WSU Tree Fruit Extension

PLANT GROWTH AND DEVELOPMENT

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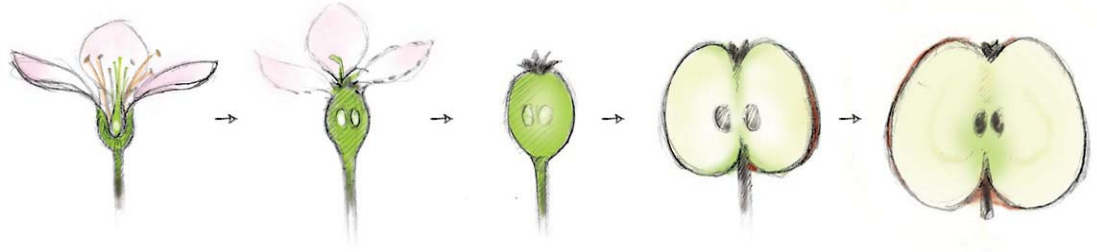
KEYWORDS
Fruit, shoots, roots, carbohydrate metabolism, partitioning, light interception, orchard system, cultivar, rootstock, meristem

ABSTRACT
Understanding how, why, and where trees, branches, fruit, and buds, are formed is fundamental for managing and manipulating growing points and canopy resources for profit. Every management practice, every limb manipulation, each decision to intervene in the natural growth and fruiting habit of trees should be done with a thorough understanding of tree growth and developmental processes. Orchardists have evolved to be master manipulators – able to reshape and refine tree growth and fruiting with exceptional precision. This is done to maximize tree productivity, with an understanding of the delicate balance between fruit quantity and quality, and the tree's ability to perennially produce. Often narrow developmental windows exist to elicit an effect: from growth regulators that are strategically applied during key developmental stages to improve fruit cell division or manage vegetative growth, to targeted thinning processes that account for pollen tube growth and fertilization rate. To be sure, an understanding of tree growth and development is fundamental to adopt precision management practices that are essential in today's high-input-high-output production models.

This presentation will provide an overview of apple and pear canopy growth and developmental processes, highlighting the 12-month developmental timeline, the canopy's acquisition and distribution of growth resources, and setting the stage for subsequent, more specific presentations.



Plant Growth and Development

Matthew Whiting
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Growth and development

- Broad topic
  - Genotype
  - Environment
  - Management

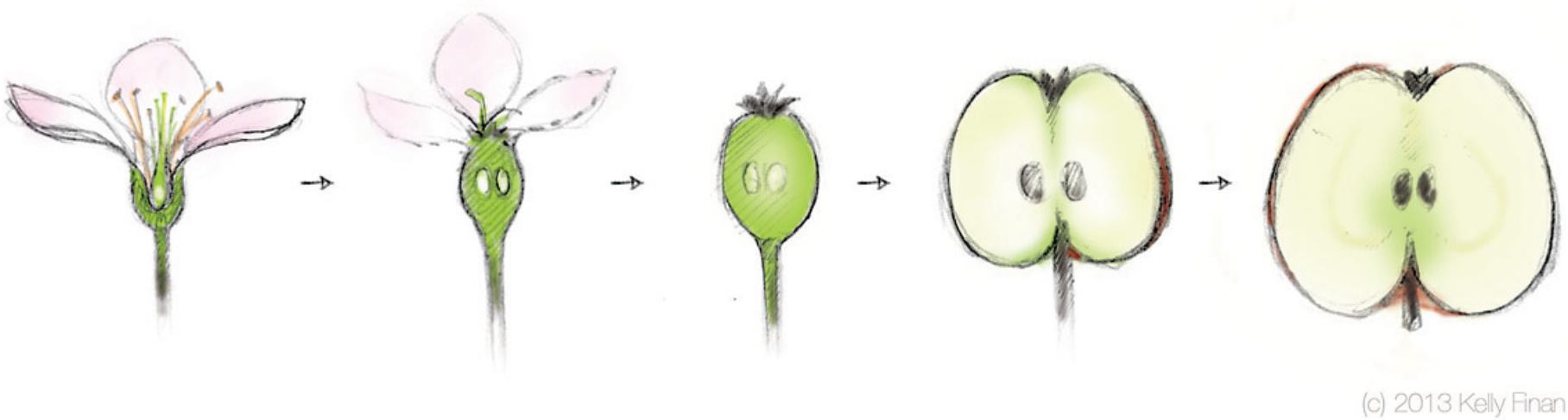
- Set stage for others
- 30,000 foot view

30,000 – foot view of pome fruit growth and development

Pome fruit growth and development

- Growth *AND* Development?

- Is there a difference between growth and development?



Growth

growth | grōTH |

noun

1 the process of increasing in physical size: *the upward growth of plants* | *the growth of the city affects the local climate.*

- the process of developing or maturing physically, mentally, or spiritually: *keeping a journal can be a vital step in our personal growth.*
- the increase in number and spread of small or microscopic organisms: *some additives slow down the growth of microorganisms.*
- the process of increasing in amount, value, or importance: *the rates of population growth are lowest in the north.*
- increase in economic value or activity: *the government aims to get growth back into the economy.*

*An increase in size or mass over time

Development

- Progressive change in size, shape, and ***function***
- Change in structure/size vs. change in function and activities

Growth and development

Growth and development

Who cares?

- Understanding growth (meristematic activity) and development is fundamental for manipulating growth and maximizing yield/quality relationship
  - What is growing?
  - When?
  - Where?
  - What limits it?
  - What controls it?

Tree growth

- Productivity of apple + pear trees is function of:
  - Vegetative growth (leaves, shoot length)
  - Canopy dimensions (height, depth)
  - Bearing surface
  - Fruiting sites per acre
  - Light interception/distribution
  - Assimilate production + partitioning

Growth and development

- Shoots/leaves
- Fruit
- Secondary
- Roots

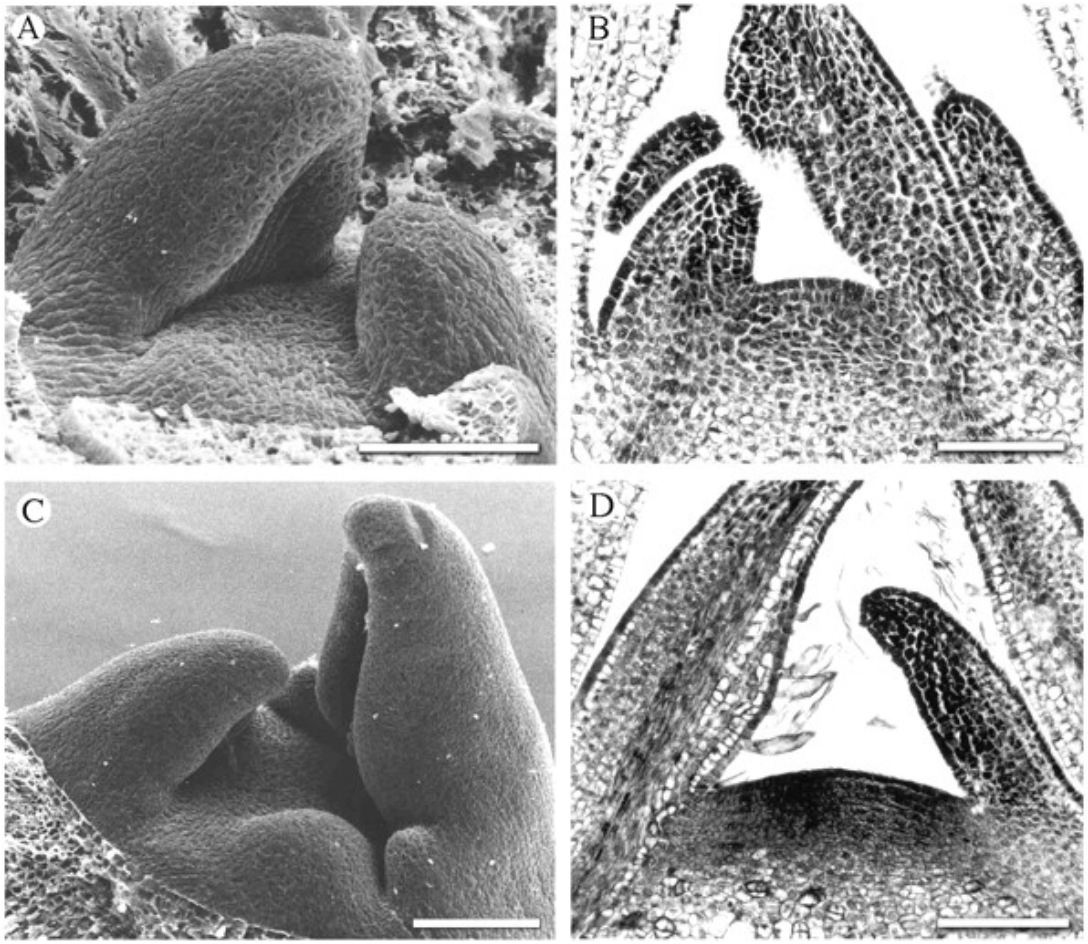
- Meristems all

Plant meristems

meristem | ˈmerəˌstem |

noun Botany

a region of plant tissue, found chiefly at the growing tips of roots and shoots and in the cambium, consisting of actively dividing cells forming new tissue.



Bud development

- All shoots and fruit arise from buds

- In established orchards bud are borne:

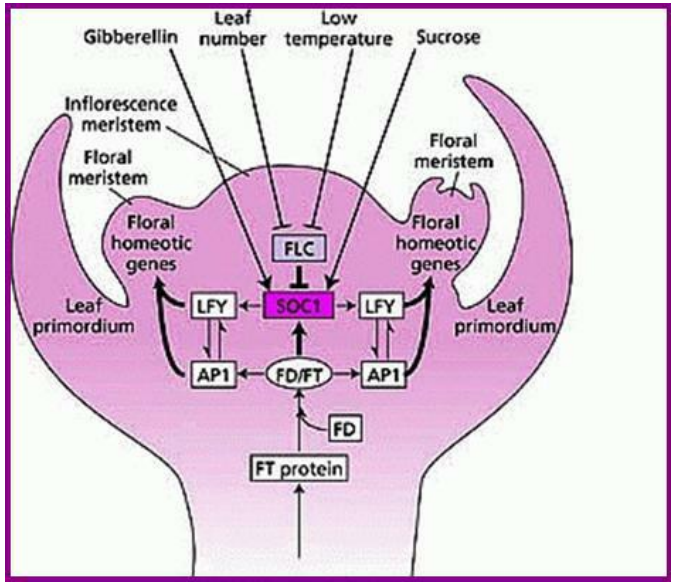
- On extension shoots
- On short shoots (spurs)

- Terminal position
- Lateral position

- Bourse bud forms at base of flower cluster

Bud development

- Each bud is a compressed/unelongated shoot
- Short axis:
  - 21 leaf formations in spiral sequence
  - 9 bud scales
  - 3 transition leaves
  - 6 true leaves
  - 3 bracts



