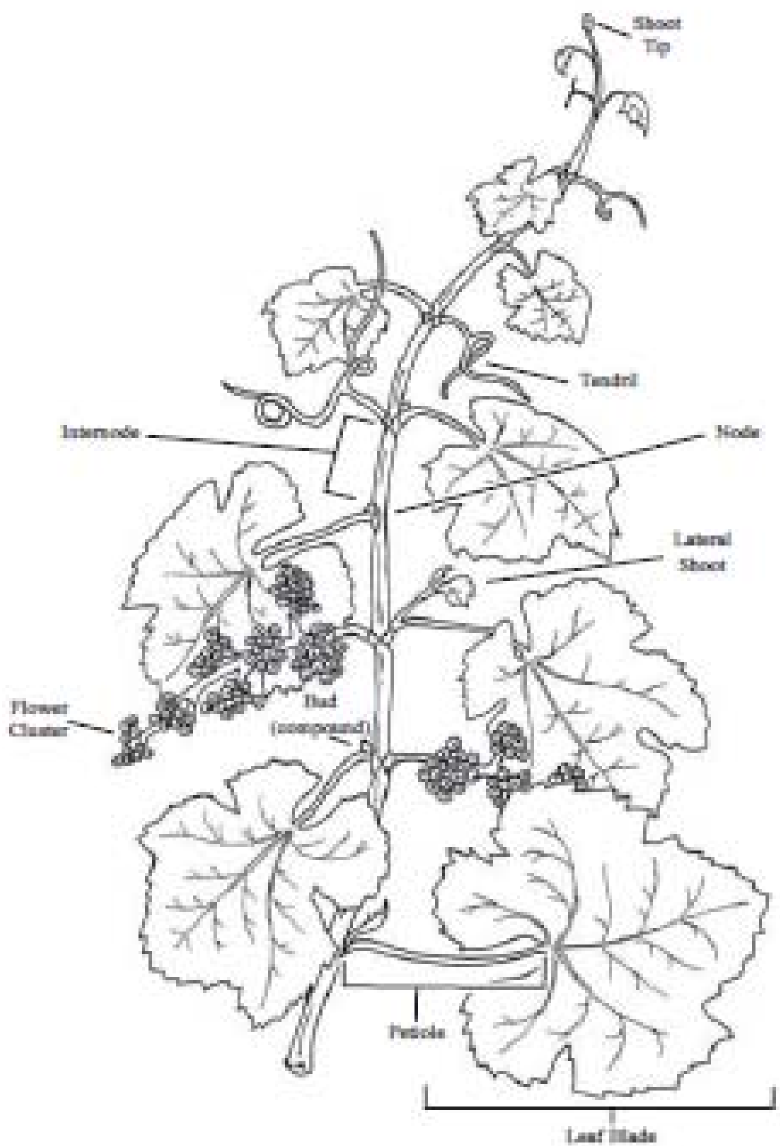
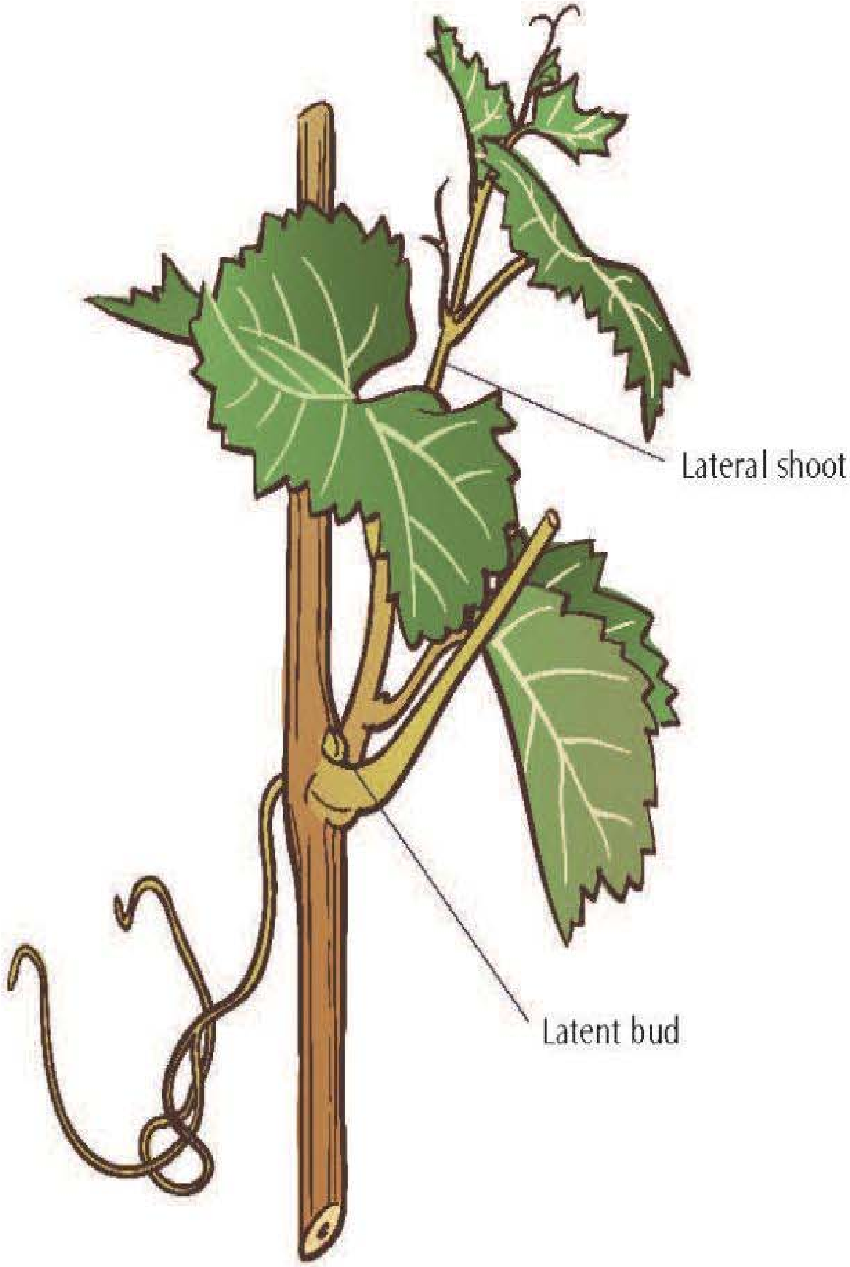


Figure 4. Principal features of a grapevine shoot prior to bloom. Drawing by Scott Snyder.



Buds

It is important to understand that on grapevines a bud develops in every leaf axil, including the inconspicuous basal bracts (scalelike leaves). In viticultural terminology, we describe two buds associated with a leaf—the *lateral bud*, and the *dormant bud* (or latent bud). The lateral bud is the true axillary bud of the foliage leaf, and the dormant bud forms in the bract axil of the lateral bud.

the two buds are situated side-by-side in the main leaf axil.

Although the dormant bud (sometimes called an *eye*) looks like a simple structure, it is actually a compound bud consisting of three growing points, sometimes referred to as the *primary*, *secondary*, and *tertiary buds*.

