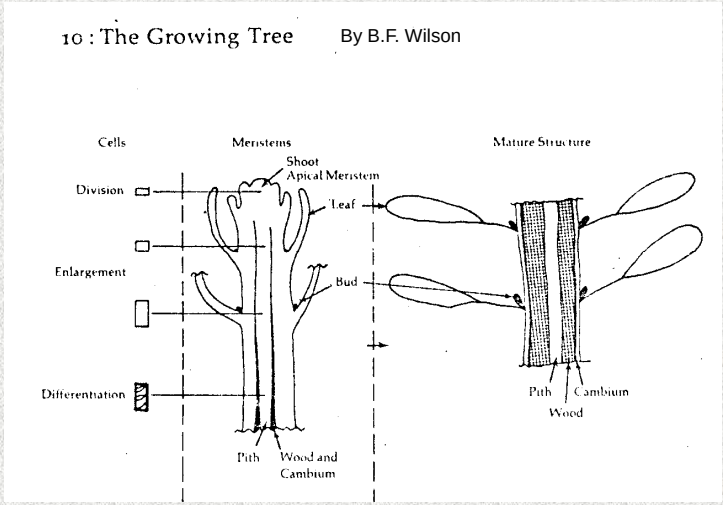
Tree growth over multiple years

All plant growth of originates from meristems or meristematic (capable rapid cell division and differentiation) tissue.

Trees are designed to face a problem that annual plants avoid – meristem survival during harsh environments.

To do this trees develop perenating buds. These buds protect the apical meristems in the shoot and go dormant in the fall and develop tolerance to cold.

The vascular cambium is also a meristematic sheath that goes dormant in the winter and is regenerated in the spring.



Perenating buds

There are three types of buds or meristematic zones from which new shoots arise.

- Lateral buds – initially have a vegetative meristem but in *Prunus* species they can differentiate into floral buds in mid to late summer
- Terminal buds - initially have a vegetative meristem but in *Malus, Pyrus and Juglans* species some of these can differentiate into floral buds in mid to late summer
- Preventitious buds – are buried in the bark of the older wood and can be stimulated to grow when older branches break off or are pruned.
- Lateral buds and terminal buds are only good for one year.

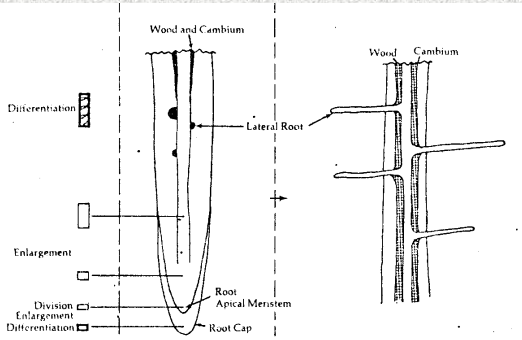


Figure 1

APICAL MERISTEMS

Each meristem has zones of cell division, enlargement, and differentiation; representative cell sizes are shown. The shoot apex produces lateral leaves and buds; the root apex produces a root cap and lateral roots.

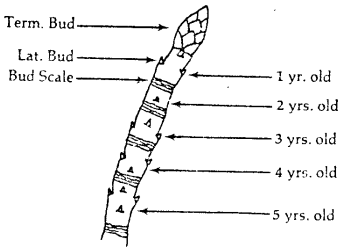
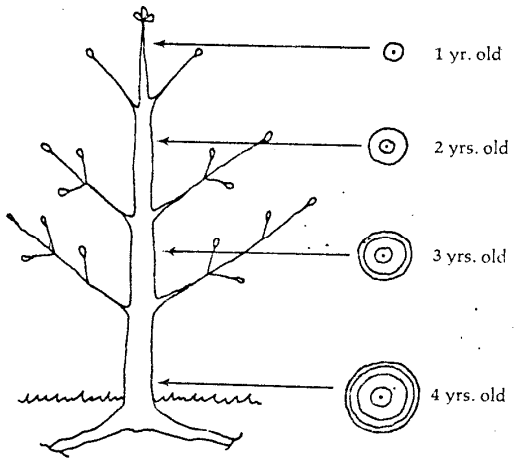


Figure 3

ANNUAL STEM INCREMENTS

Above, each annual length increment is marked both by whorls of branches and by a change in the number of rings in the wood. Annual diameter increments are marked by the rings. Below, annual length increments on twigs and small branches are marked by bud scale scars.