Bud development

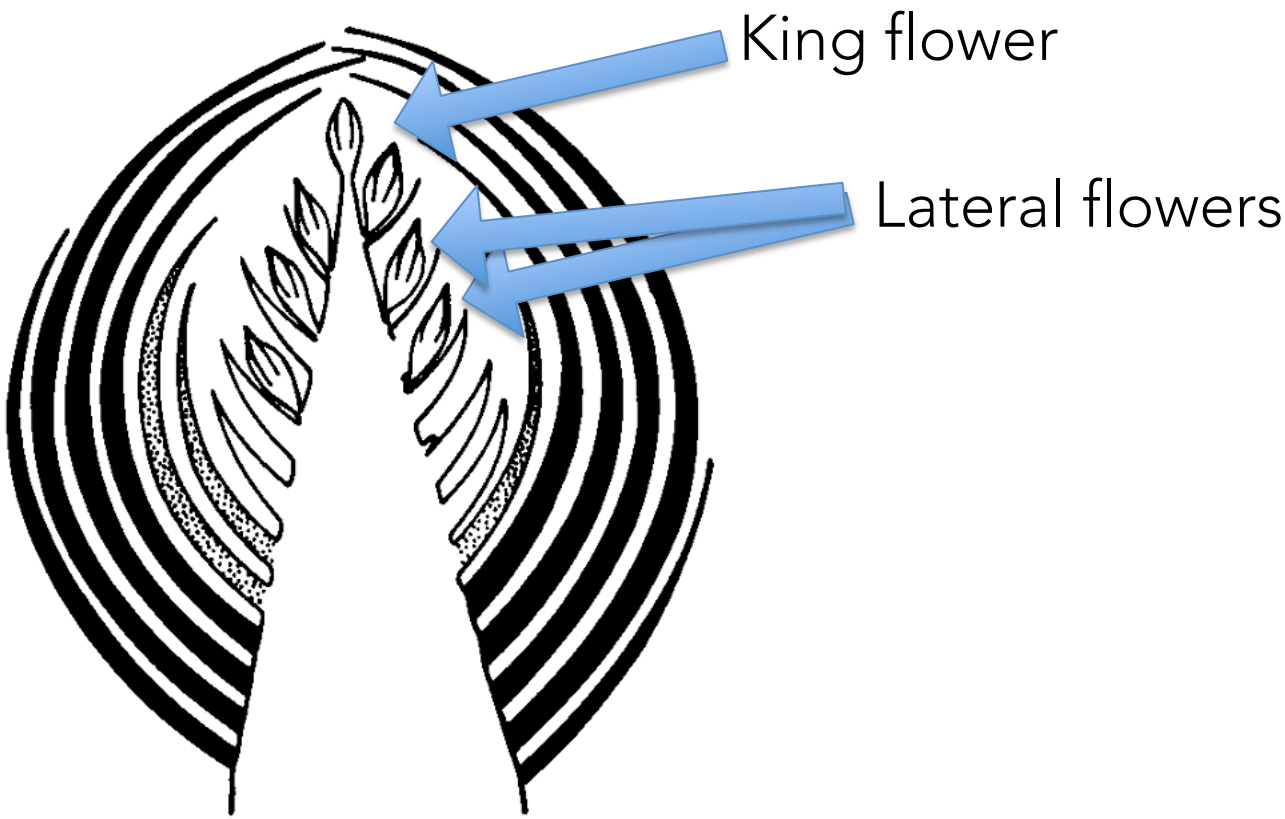


Figure 6.2 Bud structure showing, in ascending order, nine bud scales, three transition leaves, six true leaves and three bracts. The axis is terminated by a flower primordium (the king flower) and lateral primordia are formed in the axils of the three bracts and three distal leaves. After Abbott (1970). Reproduced with permission.

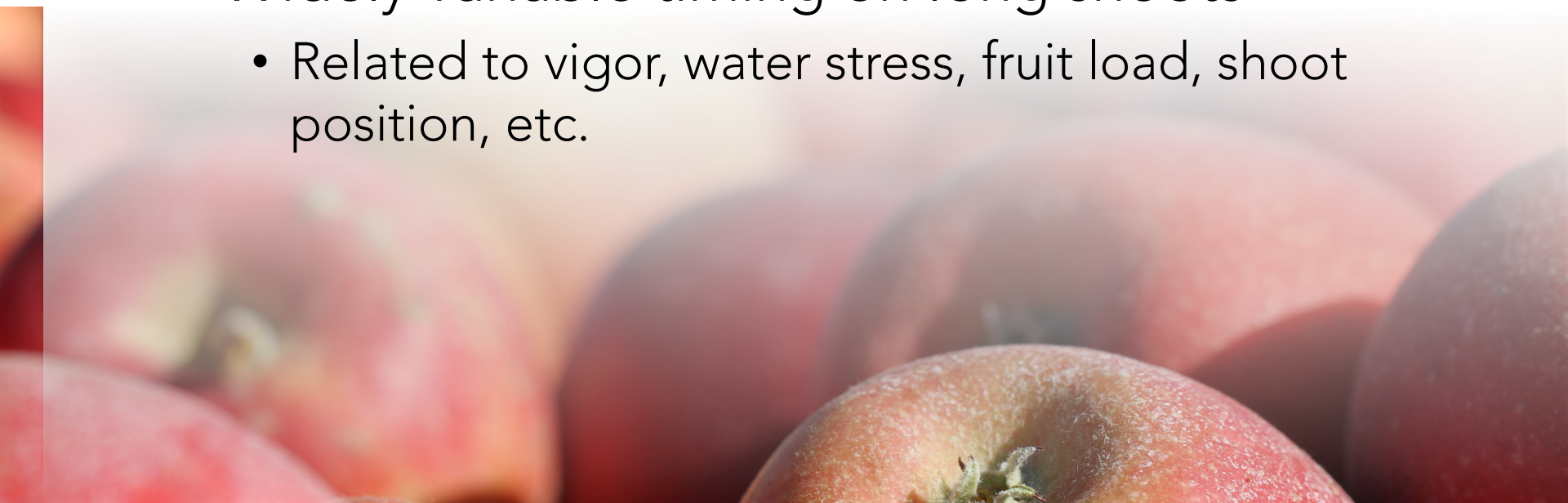
Bud development

- Fruiting vs. vegetative?
  - Type of bud (spur bud vs. terminal & lateral)
  - Length of growing season
  - Presence of fruit

  - Variable and controlled by:
    - Cultivar
    - Crop load
    - Tree management

Cessation of growth

- Terminal buds form as growth stops
  - Early in summer on spurs (these buds 'dormant' by CI)
  - Widely variable timing on long shoots
    - Related to vigor, water stress, fruit load, shoot position, etc.



Bud set

Bud dormancy

- A period of temporary suspension of visible growth
  - Includes fruit buds in winter growing slowly
  - ‘Trace’ buds (adventitious) under bark

- Dormancy enables plants to survive adverse conditions

Dormancy

- Phase of development (meristem inactivity) that allows trees to survive unfavorable winter conditions

- Trees are alive, but not growing

  - Daylength
  - Temperature
  - Hormones – ABA
  - Others……

- Need growth to stop and buds to form

Bud dormancy

- Paradormancy (summer, early fall)
  - Correlative inhibition
  - Can be stimulated to grow if inhibition removed
- Endodormancy (fall, winter)
  - Late fall, winter rest
- Ecodormancy (late winter, spring)
  - Following loss of endodormancy
  - Buds can be induced to budbreak
  - Lasts until buds exposed to sufficient warm temp

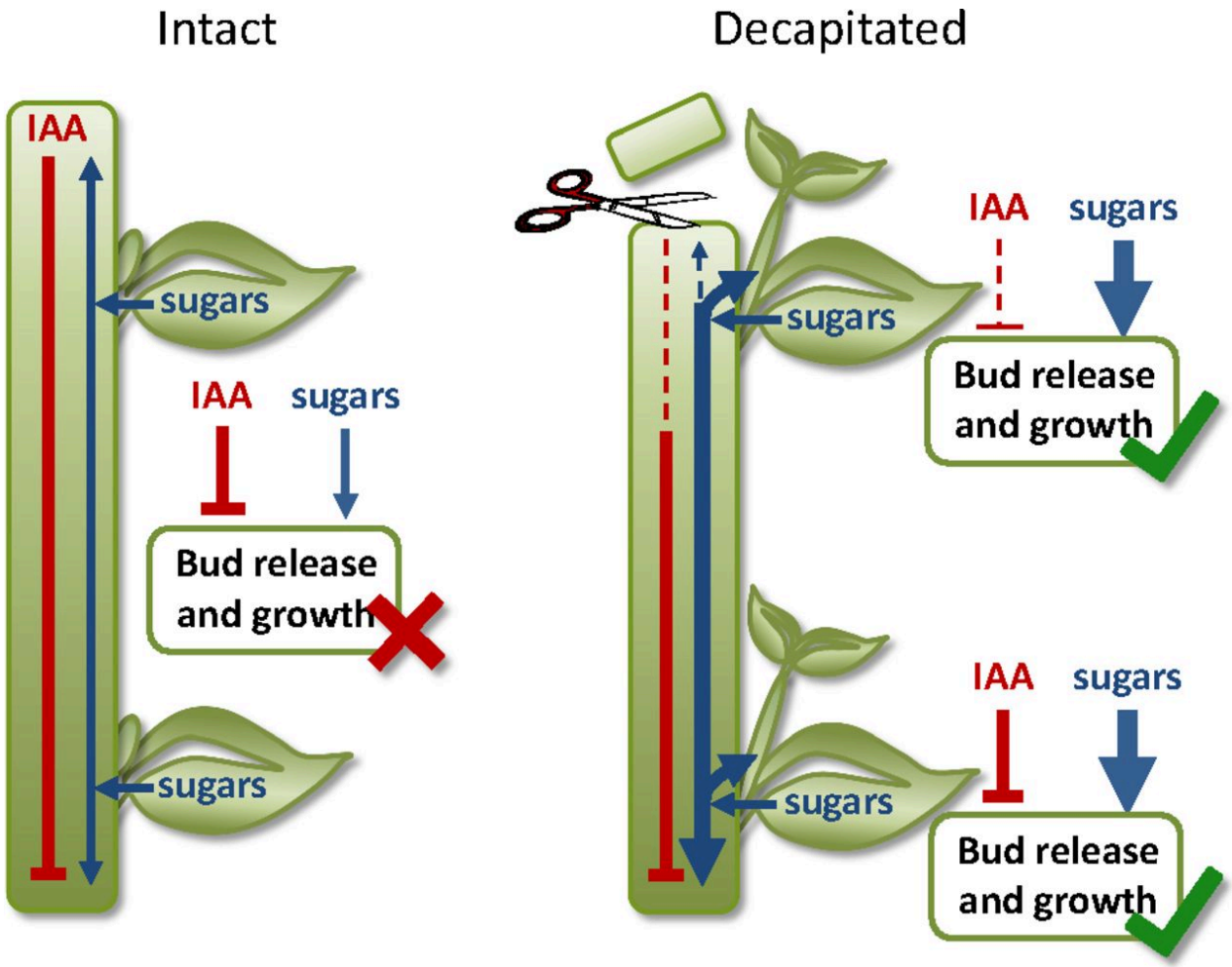
Paradormancy - apical dominance

- Dormancy through correlative inhibition
- Dormant lateral buds maintain a dormant state by distal shoot
- Remove apical shoot – dormancy released, new replacement shoots grow
- New hierarchy of apical dominance

Apical dominance

- Large cultivar differences
- Thought to be auxin-related (produced in expanding leaves)
- Cytokinins (produced in roots)
- release buds from CI

Apical dominance



Dormancy

- Endodormancy, "deep dormancy"
- Depth of dormancy declines with cold weather
- Chill units

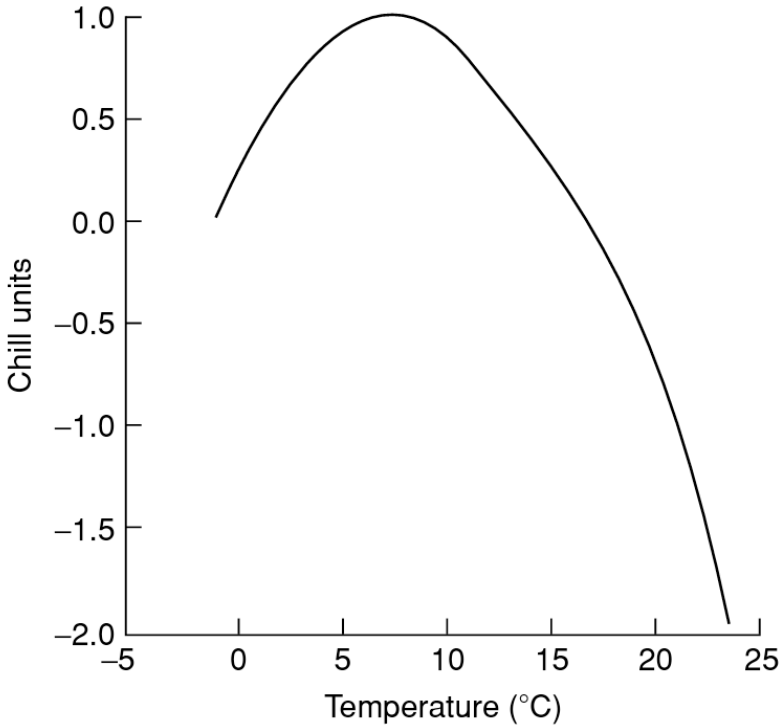
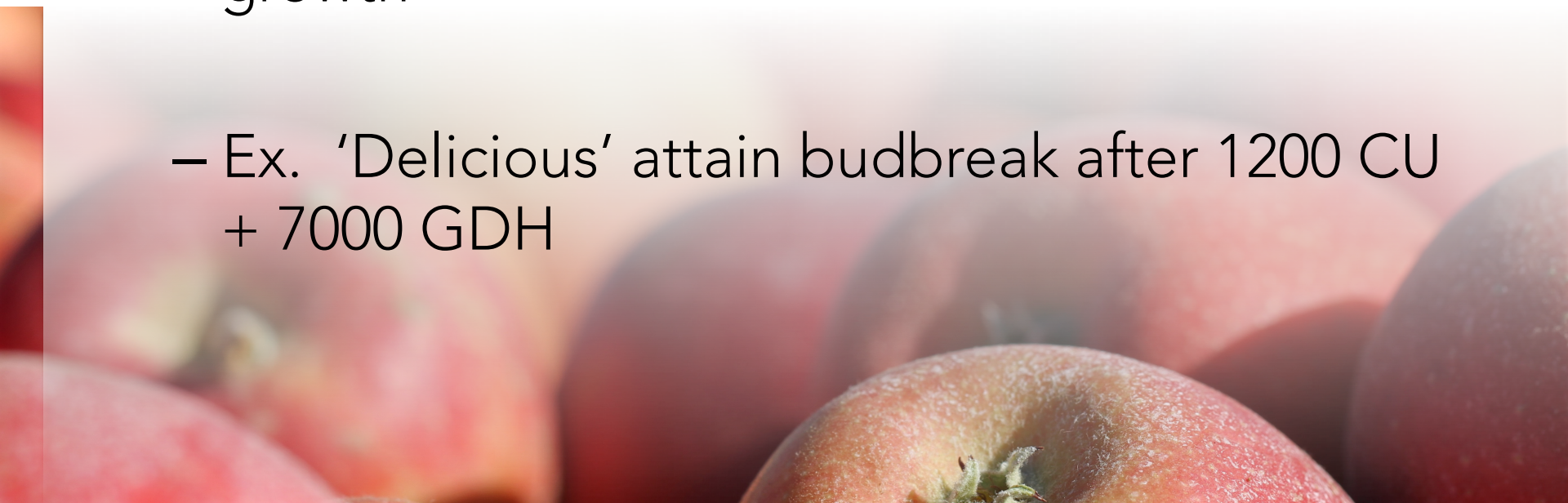