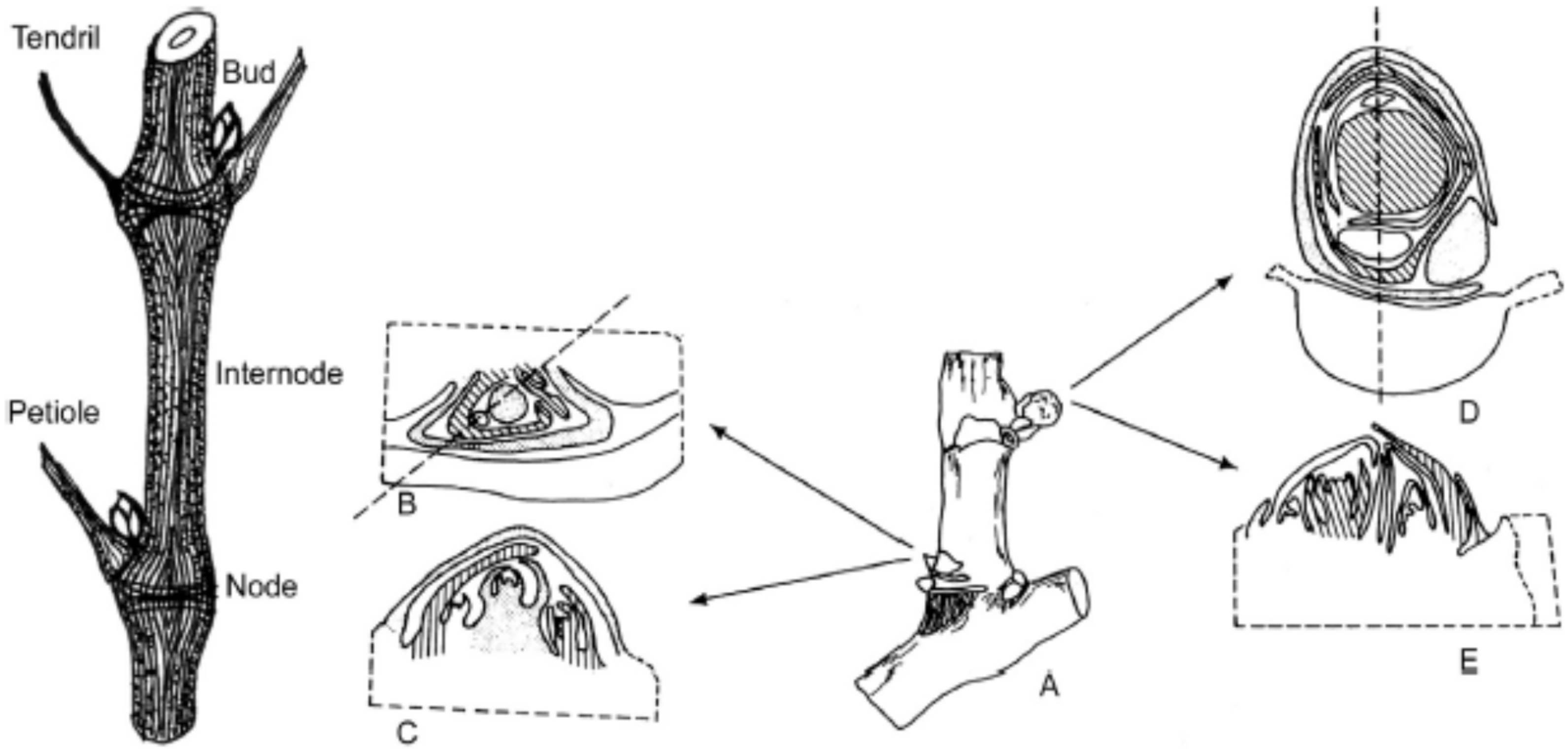


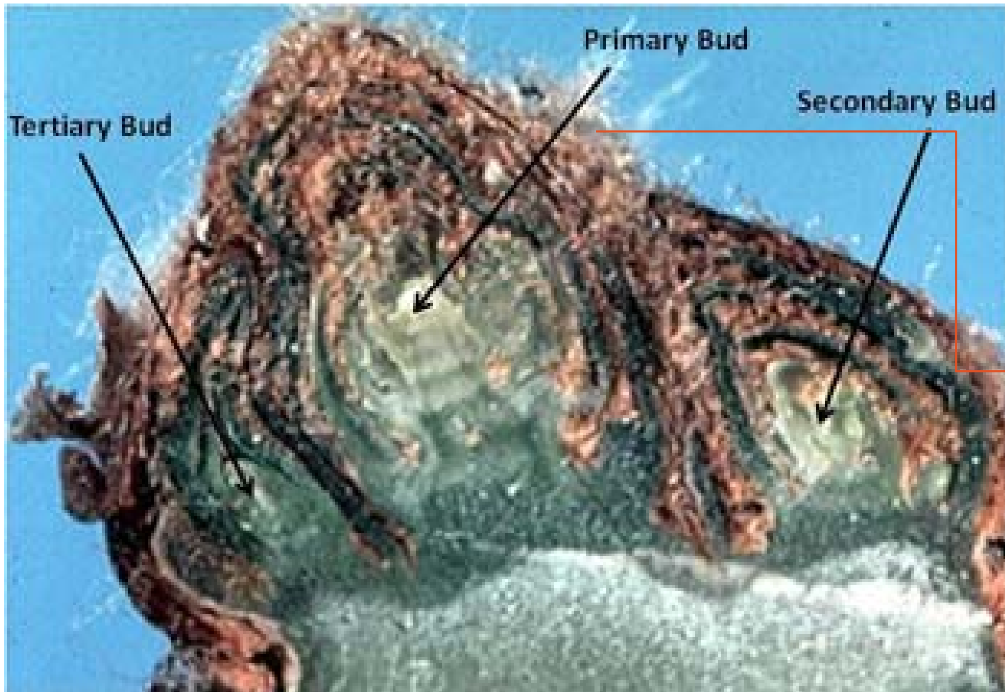
FIGURE 1.11

Location of the main features of a *Vitis* shoot (left; illustration by A. Mills) and one-node Concord spur with one count node and three basal buds (right: A, spur with buds; B, cross section of basal bud; C, longitudinal section of basal bud; D, cross section of compound bud; E, longitudinal section of compound bud; reproduced from Pool et al., 1978, reprinted by permission of American Journal of Enology and Viticulture).

. Continuing the bud development pattern, the primary growing point is the axillary bud of the lateral bud; the secondary and tertiary growing points are the axillary buds of the first two bracts of the primary growing point.

The dormant bud is of major concern at pruning, since it contains cluster primordia (the fruit-producing potential for the next season). It is referred to as dormant to reflect the fact that it does not normally grow out in the same season in which it develops.

The dormant bud undergoes considerable development during the growing season. The three growing points each produce a rudimentary shoot that ultimately will contain *primordia* (organs in their earliest stages of development) of the same basic components of the current season's fully grown shoot: leaves, tendrils, and in some cases flower clusters. The primary bud develops first, so it is the largest and most fully developed. If it is produced under favorable environmental and growing conditions, it will contain flower cluster primordia before the end of the growing season. The flower cluster primordia thus represent the fruiting potential of the bud in the following



Floss

cold hardiness

Figure 2b

Lateral bud and second crop

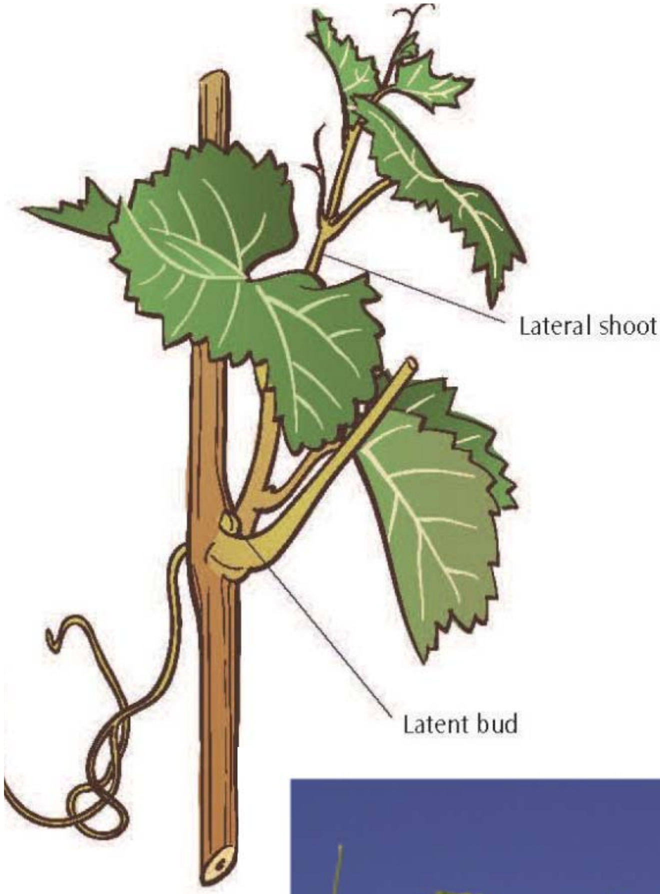


FIGURE 1.8

Repeating three-node pattern of a Syrah shoot (left); mistakes do happen in nature—three consecutive tendrils on a *V. vinifera* shoot (center); and dormant bud and lateral shoot in a leaf axil (juncture between petiole and shoot)

Suckers and Watersprout

- Shoots may also arise from bud locations on older wood such as cordons and trunks.
- Buds growing from older wood are not newly initiated bus.
- They developed on green shoots as axillary buds that never grew out.
- These buds are known as latent buds, because they can remain dormant indefinitely until an extreme event such as injury to the vine or sever pruning.