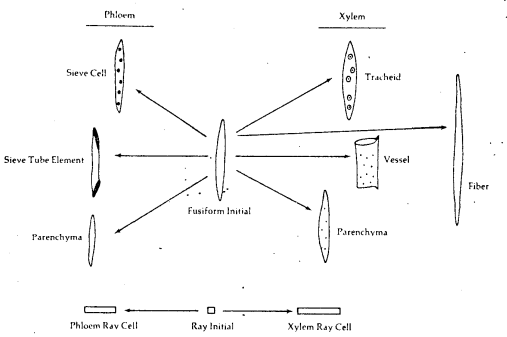


Figure 18

DIFFERENTIATION OF CELL TYPES FROM CAMBIAL INITIALS

Sieve cells and sieve tube members are specialized for phloem transport; vessels are specialized for water transport and fibers for strength; tracheids combine specialization for both strength and water transport; parenchyma often serve in storage.

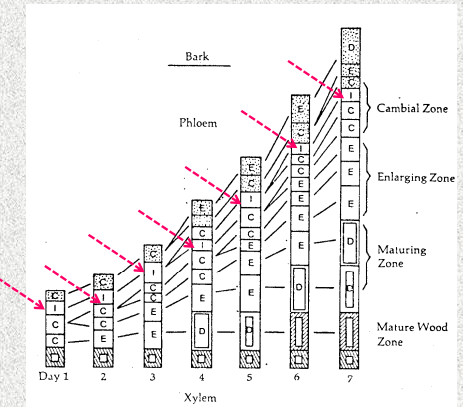


Figure 19
OPERATION OF THE CAMBIUM
In this pictorial model stippled cells are phloem, cells are lettered C *if in the phase of division (cambial cells),* E *if in enlargement,* D *if in differentiation, and unlabelled if mature.*

The vascular connections into a branch are mainly continuous with vasculature below a branch.

The vasculature of the main stem overlays the vasculature of the side branch.

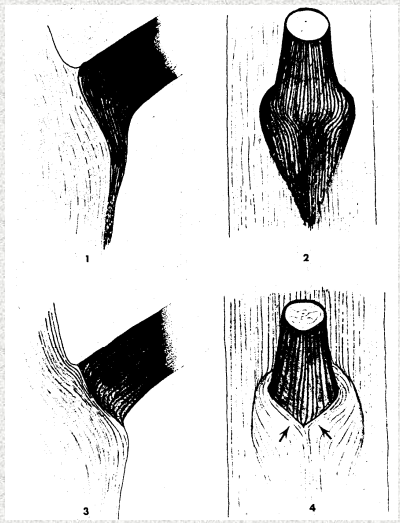
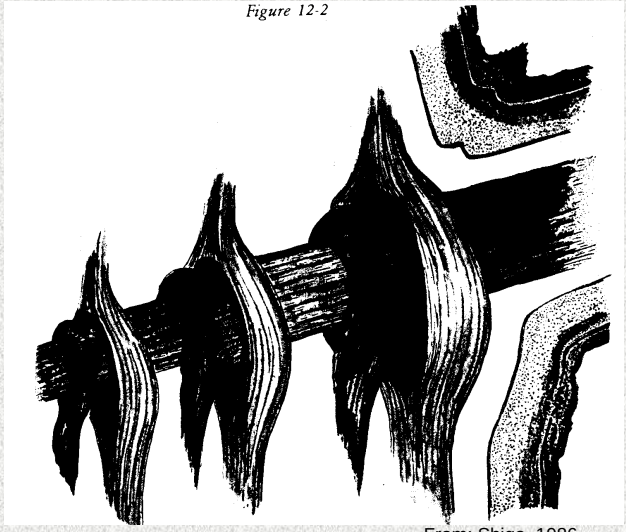


Figure 12-2



From: Shigo, 1986

Multiple year factors that need to be considered with tree crops.