Figure 6.8 The relative efficiencies of different temperatures in meeting the chilling requirements of 'Starkrimson Delicious' apple. From Shaltout and Unrath (1983). Reproduced with permission.

Dormancy

- 2 keys to emerging from dormancy
  - Low temperatures to meet chilling requirement
  - Accumulated GDH above threshold for growth
  - Ex. ‘Delicious’ attain budbreak after 1200 CU + 7000 GDH



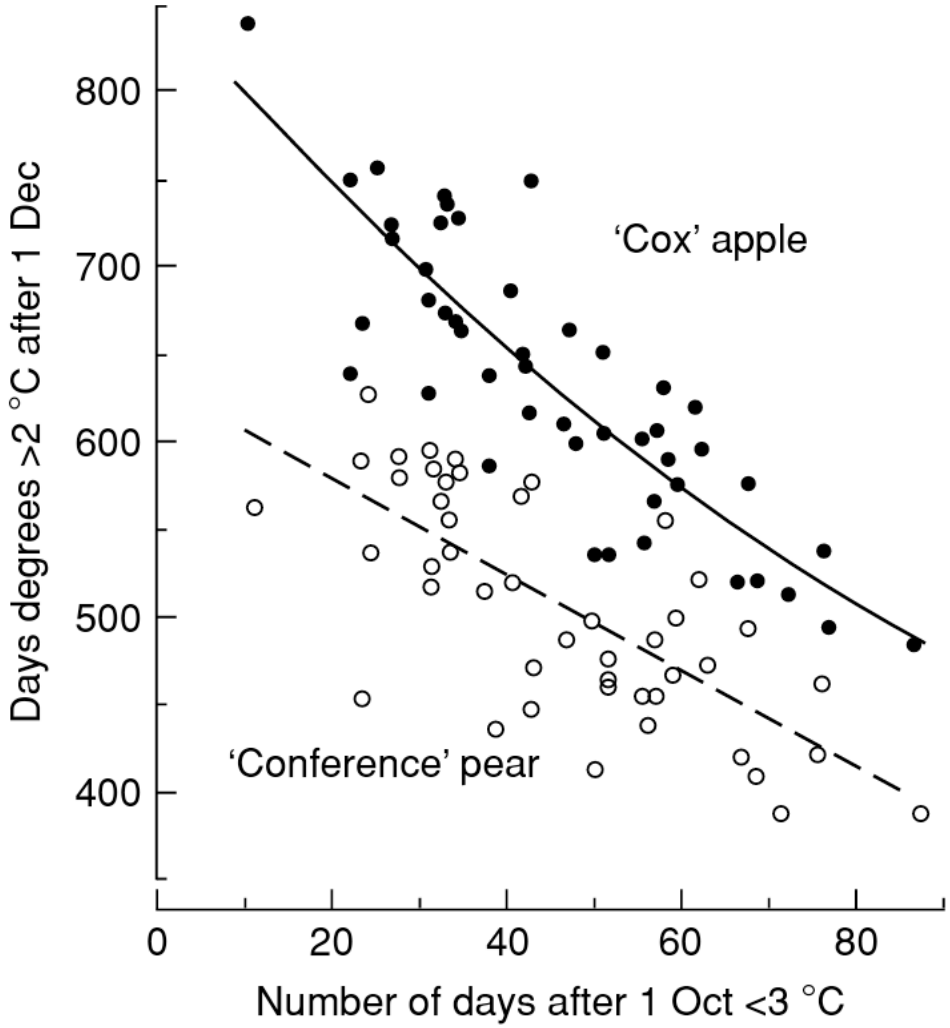
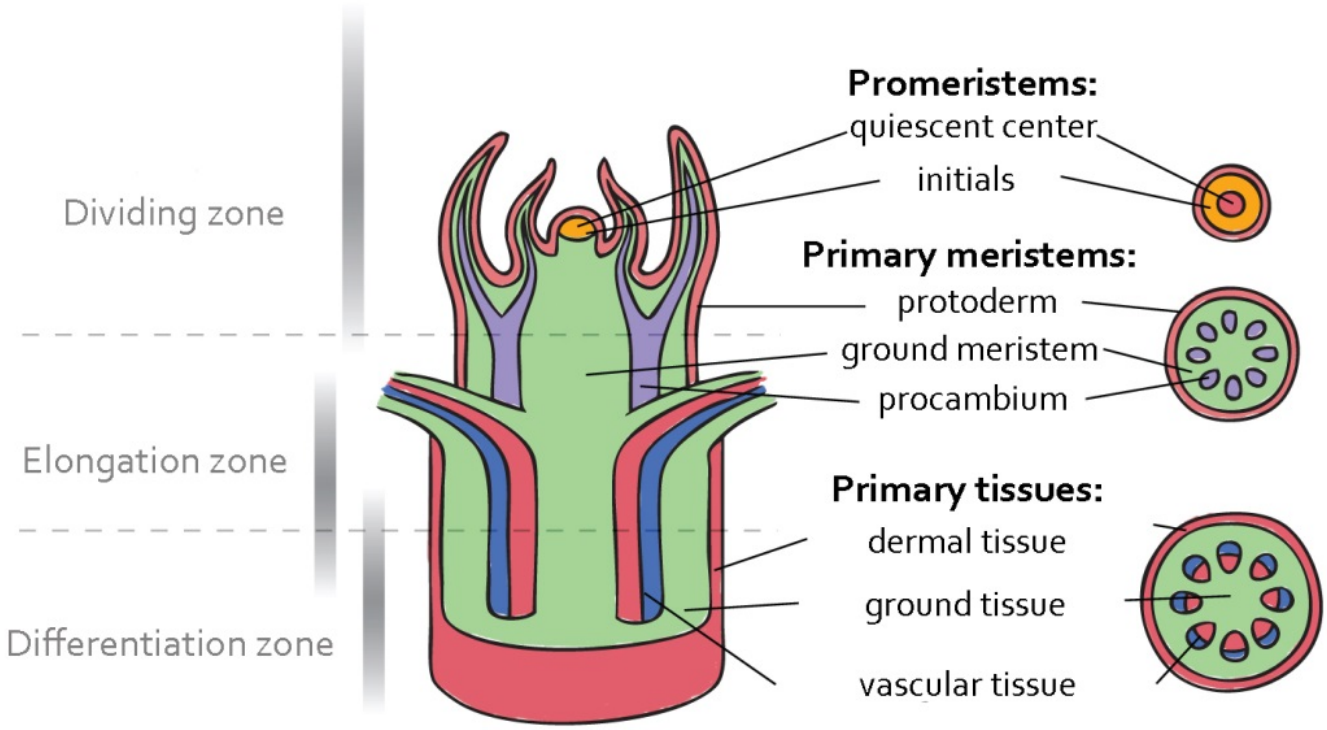


Figure 6.10 The inverse relationship between thermal time to full bloom of 'Cox' apple and 'Conference' pear and the accumulated number of 'chill days' in winter at East Malling, Kent, England. From Cannell (1989), from *Manipulation of Fruiting* by C.J. Wright. Reprinted by permission of Elsevier Science Ltd.

Vegetative extension growth

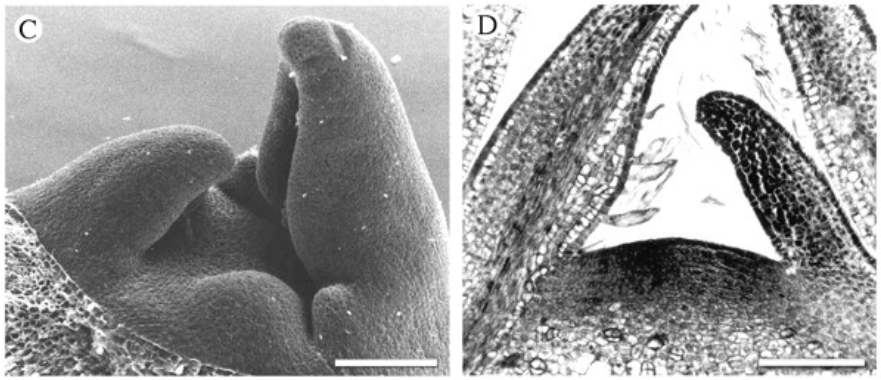
Primary growth

- Shoot apical meristem



Shoot growth

- In the beginning…..

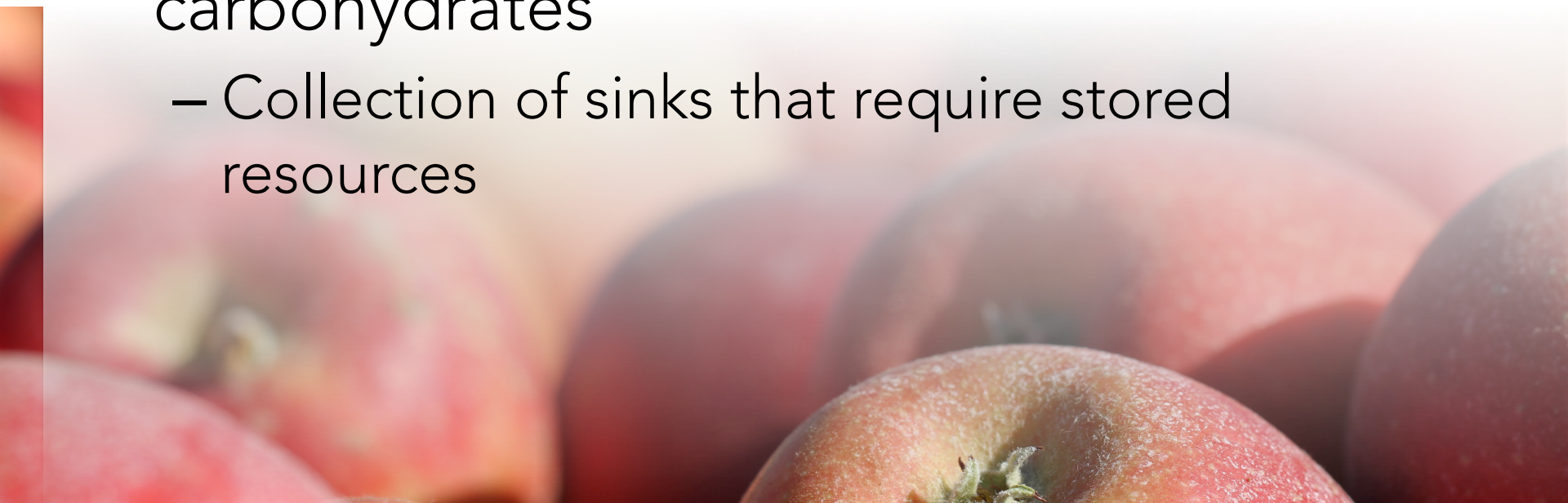


- Shoot apical meristem (bud) formed
- Growth begins in spring – cambial activity before budbreak
- Actual growth is controlled by growth inhibitors and promoters – balance between these

Shoot growth

- Initial stages dependent on reserve carbohydrates, N, other minerals

- At budbreak tree doesn't produce carbohydrates
  - Collection of sinks that require stored resources



Shoot growth

- Total shoot growth depends on:
  - Number of buds
  - Proportion that break
  - Growth of those buds

- Controlled by many separate (but often interacting) factors

Shoot growth

- Whole perennial structure of tree is important source but roots in particular
- Most N for early growth from bark and shoots nearest to bud
- Fall foliar applications of N?