Suckers are typically stripped off so that a pruning stub does not remain to produce additional latent buds that could produce more suckers in the following year.

Latent buds come into use when trunk, cordon, or spur renewal is necessary.

canes

- The shoots are called canes after they have matured and the leaves have fallen off.

10

Plate 10. Section of shoot late in the season showing the reddish lignified periderm and the still-green tissue of the cluster peduncle.

- The shoot begins a transitional phase about midseason, when it begin to mature.

- Shoot maturation begins as periderm develops, startina at the shoot base.

- Appearing initially as a yellow, smooth ‘’skin’’.

- Periderm continues to extend development toward the shoot tip through summer and fall.

- As periderm develops, it changes from yellow to brown and becomes a dry, hard, smooth layer of bark.

  - During maturation, the cell walls of ray tissues thicken and there is an accumulation of starch in all living cells of the wood and bark.

The cane is the principal structure of concern in the dormant season, when the practice of pruning is employed to manage vine size and shape and to control the quantity of potential crop in the coming season. Because a cane is simply a mature shoot, the same terms are used to describe its parts. Pruning severity is often described in terms of the number of buds retained per vine, or *bud count*. This refers to the dormant buds, containing three growing points,

Canes can be pruned to varying lengths, and when they consist of only one to four buds they are referred to as *spurs*, or often as *fruiting spurs* since fruitful shoots arise from spur buds. Grapevine spurs should not be confused with true spurs produced by apple, cherry, and other fruit trees, which are the natural fruit-bearing structures of these trees. On grapevines, spurs are created by short-pruning of canes. Figure 2

2

Plate 2. Grape cluster showing individual florets, some of which have their fused petals (calyptra) separating from the basal part of the flower (top and left).

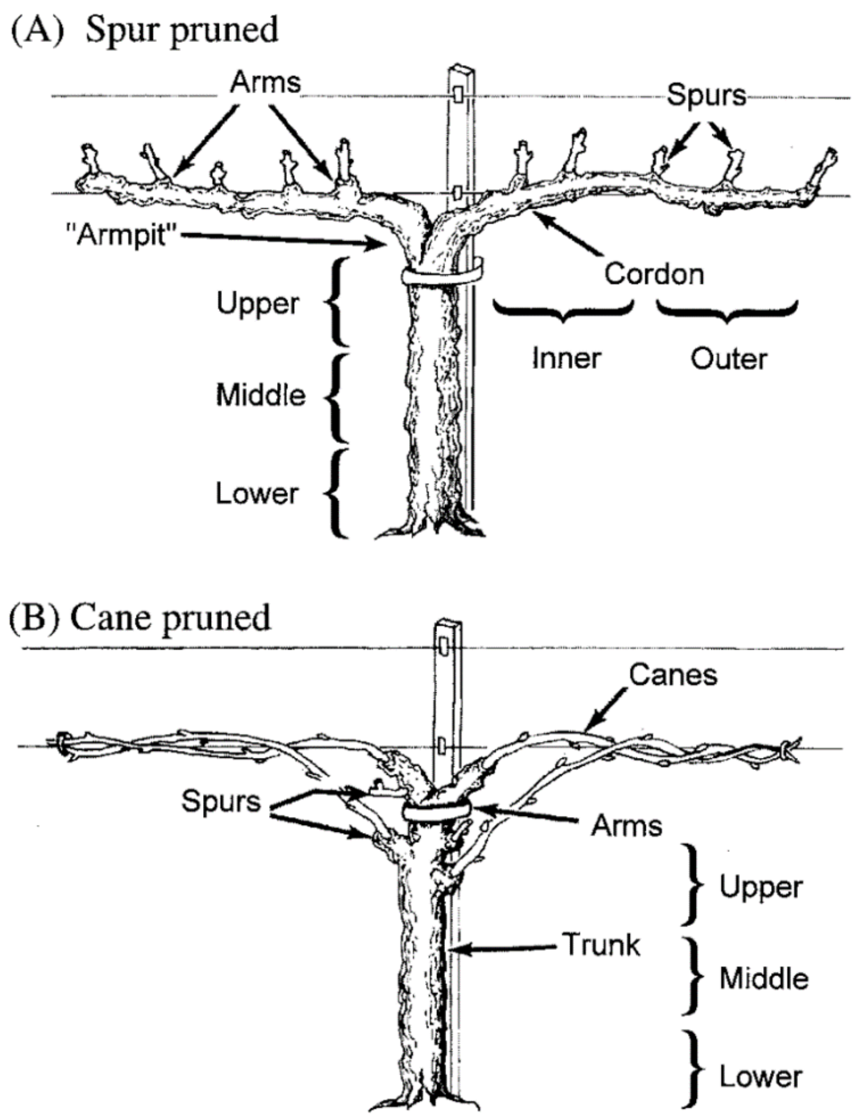

(A) Spur pruned
Arms
Spurs
"Armpit"
Cordon
Upper
Middle
Lower
Inner
Outer
(B) Cane pruned
Canes
Spurs
Arms
Upper
Trunk
Middle
Lower

Figure 2

Flower and Berries

Panicle
Perfect
Self-pollination
Dioecious or monoecious vines (many rootstock cultivars)

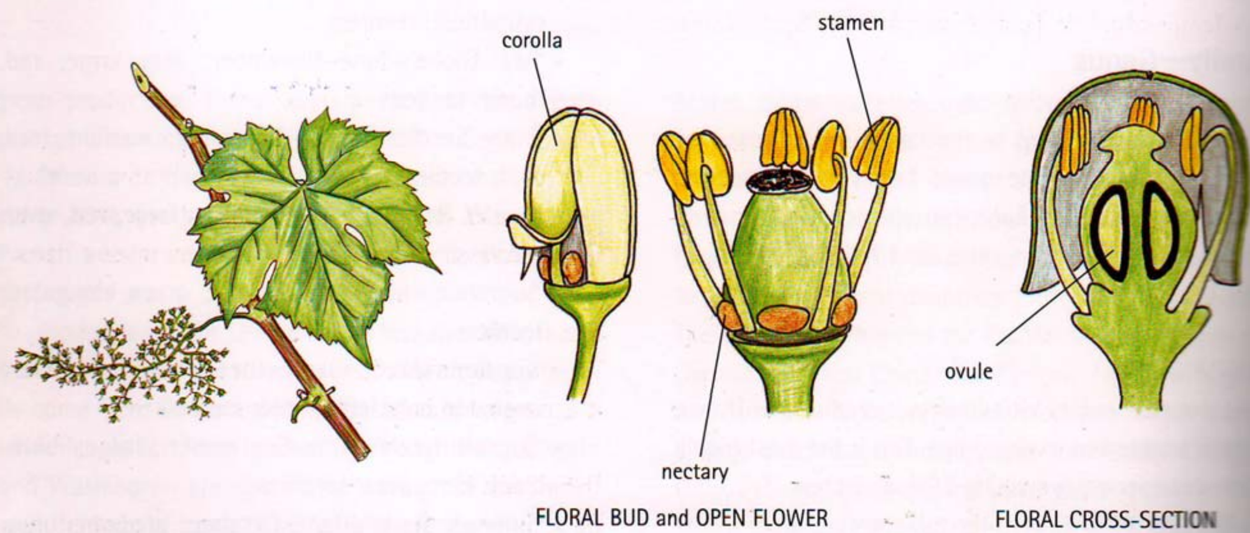


Fig. 1. Stage 1: Full blossom (source: Georges-François Charmeux).