- Factors that determine the beginning and end of growth in a given year, ie. onset and breaking of dormancy.
- Alternate bearing phenomena
- Tree ontogeny: juvenility – mature adult - decline

Three kinds of dormancy

- para-dormancy - inhibition of bud or meristem growth by actively growing apical meristem and the presence of leaves (correlative inhibition).
- eco-dormancy – growth is shut down because of unfavorable environmental conditions (water or nutrient stress, temperature stress).
- endo-dormancy – dormancy is caused by factors inside the bud or meristem (true rest)

Onset and breaking of endo-dormancy

- Onset of endo-dormancy is generally thought to be caused by decreasing day-lengths and decreasing temperatures
- Breaking of dormancy in fruit trees is primarily caused by:
  - accumulation of winter chilling (temperatures between 32 and 45 ^{o}f most effective but there are numerous models for accumulating chill)
    - Temps below 45 ^{o}f
    - Temps between 32 and 45 ^{o}f
    - "Utah Model" (specific temp ranges are given different weighting)
    - Dynamic model ("chill portions)
  - accumulation of post chill heat

The chill portion model

The chill portion model is a two step model in which temperatures within a "chill effective range" are accumulated and put in an "intermediate" category. When a defined amount of "intermediate" chill units are accumulated without any intervening temperatures that exceed a defined "upper negating threshold" a "chill portion" is accumulated. The key is that "intermediate chill units" can be negated by high temperatures but "chill portions" cannot be negated one they are accumulated.

Erez and Fishman 1998 Acta Hort. 465

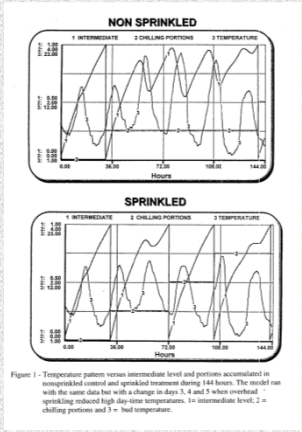
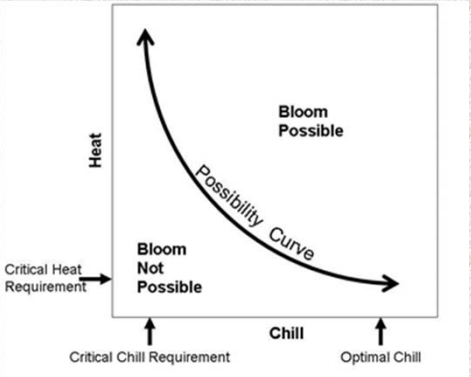


Figure 1 - Temperature pattern versus intermediate level and portions accumulated in nonsprinkled control and sprinkled treatment during 144 hours. The model ran with the same data but with a change in days 3, 4 and 5 when overhead sprinkling reduced high day-time temperatures. 1= intermediate level; 2 = chilling portions and 3 = bad temperature.

Post-rest heat requirement

It is generally thought that there is a "critical chill requirement' below which bloom will not occur (bud-drop occurs, etc.) but above that critical chill req. chill can occur after enough heat is accumulated.

If actual chill hours are above but near the low threshold bloom will likely be delayed, extended and somewhat erratic. This can also cause increased blind wood on vegetative growth.



Lack of chill can cause blind wood or delayed leaf growth.

Walnut example

Chilling and post-rest heat can affect bud-break differently on the same trees because flower buds and vegetative buds can have different chill/heat requirements.

The figures on the right indicate that on average, vegetative bud-break of walnuts were getting earlier (presumably due to warmer springs) until about 1992) and then later (presumably due to warmer winters and the need for more post-chill heat.

On average, male flowering dates continued to occur earlier.

Pope, et al, 2013, Climate Change Biology

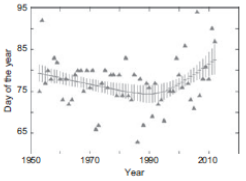


Fig. 2 Model averaged function fit of leaf-out data. This and all remaining figures prepared with gnuplot (Williams & Kelley, 2012).

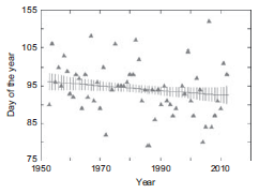


Fig. 5 Model averaged function fit of male bud data.

Alternate bearing

- Alternate bearing occurs when high crops are followed by low crops in a fairly regular pattern
- Many people associate alternate bearing with a general depletion of resources in the trees in a heavy crop year that causes decreased flower production or fruit set in the subsequent year.
- Data suggest that it is more likely a function of alternate bearing at the shoot or spur level that extends to the whole tree when there is over-synchronization of most bearing shoots or spurs within a tree and orchard.