Shoot growth

- Rate of growth heavily influenced by temperature
  - Above and below-ground
- Light – generally positive relationship between shoot growth and light
- Water status – manipulating soil water content can affect shoot growth

Shoot growth

- Hormone effects
  - Auxins & ABA have relatively minor effect
  - GAs – some are active in promoting apple + pear shoot growth
    - Inhibitors of biosynthesis reduce growth
  - Cytokinins affect budbreak (# of shoots) and cell division

Shoot growth

- Leaf effects – source of carbohydrates, play a major role in plant growth
  - After 5-6 new expanded shoot leaves current Pn is more important than reserves
  - Upper leaves export to shoot tip
  - Lower leaves export to other tree parts

Shoot growth

- Fruiting effects
  - Diversion of metabolites/carbohydrates from vegetative growth
  - Direct effect via competition for resources
  - Indirect (subsequent season) effect via bud development

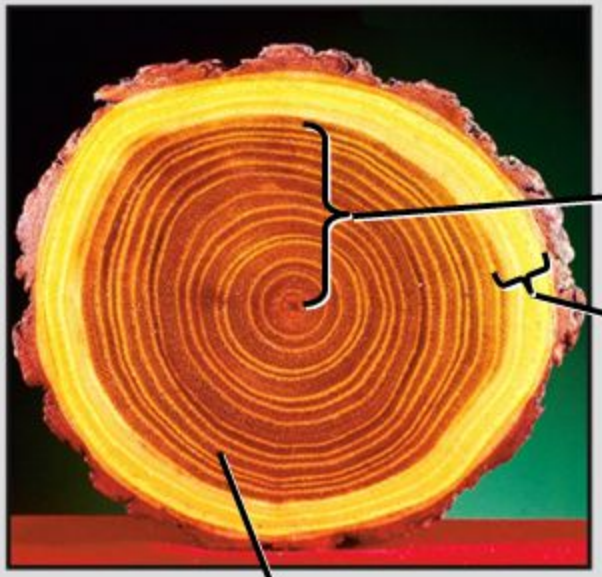
Secondary growth

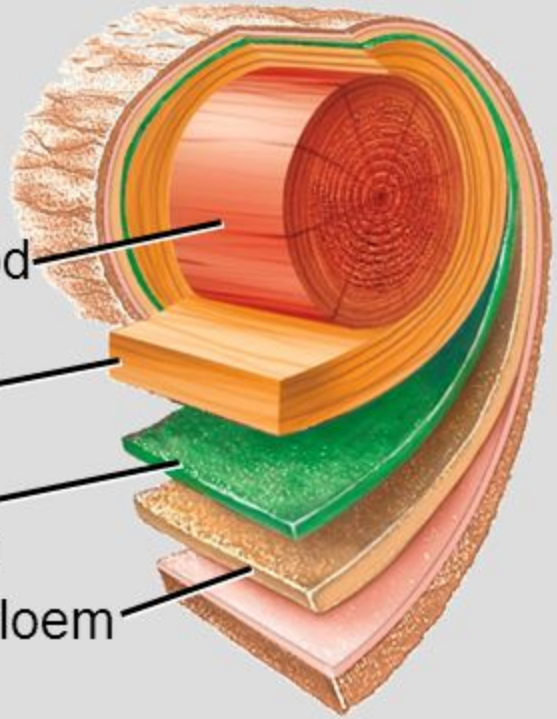
- In woody plants – cambial meristems create radial growth (increase in diameter)

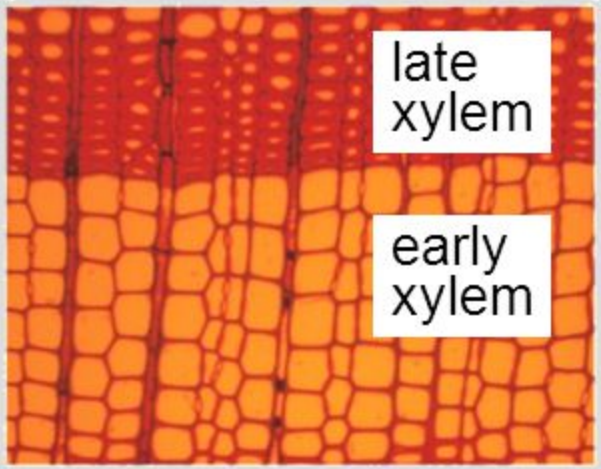
- Secondary growth is a weak sink

Plant Growth

Stem – Secondary Growth:







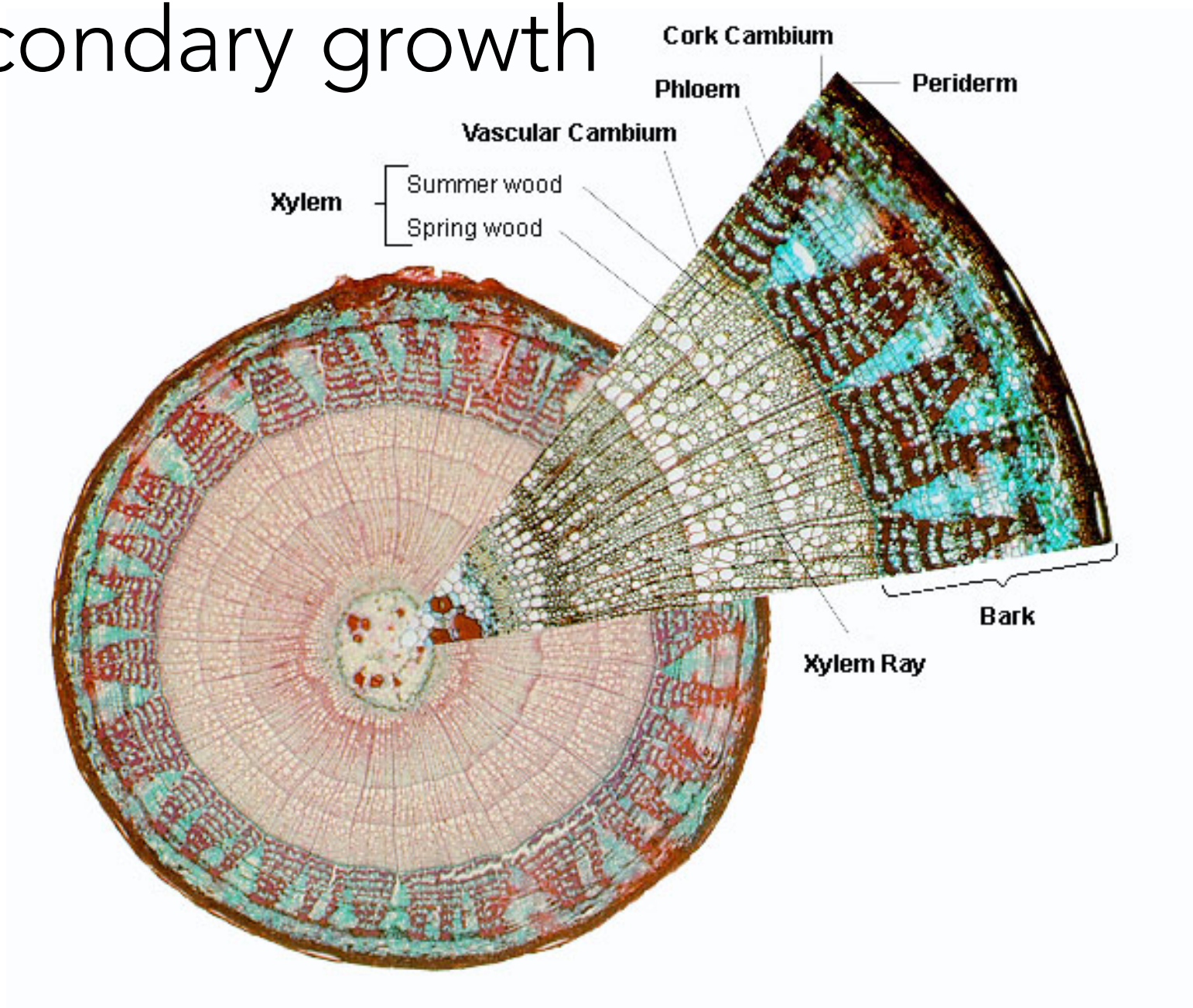
Sapwood = Young xylem, water

Heartwood = Old xylem, support

Seasonal Growth = annual rings

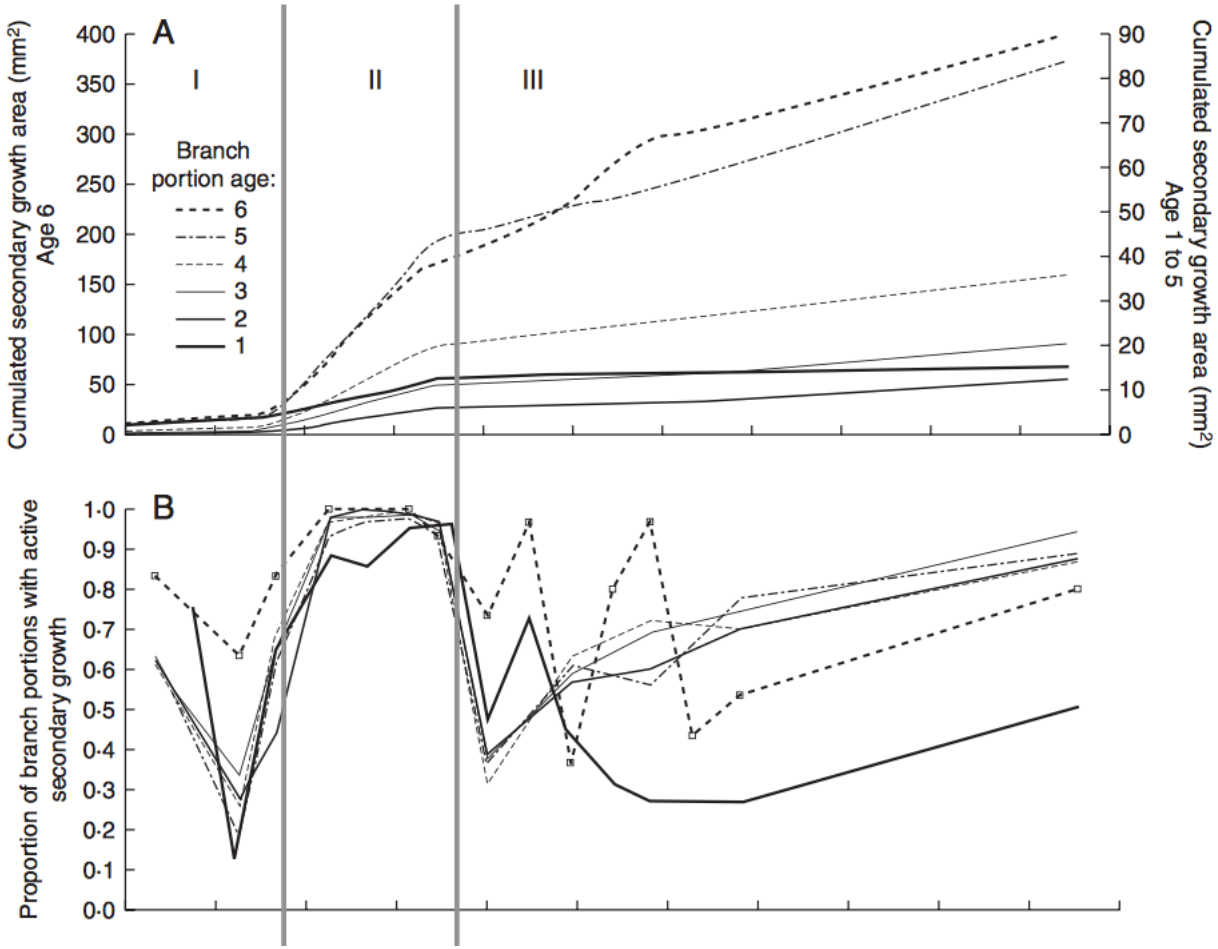
Secondary phloem = grows outward
older phloem crushed