The floret is attached to the **rachis** by the **pedicel**, and the rachis is attached to the **peduncle**, or stem, of the cluster. Flowers, because they open from the base rather than the tip, form a **cap** (called the **calyptra**), which pops off at flowering (anthesis). As with other flowers, there are anthers, which produce the pollen, and a stigma, which receives the pollen.

The protective testa contains inclusions of calcium oxalate crystals and is rich in phenolic compounds such as tannins that protect the seed against premature “consumption” by microorganisms or insects

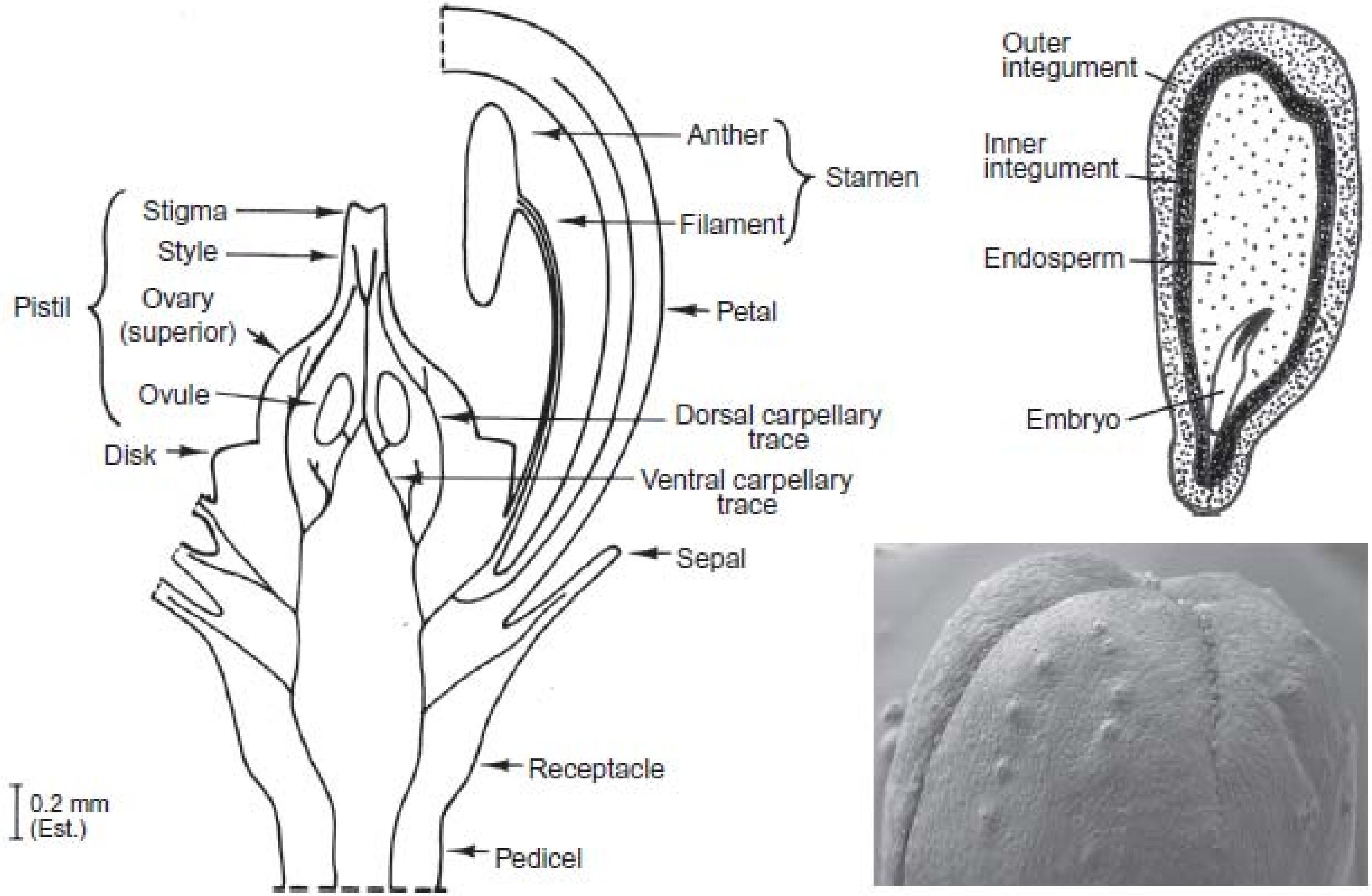


FIGURE 1.18

Diagrammatic longitudinal section of a Muscat Hamburg flower (left; reproduced from Rafei, M.S. 1941. Anatomical studies in *Vitis* and allied genera. I. Development of the fruit. II. Floral anatomy. PhD thesis, Oregon State College), longitudinal section of a *Vitis* seed (top right; illustration by A. Mills), and tip of flower cap with interlocking cells and protruding stomata (bottom right; photo by O. Viret).

The time during which flowers are open (the calyptra has fallen) is called *bloom* (also flowering or anthesis) and can last from one to three weeks depending on weather. Viticulturists variously refer to *full bloom* as the stage at which either roughly one-half or two-thirds of the caps have loosened or fallen from the flowers. Bloom typically occurs between 50 and 80 days after budburst in Oregon.

12

The flower clusters are closely related to the tendril and usually arise from the 3rd or higher node on a shoot. The number of flower clusters per shoot varies with cultivar, management and environmental conditions, but can range from none to five or even more.

Plate 12. Tendril-like cluster of berries, the result of only a small number of flowers being initiated when the tendril was being formed.

True berry

Euvitis can have up to four seeds while the muscadine grapes can have up to six.

has a waxy outer covering called the cuticle, Later in berry development will appear as the white or greyish bloom on the skin

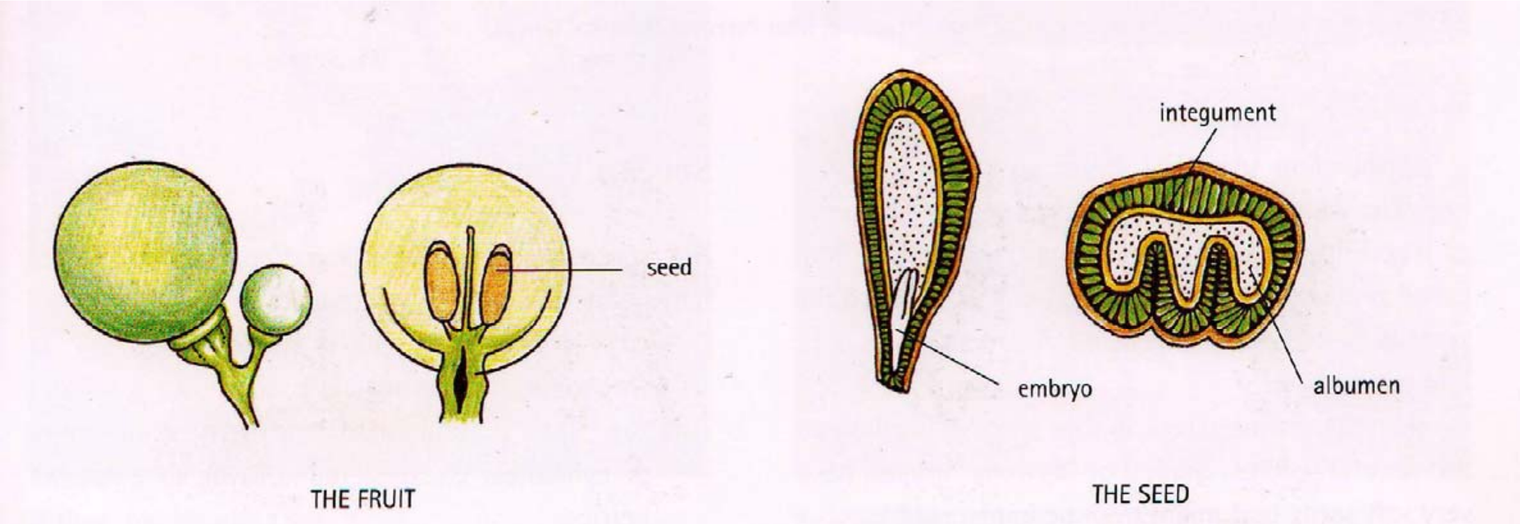


Fig. 3. Grape-berry (source: Georges-François Charmeux).