Pistachio alternate bearing (extreme example)

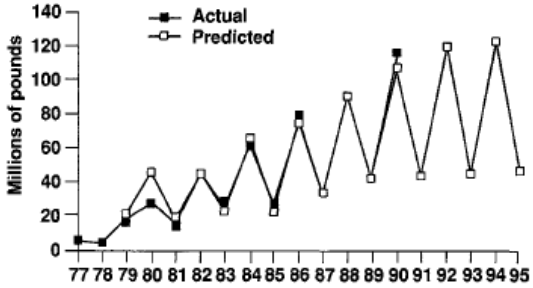
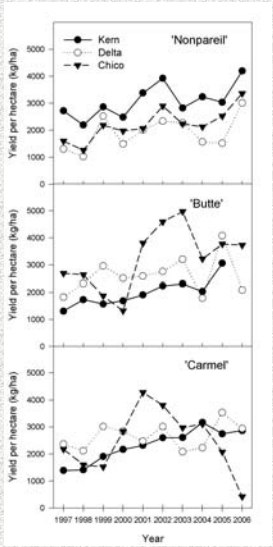


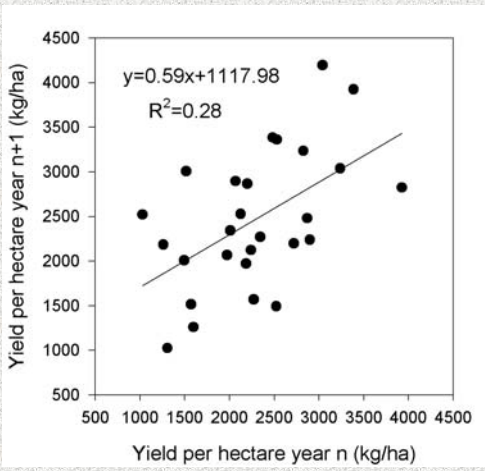
Fig. 2. Actual and predicted production levels, 1977–95.

Almond bearing patterns at sites of the regional variety trials.

Nonpareil shows a tendency especially in Kern County plot. Other cultivars not so much.

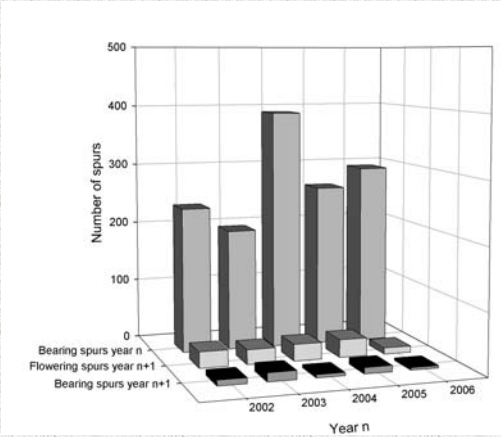


If almond was an extreme alternate bearing species you would expect to see the slope of this relationship be the opposite of what it is.