Secondary growth

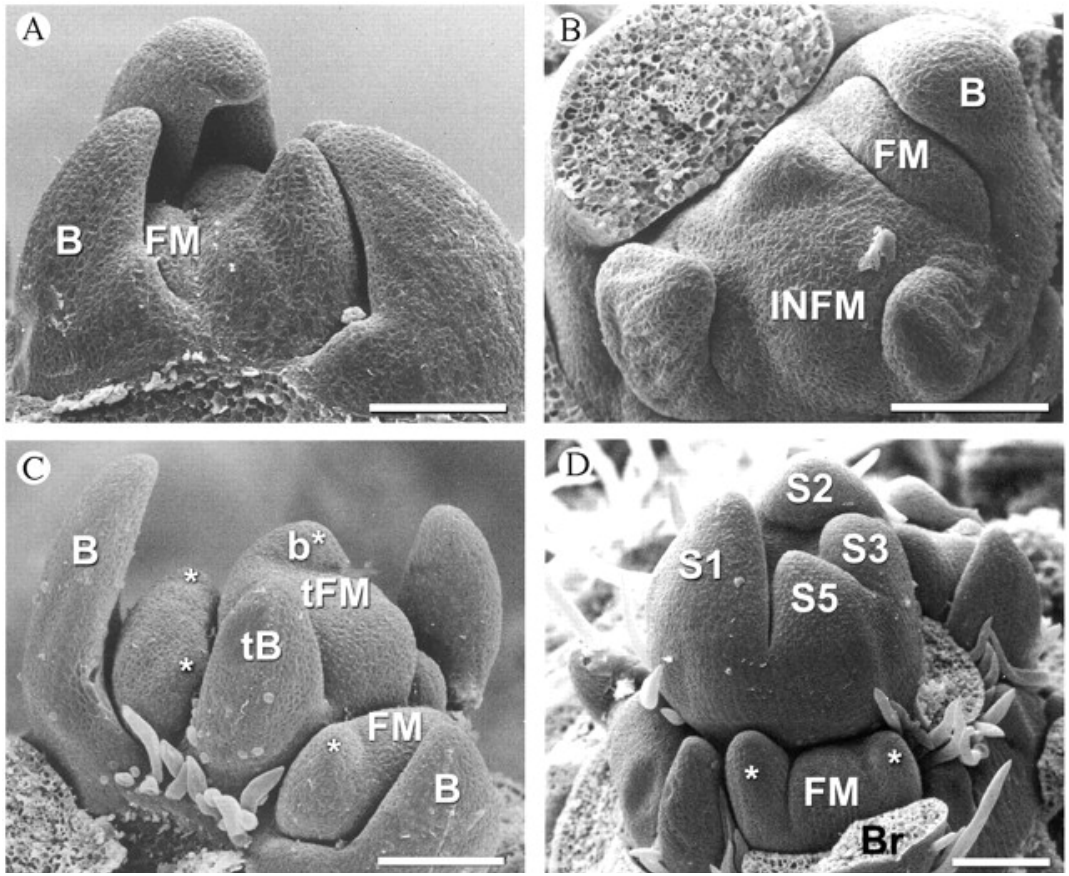


Secondary growth

Lauri et al. — *Effects of tree architecture and fruit load on secondary growth dynamics*

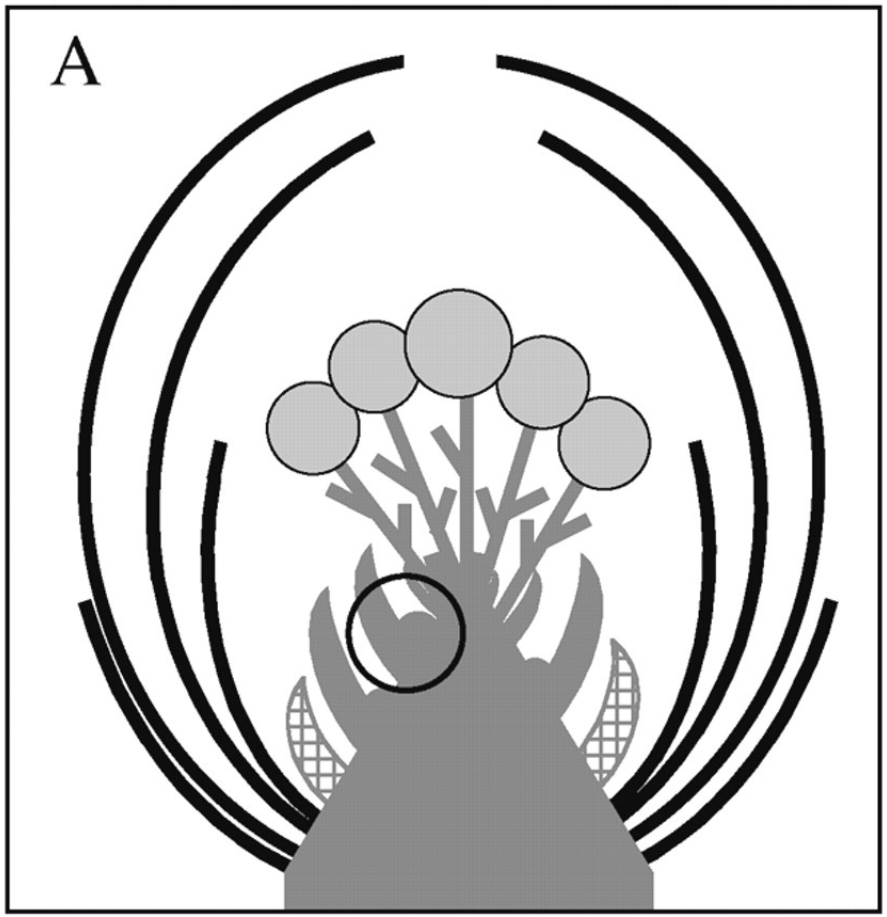


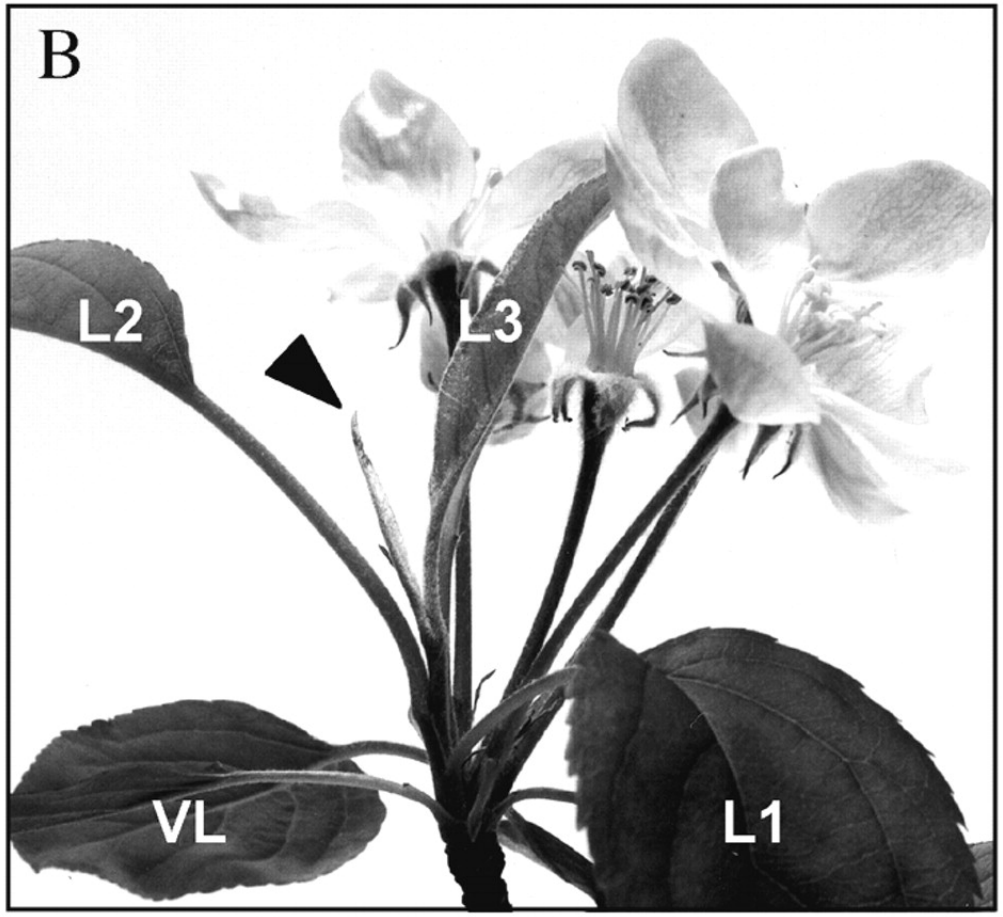
Floral initiation:



- Shoot apical meristem domes

Flowering





Floral anatomy

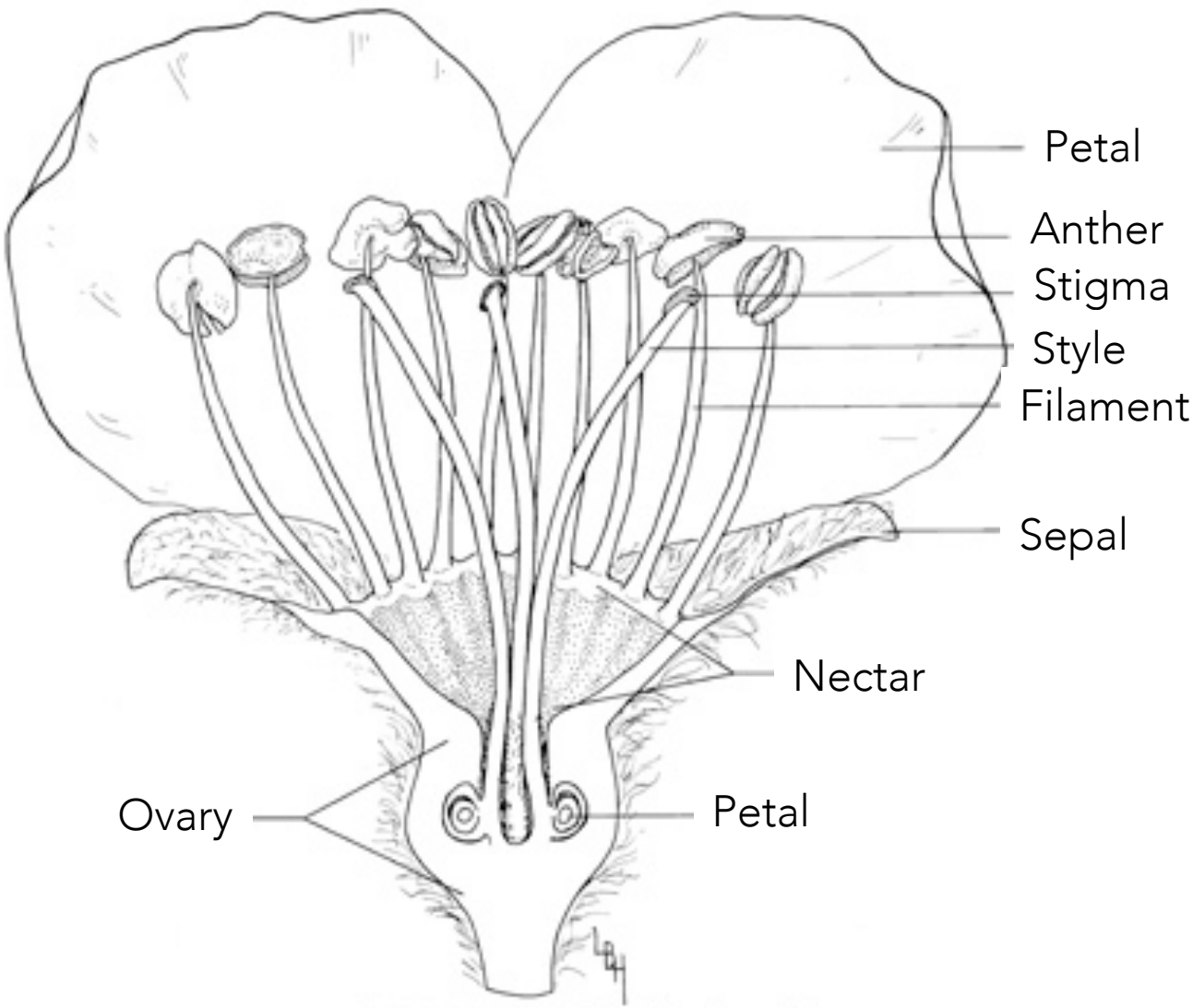
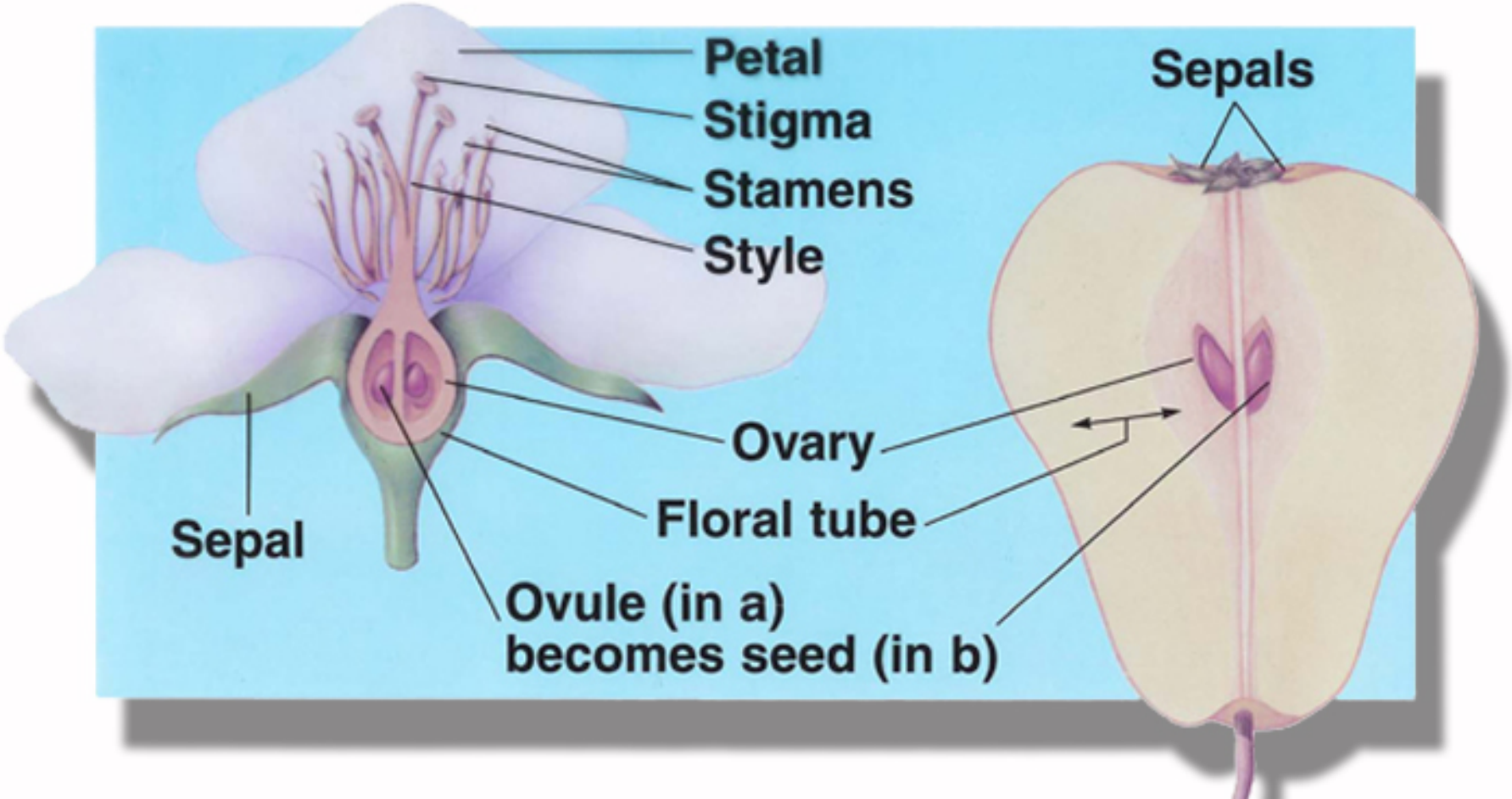


FIGURE 149.—Longitudinal section of 'Bartlett' pear flower, ×9.

Fruit development

- Apple and pear fruit derived from base of flower



Fruit development

Floral and fruit anatomy:

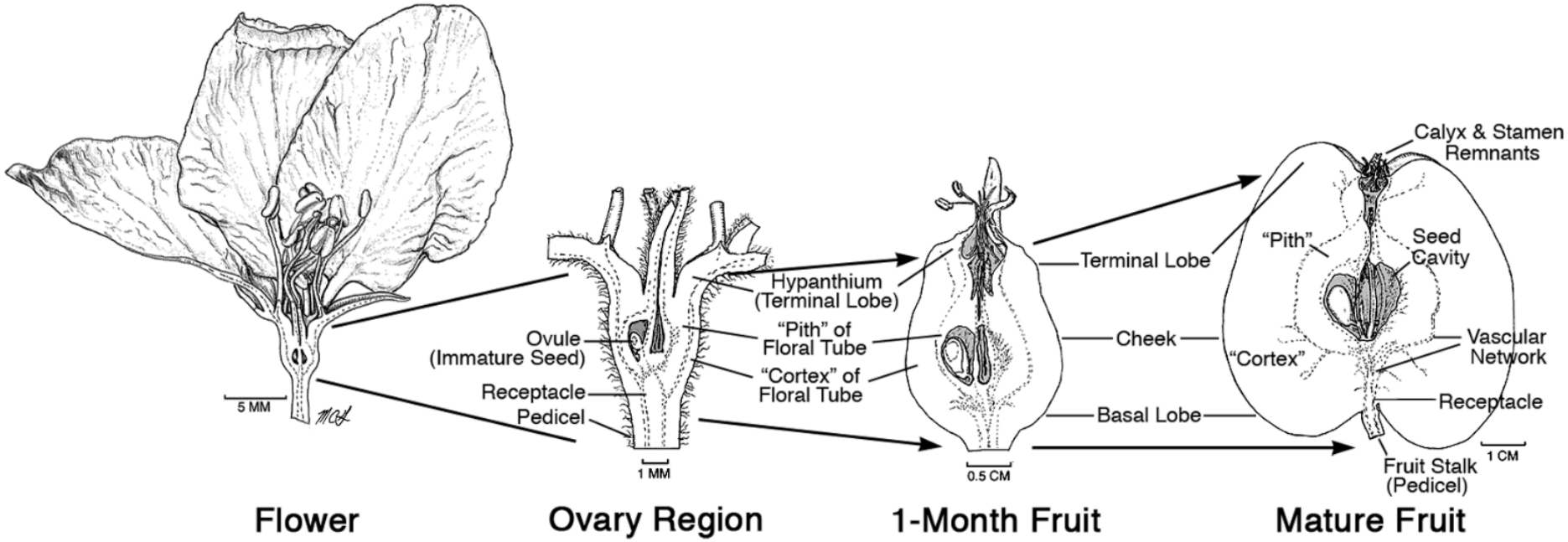
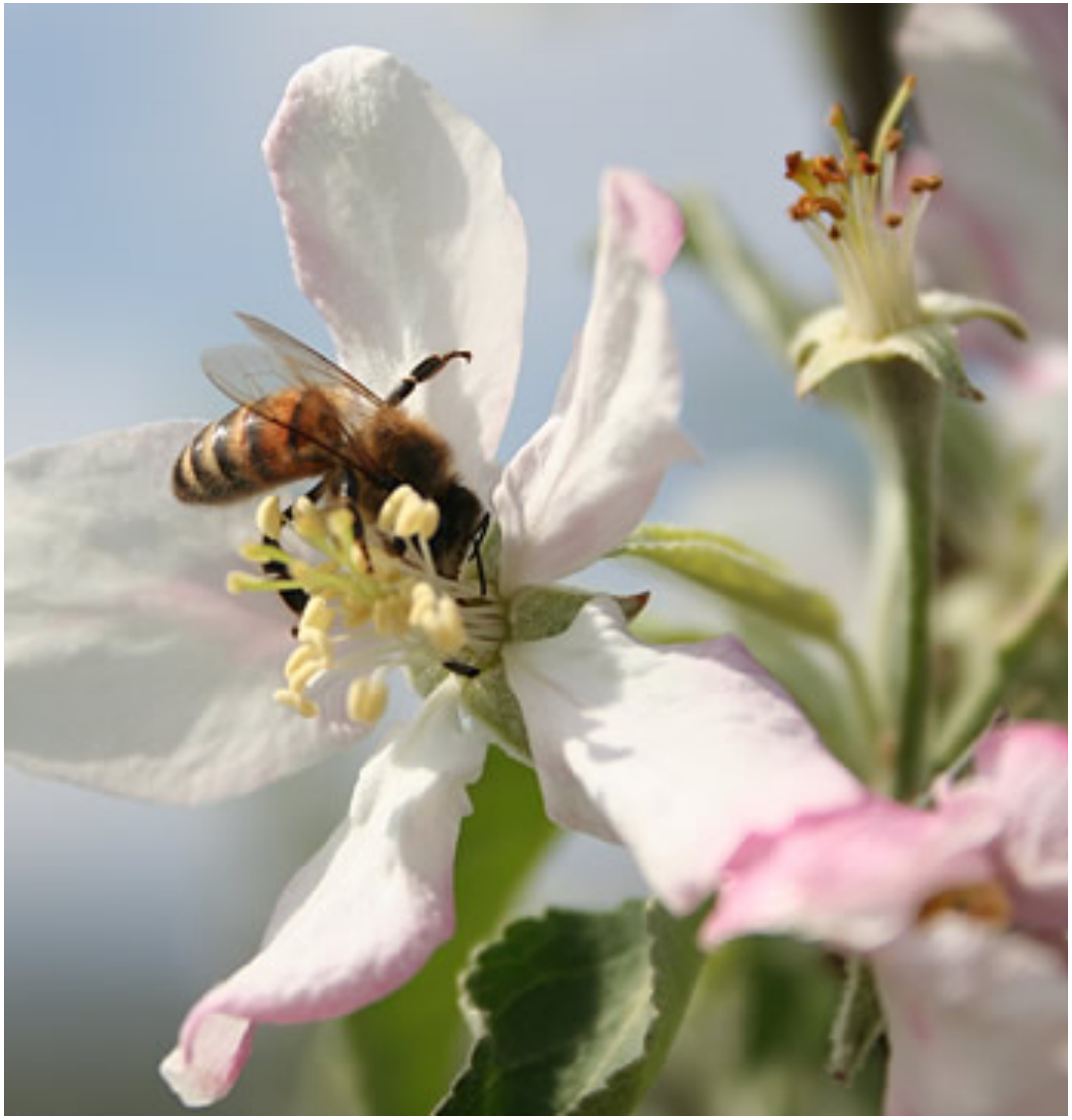