The epidermal layer of cells, or skin, of the berry also serves this function, as well as being the source of colour and some flavour compounds. In some cultivars lenticels are visible on the berry surface as well, which help exchange gas through the berry skin. Lenticels may become more visible later in the season as the berries start to senesce.

6

Plate 6. Chardonnay berries near harvest, showing the brown spots that are lenticels in the skin.

5

Plate 5. Example of a mutation of berries on a Pinot blanc cluster that starts production of anthocyanins in the skins.

- After fruit set, the inflorescence is called a cluster or bunch.
- It is composed of the peduncle (the entire branched axis apart from the pedicels of individual flowers) carrying the flowers or, following fruit set, the berries.
- Each flower or berry is attached to the peduncle via a pedicel (final branch or flower stalk) that widens into the receptacle that carries the flower or berry.
- The main stem or axis consists of the hypoclade (between the shoot and the first branching- 2-10 cm) and the rachis (central axis) that is made up of a main axis and a lateral wing or shoulder (also called outer arm).
- Both arms carry multiple secondary branches (and many of these tertiary branches, some of which in turn carry quaternary branches), although the shoulder may be missing or may be a tendril or, occasionally, a shoot.
- A single inflorescence may carry between less than a handful and well over a thousand flowers; this variation contributes to large variations in yield in cultivated grapes.
- Clusters vary widely in length from 35 cm in wild grape species to more than 50 cm in some table grape cultivars, and this is accompanied by varying degrees of branching. Indeed, the development of the inflorescence requires active transport of auxin in the cambium and xylem parenchyma down the inflorescence axis.

Because there are four ovules per flower, there is a maximum potential of four seeds per berry. Unfavorable environmental conditions during bloom, such as cool, rainy weather, can reduce both fruit set (number of berries) and berry size. Berry size is related to the number of seeds within the berry but can also be influenced by growing conditions and practices, particularly water management. Some immature berries may be retained by a cluster without completing their normal growth and development, a phenomenon known as *millerandage* or *"hens and chicks."*

3

Plate 3. Examples of Sultana (left; also known as Thompson Seedless. This cluster has not been grown for commercial table grape production and so the berries are smaller than those found on clusters in a shop) and Einset Seedless (right; a French-American hybrid grape) clusters.

Tendrils

- The production of leaf-opposed tendrils and clusters appears to be unique to the Vitaceae family.
- typically discontinuous; that is, two of every three nodes bear a tendril. One notable exception is V. labrusca, which has a continuous pattern—that is, a tendril at every node.
- Why the other members of the family leave a “blank” at every third node and how they keep count is still mysterious.
- The first (i.e., lowest) two or three nodes usually carry only leaves; the next two nodes are generally the ones with clusters, followed by a node with a leaf only and then a succession of repeating mirror images of three-node units with the clusters replaced by tendrils.

- Tendrils and fruiting clusters of the grapevine are generally considered homologous on the basis of anatomical, morphological, and physiological similarities.

- Darwin (1875) concluded from observations of grapevines growing in his backyard that "there can be no doubt that the tendril is a modified flower-peduncle."

- Indeed, studies of gene expression—that is, of the manufacture of RNA and protein from the segment of DNA making up a gene—also suggest that tendrils are modified reproductive organs that have been recruited (i.e., adapted during evolution) as climbing organs.

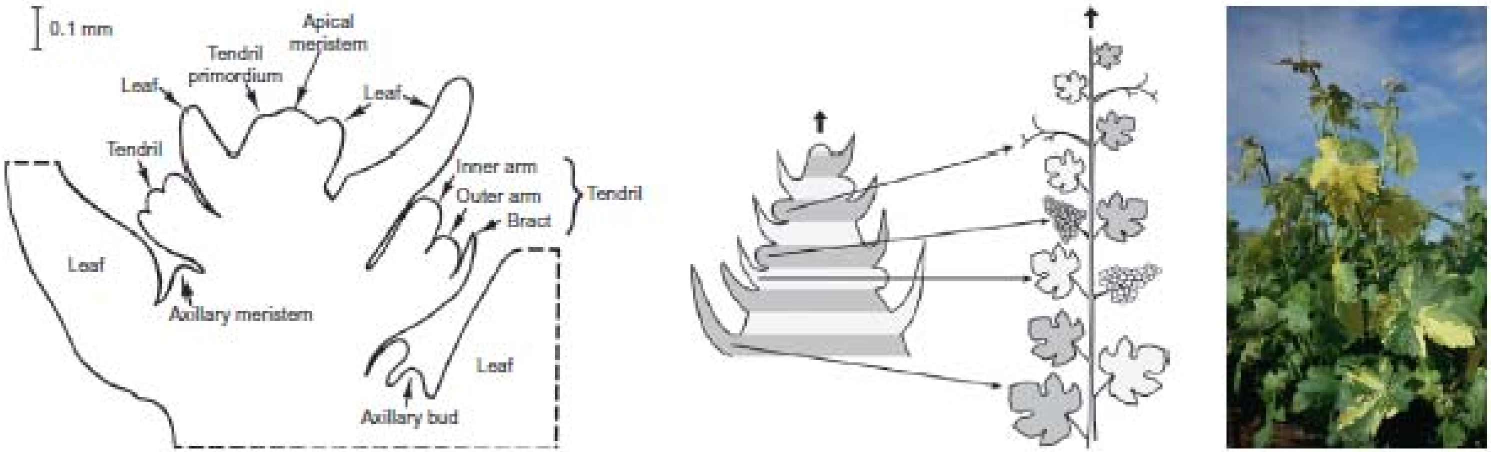


FIGURE 1.7

Diagrammatic longitudinal section of Concord shoot tip (left; reproduced from Pratt, 1971, reprinted by permission of American Journal of Enology and Viticulture); lateral organs arising from various positions in the dormant bud, illustrating the repeating three-node pattern unit of the shoots of many *Vitis* species (center; reproduced from Carmona et al., 2002); and chimeric Cabernet Sauvignon shoot (right; photo by M. Keller).

- As sterile reproductive structures, they are prevented from completing floral development by the cell-elongation hormone gibberellin.

- Accordingly, the absence of gibberellin production or suppression of its activity at the site of organ initiation gives rise to an inflorescence (flower cluster), whereas the presence of gibberellin results in a tendril.

- The cell-division hormone cytokinin, in contrast, promotes inflorescence formation over tendril formation.

- It seems likely that the response to these hormones is quantitative because there is a continuum of transitional or intermediary structures that are partly tendril-like and partly inflorescence-like. Moreover, the degree of differentiation depends largely on the cultivar and environmental conditions during the time of cluster initiation and differentiation.

- Similar to leaves, tendrils grow in intercalary fashion in addition to growth in their own apical meristem .
- They also differentiate an epidermis with numerous stomata, a spongy parenchyma, and a large but short-lived hydathode at each of their tips, which soon become suberized.
- Although two tips are most common, vigorously growing shoots often form tendrils with three or more tips (Figure 1.17).

FIGURE 1.17

Vitis shoot tip showing tendrils with two and three tips (left) and tips of a tendril coiling around a trellis wire (right).

Photos by M. Keller.

Tendrils enable wild vines to access sunlight at the top of tree canopies with a relatively small investment in shoot biomass per unit height gain. The tendril's tips search for surrounding objects by making sweeping, rotating movements during growth; this oscillatory growth pattern is termed circumnutation. When one of the tips detects a support (via contact-sensitive epidermis cells), the arms rapidly coil around the support in two directions. Following this so-called thigmotropic movement, the entire tendril lignifies and stiffens to prevent unwinding. Tendrils that fail to find a support die and are abscised at the point of attachment to the shoot.

9

Plate 9. A dormant tendril that had wrapped around a foliage wire during the growing season. Tendrils such as these can be quite woody and difficult to remove at pruning, which demonstrates their role in helping to support the vine.