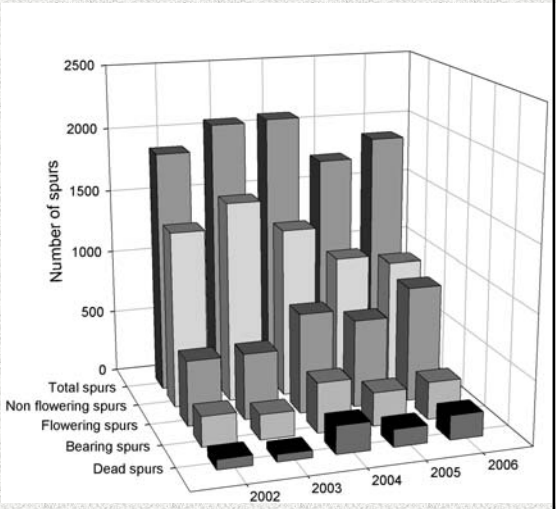


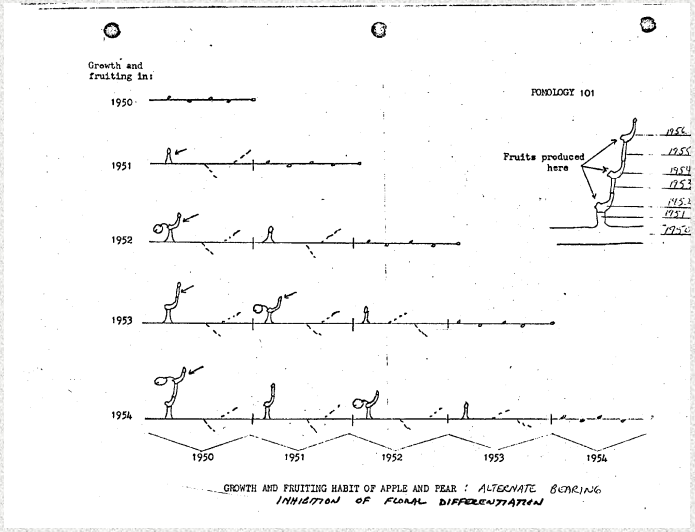
However, individual almond spurs rarely bear fruit two years in a row. Thus one might think they should be strongly alternate bearing.

Why aren't they?



Almond trees are not strongly alternate bearing because of the whole population of spurs in a tree, not more than 20% bear fruit in a given year. Thus, there are generally enough non-bearing spurs present in each year to provide a new population of bearing spurs for the next year.
However, between 10 and 20 % of the population of spurs die each year so new growth is necessary to replace spurs that dies.





Alternate bearing in pistachios is different than most other crops.

- In apples, pears, almonds, pecans, etc. **flower bud initiation is inhibited by the presence of a fruit on the spur** in the same year and alternate bearing occurs when the production of a majority of spurs is synchronized.
- In pistachio inflorescence bud development occurs on fruiting shoots but **the presence of fruit on a shoot makes the inflorescence buds abort.**

The primary method of combating alternate bearing is by pruning.

- Pruning encourages different aged fruiting shoots and/or spurs so that there are a mixture of on and off spurs or shoots on the tree at the same time.
- This is probably why alternate bearing is never a problem with peach.
- Pruning has been shown to decrease alternate bearing with pistachios, apples, pears, prunes, etc.

Tree ontogeny

In nature tree ontogeny proceeds through stages such as seedling, sapling (juvenile, non-flowering), mature tree (regular flowering) and declining tree.

The terms **seedling, sapling and juvenile rarely apply to fruit trees** because most fruit trees are propagated by grafting mature wood onto a seedling or clonal rootstock.

The primary issue related to juvenility that effects pomology is the delay it causes in developing new cultivars.

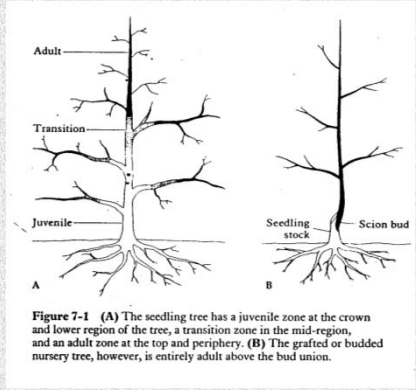


Figure 7-1 **(A)** The seedling tree has a juvenile zone at the crown and lower region of the tree, a transition zone in the mid-region, and an adult zone at the top and periphery. **(B)** The grafted or budded nursery tree, however, is entirely adult above the bud union.

Types of fruit tree propagation in nurseries.

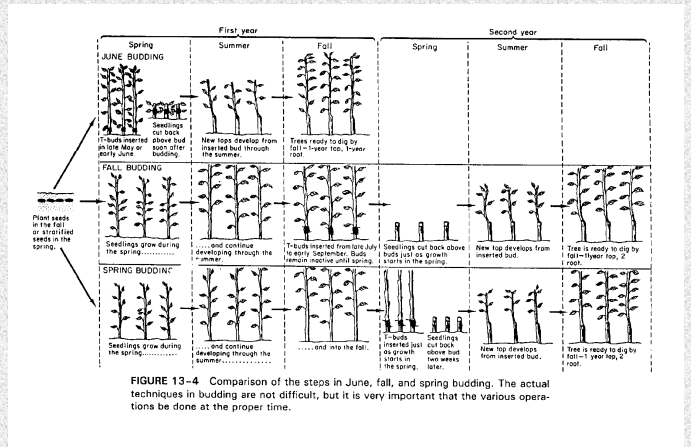


FIGURE 13–4 Comparison of the steps in June, fall, and spring budding. The actual techniques in budding are not difficult, but it is very important that the various operations be done at the proper time.