Illustration by M. Goffinet

Fruit development

- Pollination
- Mediated by *Apis mellifera*

- Fertilization
  - 5 locules
  - 10 ovules
  - Seed set

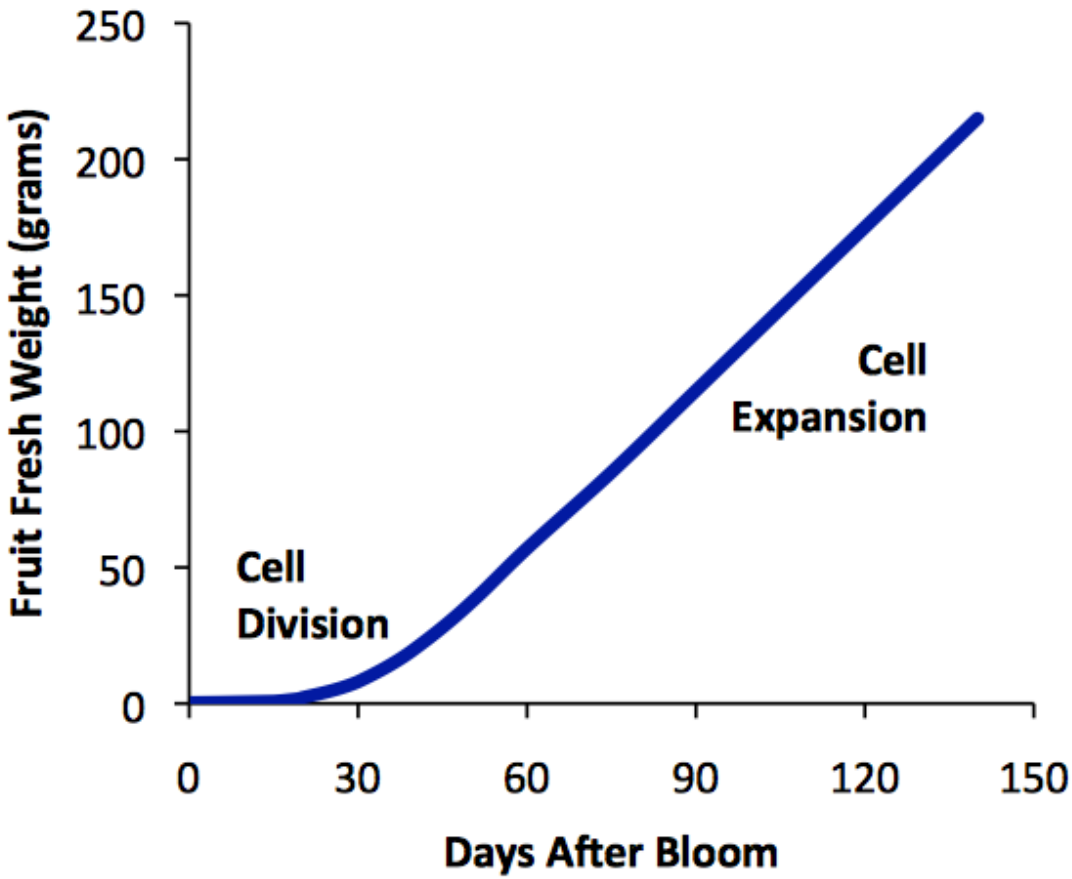


Fruit growth

- Fruit growth measured in weight gain
  - Diameter misleading
- Initial growth exponential cell division
  - 7-14 days
- Then both cell division and expansion
  - Until ca. 4-5 weeks after full bloom

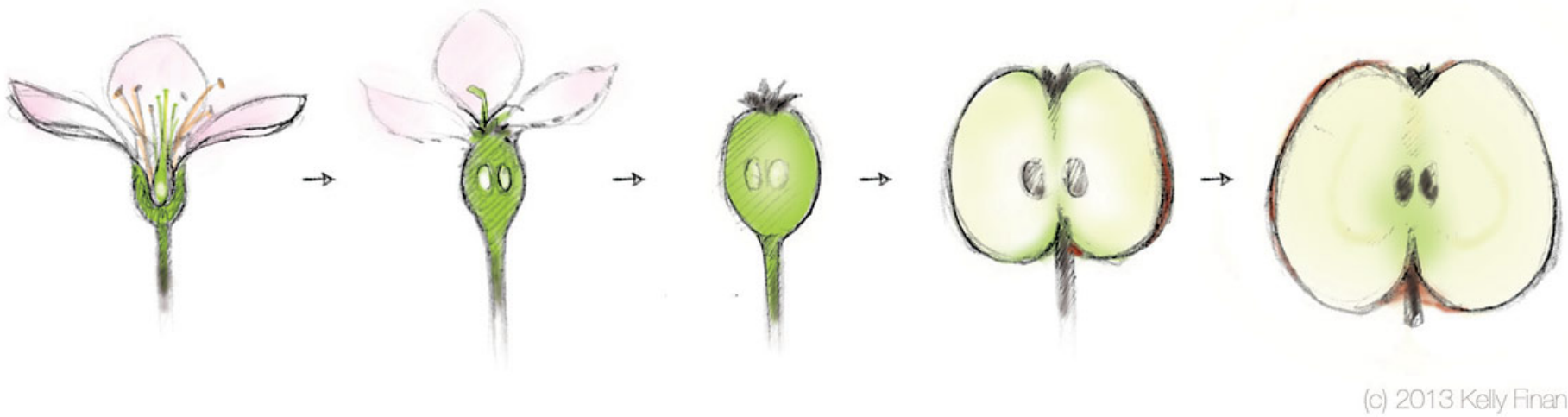
Fruit growth

- Growth by cells expanding for remainder



Fruit growth

- Unlimited in resources, add about 2 g/day (0.07 oz/day = 0.5 oz/week)
- Large fruit have higher growth rates
  - Proportional to cell number
  - Cells growth the same in all fruit

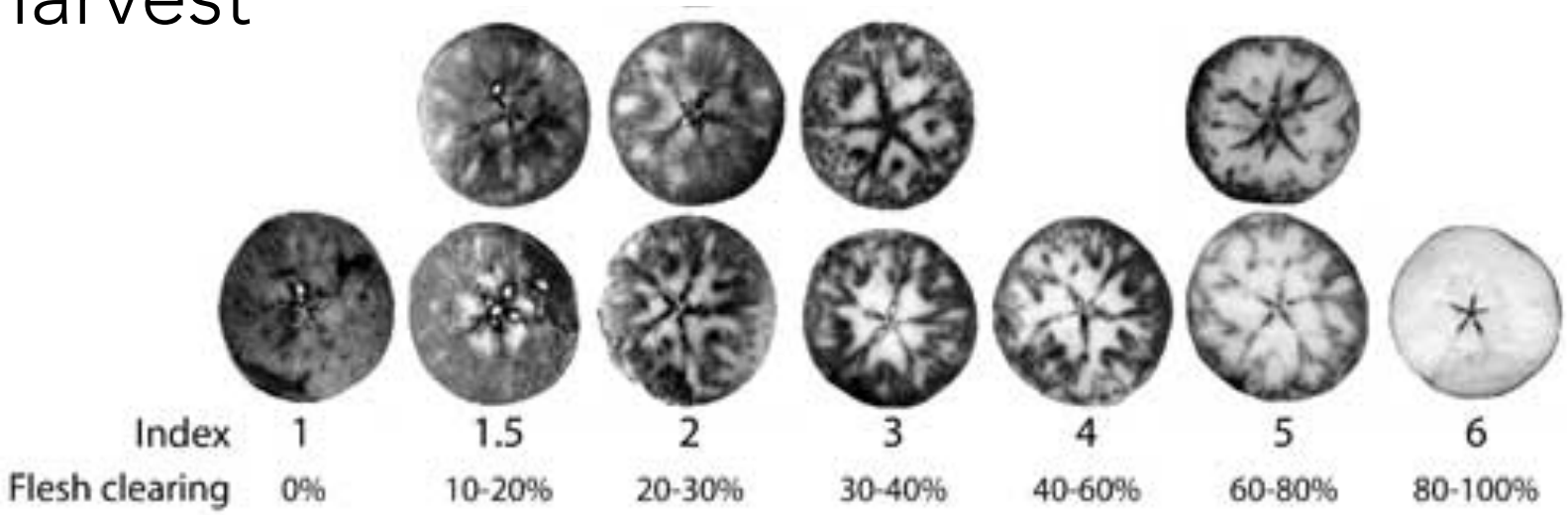


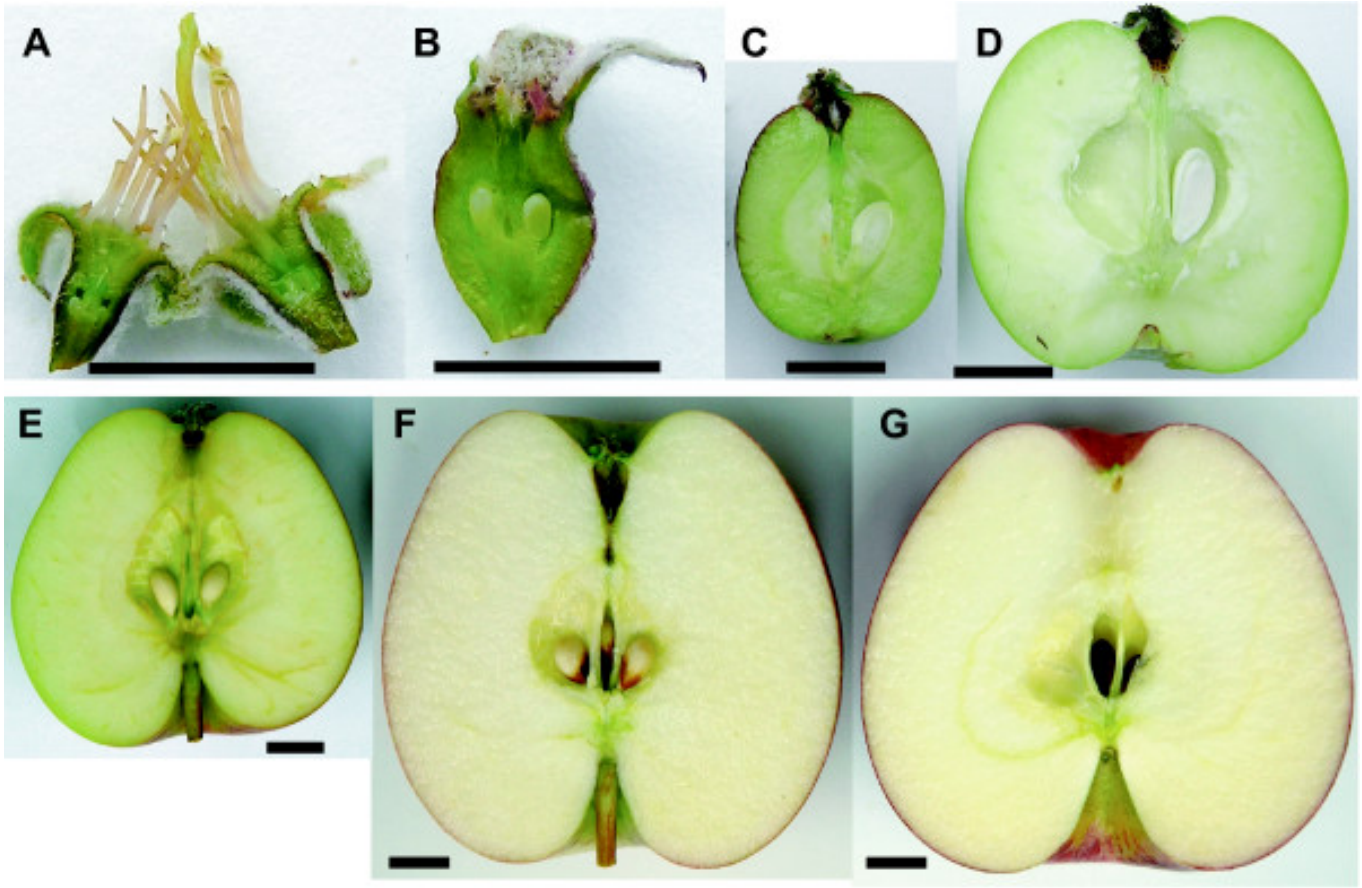
Fruit set

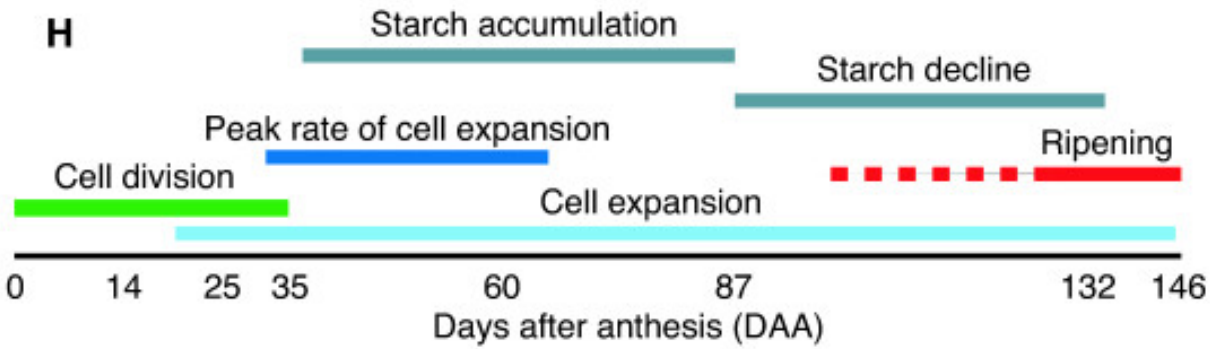
- Trees produce 10-15x more flowers than desirable fruit number/tree
- Cell division reduced if too many fruit = small fruit
- Critical to adjust fruit numbers early
  - Benefits fruit size, current season
  - Benefits bloom, subsequent season