- **AMPELOGRAPHY**
- Ampelography is the science or art of distinguishing grapevine cultivars by examining their appearance.
- Through the observation of leaves, shoots, shoot tips, clusters and fruit, it is possible to determine the cultivar and, in most cases, the clone of a cultivar.
- Some examples of parameters that are examined in ampelography include:
- (i) the number of teeth between major leaf veins;
- (ii) the form and colour of the shoot tip;
- (iii) shoot growth habit;
- (iv) presence and position of hairs on plant parts;
- (v) cluster openness or shape;
- (vi) berry shape and skin thickness;
- (vii) leaf shape and angles between veins

PHENOLOGY

Phenology is the study of events or growth stages of a plant or animal that recur seasonally and their relations with various climatic factors, including temperature, solar radiation and day length.

With respect to grapevines, it can be used as a predictive tool, allowing the manager to plan vineyard operations in advance.

Annual Cycle

- Winter repose
- Bleeding
- Bud break
- Branch growth
- Flowering and Veraison
- Leaf drop

ABSTRACT

The annual growth cycle of fruiting grapevines is divided into a vegetative and a reproductive cycle. Fruit production extends over 2 years: buds formed in the first year give rise to shoots bearing fruit in the second year. Seasonal growth is driven by day length and temperature, and alternates with winter dormancy. The transition from dormancy to active growth in spring is marked by bleeding of xylem sap from pruning wounds due to root pressure. Root pressure restores xylem functionality and rehydrates the dormant buds. Increasing temperature then leads to budbreak and shoot growth that is marked by apical dominance. Shoots and roots grow as long as the environment permits. The shoots form brown periderm when the days shorten in late summer, enter dormancy, and shed their leaves in autumn. Chilling temperatures release dormancy to resume growth in spring. Flower clusters are initiated in the buds in early summer, and flowers differentiate after budbreak the following spring. Double fertilization during bloom initiates the transition of flowers to berries. Berry growth follows a double-sigmoid pattern of cell division and expansion, seed growth, and final cell expansion concomitant with fruit ripening. Seedless berries have less discernible growth phases. Ripening makes berries attractive for seed dispersers to spread a vine's genes.

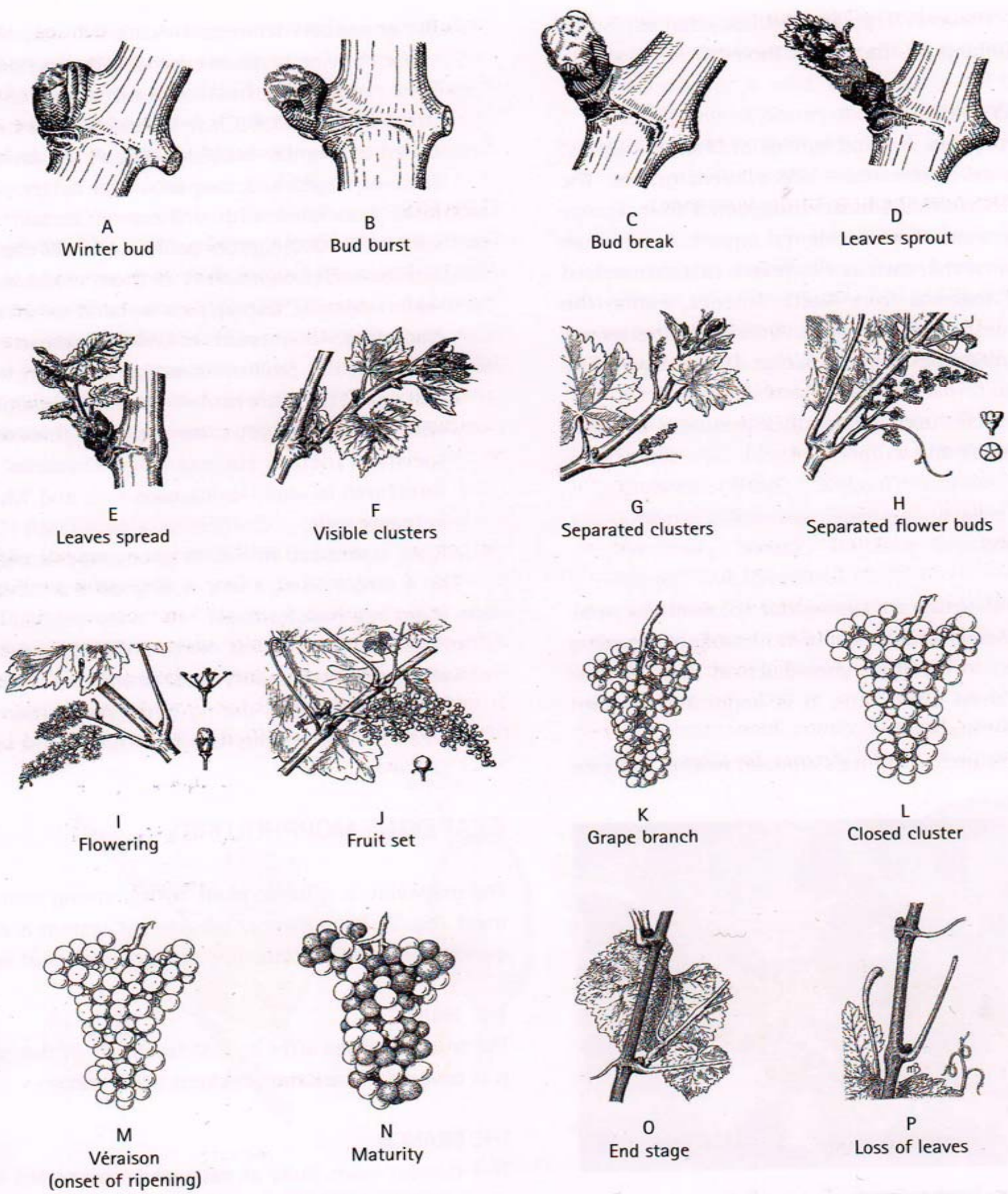


Fig. 2. Benchmark vine stages (drawings by M. Baggiolini).

Before any visible signs of growth, the vine begins to come out of dormancy at about the same time as the soil temperatures starts to rise (due to increased solar radiation and air temperatures).

The roots reactivate, and the phloem and xylem tissues start to function again. **Visibly**, this leads to **sap exuding** from fresh cuts on the vine, as root pressure builds to fill the empty xylem vessels.

In late winter or early spring, grapevines often exude xylem sap from pruning surfaces and other wounds that have not yet been suberized (Figure 2.3). Such sap flow or "bleeding" marks the transition from dormancy to active growth. Initiation of bleeding is related to the restoration of metabolic activity in the roots and is influenced by soil temperature, moisture, and rootstock, but on average it seems to begin when the soil temperature rises above approximately 7C (Alleweldt, 1965). Indeed, root respiration, as a proxy for metabolic activity in the roots, is closely coupled to soil temperature (Franck et al., 2011). Within days after the first signs of bleeding, the callose that has sealed the sieve plates in the phloem of trunks and canes during the winter begins to be degraded (Pouget, 1963). Bleeding can last for a few days or several weeks (probably depending on whether or not air temperatures are conducive to budbreak); it can also be a stop-and-go process that fluctuates with changes in soil temperature (Andersen and Brodbeck, 1989). A vine can exude bleeding sap at rates of less than 0.1 L to greater than 1 L per day, with the highest rates occurring on warm and moist soils.

FIGURE 2.3

Bleeding grapevine cane (left) and swelling, woolly bud just before budbreak (right).

Fig. 3.1. Part of a vine trunk cut with a saw late in the dormancy period. Xylem sap, flowing from the roots and the cut vessels, oozes out; it contains low concentrations of sugars (Bennett, 2002) – in the range of 5–6mg/ml, which supports the proliferation of fungi and bacteria, making the sap here appear white.

Bud Break

Root pressure arises from the remobilization of nutrient reserves from proteins and starch and pumping of amino acids and sugars into the xylem tracheary elements (Roubelakis-Angelakis and Kliewer, 1979). The concentration of sugars apparently increases exponentially as the temperature declines close to and below 0C; this response occurs within a few hours and is equally rapidly reversible when the temperature rises again (Moreau and Vinet, 1923). Sugars (especially glucose and fructose), however, are only a minor component of the bleeding sap. Organic acids (especially malate, tartrate, and citrate), amino acids (especially glutamine), and mineral nutrient ions (especially potassium and calcium) together contribute a much greater fraction (.90%) of the total solutes present (Glad et al., 1992). The resulting increase in the osmotic pressure of the xylem sap provides the driving force for osmotic water uptake by the roots from the soil, which generates a positive pressure in the entire xylem of 0.20.4 MPa at the trunk base that declines at a rate of 0.01 MPa m21 due to gravity as the sap rises (Sperry et al., 1987). Because a pressure of 0.1 MPa can support a water column of approximately 10 m high, root pressure lifts water up the vine and to the swelling buds of even tall, wild grapevines.

Actual breaking (or appearance of green tissue through the bud scales) of the dormant buds has usually been said to occur when the air temperature reaches approximately **10°C.**

الیاف فیبری (فلوس) که نقش حفاظت از جوانه ها در زمستان را داشتند شروع به باز شدن میکنند

FIGURE 2.5

Emerging Merlot shoot with pink unfolding leaves and inflorescences days after budbreak (left) and Muscat Ottonel shoot with red young leaves (right).

Photos by M. Keller.

7

Plate 7. A series of photos showing early bud growth, from dormant, Stage 1 (top left); budswell, Stage 2 (top middle); wooly bud, Stage 3 (top right); green tip, Stage 4 (bottom left); rosette of first leaves visible, Stage 5 (bottom right). Stages of development are labelled according to the Modified E-L System (Coombe 1995).

Patterns of root growth

The exploration of soil available to a vine is extensive.

Vine roots have been found to penetrate to depths of more than 10 m in favourable soils.

Most roots in a typical soil profile will be found in the top 1 m.

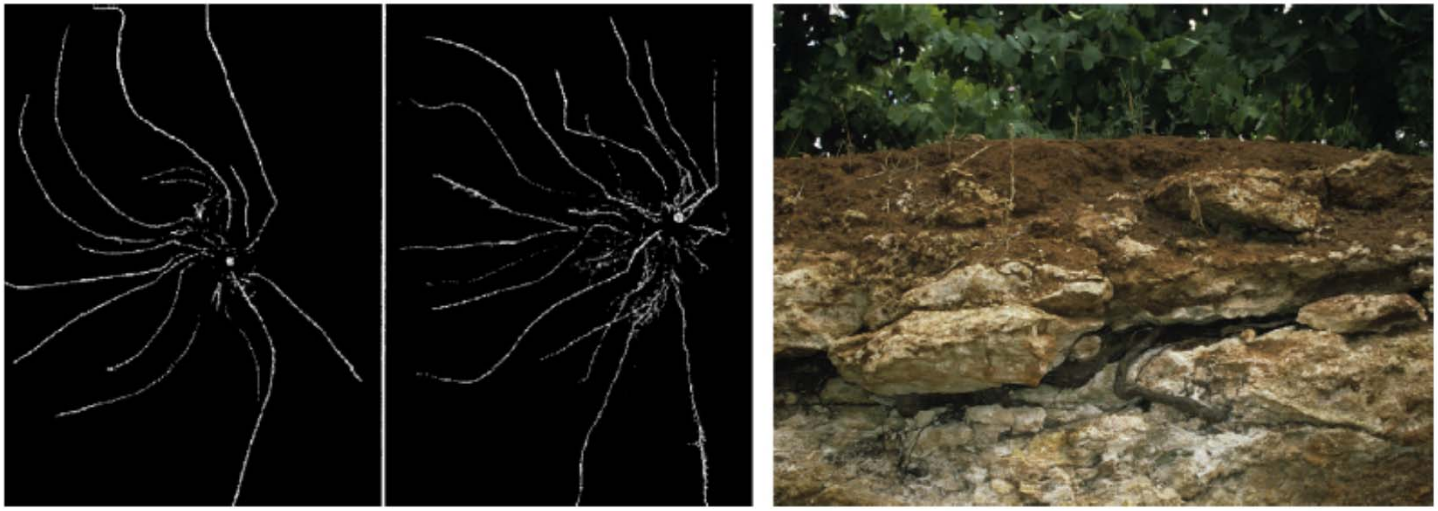


FIGURE 2.9

Riesling roots grown at 15°C (left) or 25°C (center; reproduced with permission from Erlenwein, 1965b), and Cabernet Sauvignon roots growing down fractures in limestone bedrock (right; photo by M. Keller).

many factors influence root growth, including soil structure, compaction, water availability, plant genotype, planting density, competing plants, seedling or sapling, etc.

Nonetheless, the vertical and horizontal distribution of the root system of various rootstocks, it seems, is mostly a function of soil texture, composition, and water availability, rather than an inherent trait of the rootstock genotype (Smart et al., 2006).

Scion cultivars also alter the root growth of different rootstocks. Such genetic influences and interactions may be partly responsible for the variation in shoot vigor observed with different scion/rootstock combinations because grapevines, like other plants, try to maintain an equilibrium in root:shoot ratio.

Total root length normally correlates closely with leaf area, and root dry weight correlates with aboveground dry weight in grapevines. It has been estimated that a 1-ha vineyard may contain more than 30 t of roots. However, whereas root density may be dependent on the genotype, it appears that root distribution is dictated by soil properties. Even genetically identical plants (i.e., clones) can develop vastly different root systems in terms of both size and architecture, depending on microscale variations in soil conditions that the roots encounter during growth.

Thus, temperature, soil texture, moisture, and nutrient availability also strongly and rapidly affect root growth and distribution. In some cases, the effect of temperature on root growth may be even more pronounced than its influence on shoot growth.

The roots also have a period of quiescence in the dormant season.

- As the soil warms in the spring, root tips begin to explore the soil, but their development is relatively slow compared with the growth and development of the shoots and flower clusters.

- After fruit set, the full canopy of the vine is able to support more root development.

- As the berries ripen toward the end of the season, root growth again slows due to the shift in partitioning of carbohydrates towards the fruit.

- In areas where there is sufficient warmth to allow photosynthesis after harvest, there may be another flush of root growth before the vine becomes dormant, which appears to be related to the excess photosynthetic capacity on the vine after the fruit is removed
- In cooler climate areas where there is little or no time between harvest and leaf-fall this cannot, of course, happen.

Shoot Growth

Shoot growth begins with *budburst* (or *budbreak*), when previously dormant buds begin to grow after they have received adequate heat in the spring. This usually occurs when average daily temperature reaches about 50°F. Representative stages in the growth and fruiting of a grapevine are illustrated in Figure 5. At budburst, the primary growing point usually contains 10–12 leaf primordia and one or two cluster primordia, located opposite leaf primordia at node positions three to six. Development of these structures continues as the shoot grows out from the bud. Early shoot growth is relatively slow, but soon it enters a phase of rapid growth called the *grand period of growth*, which typically continues until just after fruit set. Even when the shoot is only a few inches long, developing flower clusters can be seen opposite the young leaves.

Fig. 3.2. Young shoot showing the first leaves and two flower clusters. Individual florets have already differentiated by this stage.

As each new leaf unfolds, …..

After fruit set, shoot growth generally continues to slow by about the time the fruit begins to ripen.

Under conditions of high vigor, shoot growth may continue at a steady rate throughout the season (**abundant water, excessive nitrogen fertilizer, sever pruning, extreme undercropping).**

Ideal shoot: 60-90 cm (10-15 full-sized leaves).

Shoots can grow as fast as 2-5cm/day (4, 1.8, 5 cm/day), forming a new internode every 2-3 days.

Photosynthesis occurs as soon as there is green tissue on the shoots; however, due to the high metabolic activity and use of stored carbohydrates, there is no net production of photoassimilates until several leaves have fully expanded.

Shoot growth starts in the distal (topmost or apical) buds of a cane or vine, proceeding basipetally to the roots. Yet preferential budbreak of distal buds often inhibits the growth of the proximal (basal) buds. This phenomenon is often attributed to **apical dominance**.

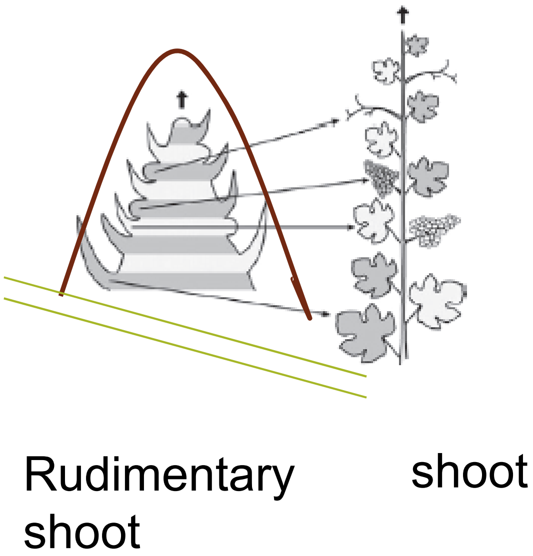
This inhibition of basal bud outgrowth is especially prevalent in **warm climates**, where it can lead to erratic and nonuniform budbreak.

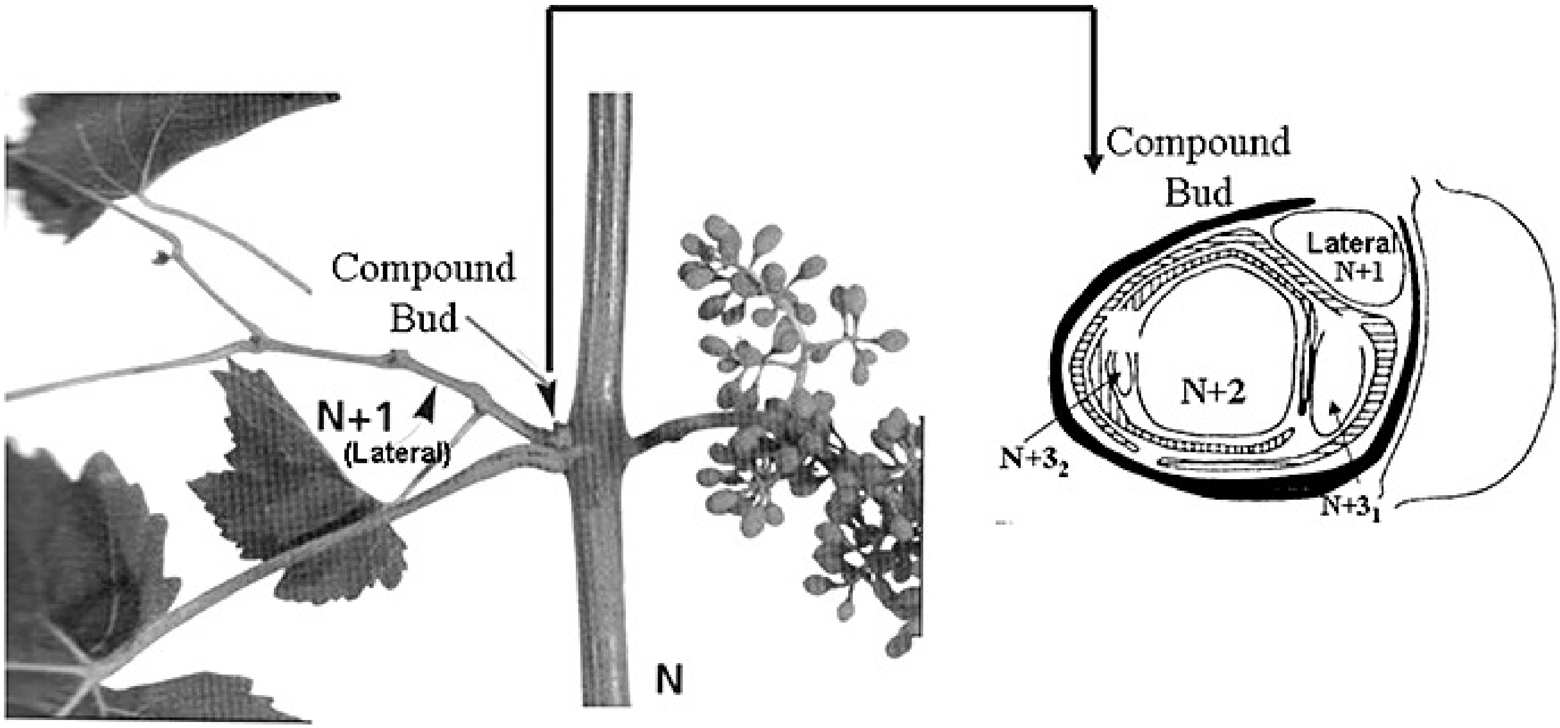
Like the evolution of tendrils, this behavior is an adaptation to the habitat of wild vines, which enables them to **access sunlight** at the top of tree canopies with a small investment in shoot biomass per unit height gain.

This adaptive behavior creates both a **viticultural problem** (mainly in warm climates) and an **opportunity** (mainly in cool climates, delay in budbreak) for cultivated grapevines. The problem arises from the inconsistent budbreak of cane-pruned vines. Viticultural practices aimed promoting uniform budbreak include **spur pruning**, **bending** and **partial cracking of canes**, and application of **hydrogen cyanamide**.

Flower Cluster Initiation

As the shoot grows, considerable development takes place within the dormant buds in the leaf axils. Of greatest interest is the development of flower cluster primordia, since they represent the fruiting potential of the vine for the following season. The period at which flower cluster primordia begin to form on the rudimentary shoot is called *flower cluster initiation.* The process occurs first in the midsection of the primary shoot at node positions four through eight, beginning soon after bloom of the current season's flower clusters (initiated in the previous season) and continuing for up to six weeks. The buds at basal nodes one to three undergo cluster initiation a little later, and initiation continues progressively in buds toward the growing tip. Usually, by the end of the season, fruitful buds exist along the cane to the extent to where it is fully ripened.





Compound (dormant) and lateral bud

- **Flower development in grape is described as a three-step process (occurring within …)**

- 1- formation of uncommitted primordia by the growing points od developing dormant bud. (similar primordia for both flower and tendril: anlage)

- 2- The primordia become committed to becoming a flower cluster or a tendril (before or just at bloom). (Difference in branching) (time of branching)

Cluster primordia develop during current season, and the final step:

- 3- formation of flower from the cluster primordia, begins after budbreak in the following spring (this stage is completed as bloom time is approached)

Effect of light and temperature on flower cluster initiation (tendril or flower?)

Fig. 3.5. A bifuricated shoot (centre), where a new shoot tip arises from a node position opposite a leaf.

Factors affecting branching …

Because buds in the varying node positions go through the process of flower cluster initiation at different times, changing environmental factors that affect this process will also affect the potential crop for each bud in the following season.

Temperature

- Cool and excessively hot temperatures discourage the initiation process

- The optimum for maximizing potential crop is thought to be in the range of 30-35°C, but this also appears to vary with cultivar.

- In many cool climates, achieving this range of temperature during flowering, when flower cluster initiation is going on, is relatively rare, …

Light

- It affects the rate at which photosynthesis can occur and hence photoassimilate supply.

- The carbohydrate supply near bloom is an important factor affecting the number and potential size of the flower clusters being initiated.

- Vine carbohydrate status following fruit set will also affect flower **cluster number** and **size** in the following season.

- Overly vigorous shoots are associated with fewer flower clusters because vigorous vines generally have shadier canopies, and also the growing points of a vigorous shoot are much better at drawing carbohydrates away from the developing flower clusters.

Plant growth regulators

- The two most involved are gibberellines (GAs) and cytokinins (CKs).

- GA enhances the development of an uncommitted primordium that forms to the side of the shoot apex, encouraging the development of tendrils.

- CKs will encourage the formation of flower clusters from the tendrils.

- So the net effect of applying GA to a grapevine shoot during the flower cluster initiation period will be to promote the production of tendrils rather than flower clusters.

- The net effect of applying CKs to the shoot would be more flower clusters.

- Chlormequat blocks the synthesis of GA (primarily, though it may have some effect on CK production as well).

- Cytokines are also important later on in flower development, as their presence promotes the formation of flower primordia on the inflorescence near budbreak in the following spring, and can improve fruit set during flowering as well.

- Analysis of the bleeding sap from cuts on vines before budbreak show that CKs are being transported from the roots to the upper parts of the vine at this time of year.