Fruit growth

- Pome fruit accumulate large amounts of starch
- Starch is not available for fruit growth
- Stored, and converted to sugar near harvest

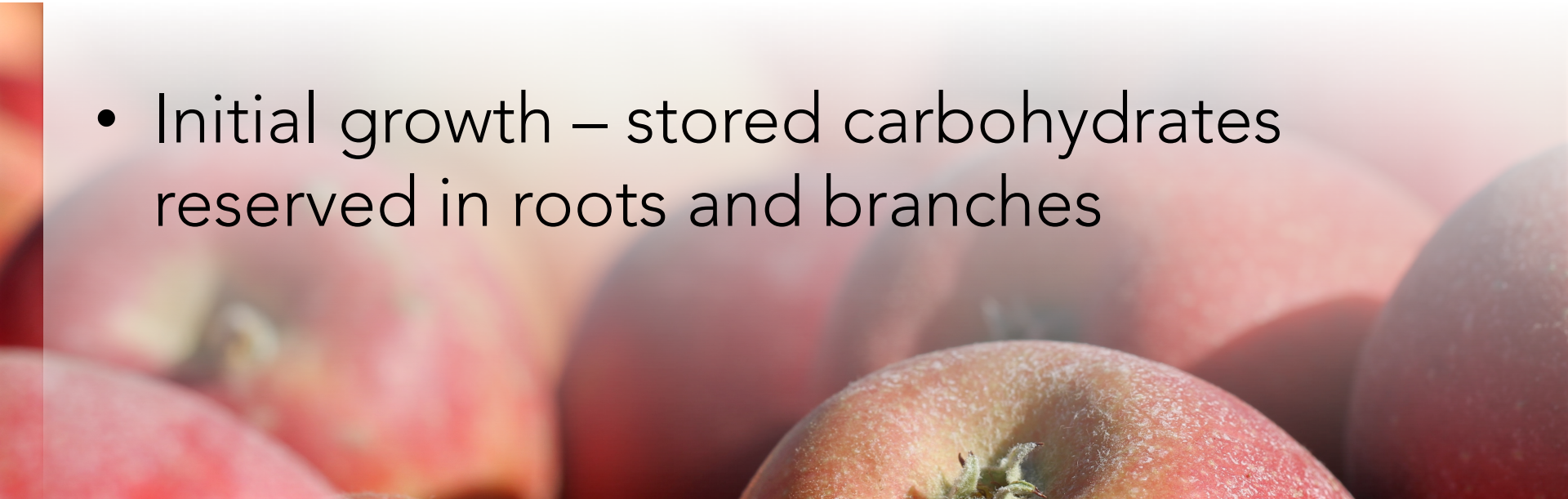



A
B
C
D
E
F
G


H
Starch accumulation
Starch decline
Peak rate of cell expansion
Ripening
Cell division
Cell expansion
0
14
25
35
60
87
132
146
Days after anthesis (DAA)

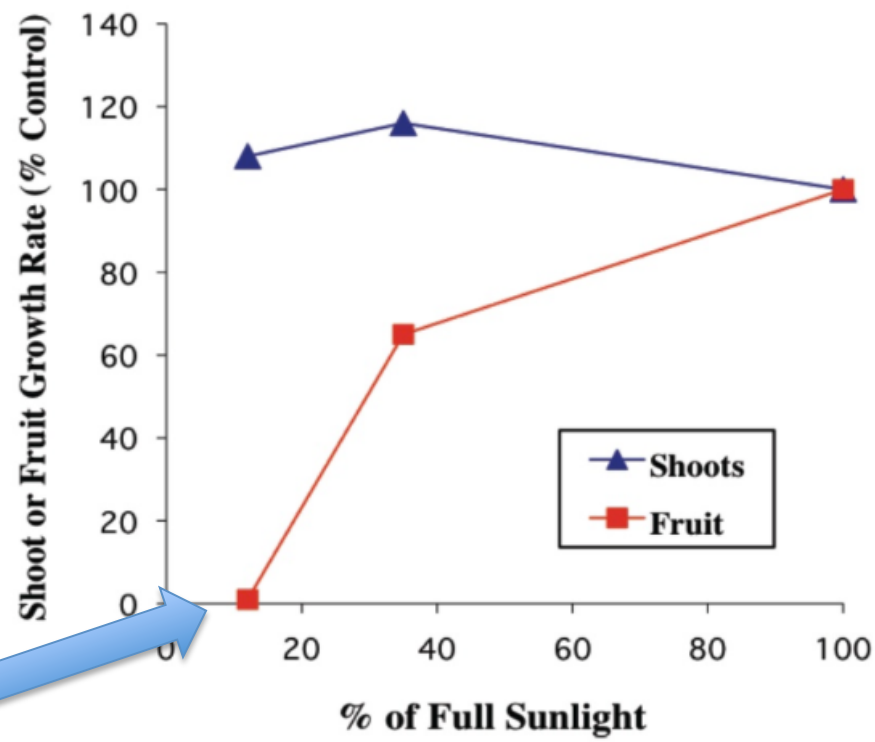
Support for fruit growth

- Support for fruit growth:
- Goal is to balance tree's ability to create growth resources and their partitioning to fruit
- Initial growth – stored carbohydrates reserved in roots and branches



Support for fruit growth

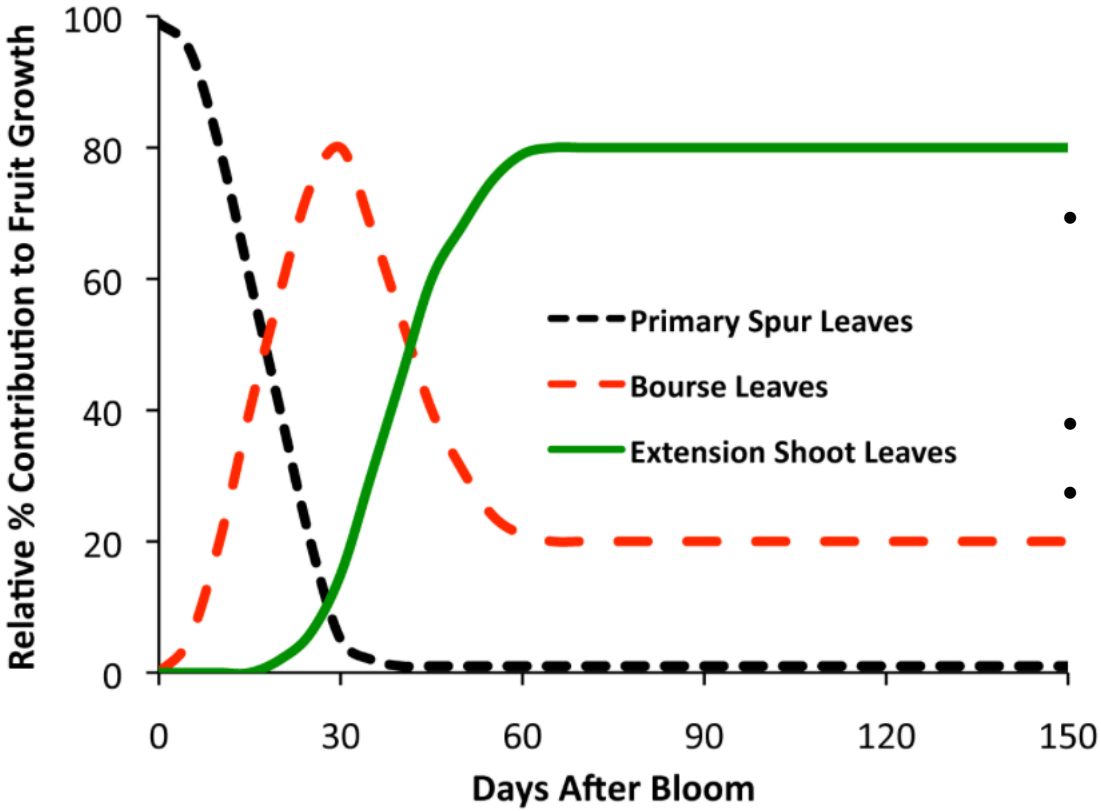
- Spur leaves + spur-like leaves on short laterals
  - Heavy shade reduces apple but not shoot growth



Complete fruit drop

Support for fruit growth

- Pattern of support after bloom



- Primary spur leaves
  - (those that come out before bloom)
- Lateral bourse shoots
- Extension shoot leaves (+12 lvs)

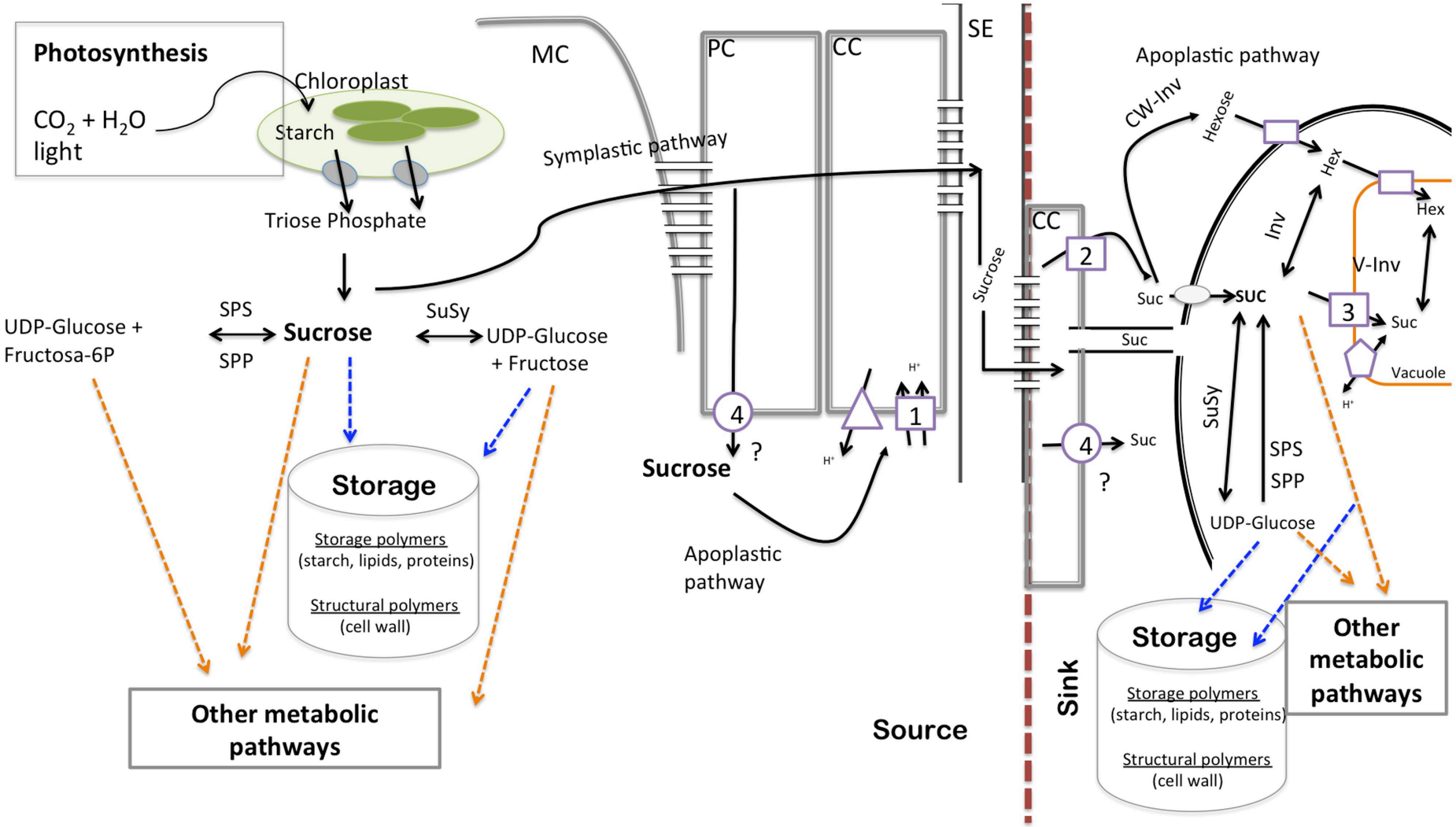
Fruit growth summary

- Fruit develop at base of flower
  - Walls around seed cavity expand – flesh
- Fruit grow by cell division about 1 week, cell division + expansion 3-4 weeks, expansion thereafter
- Fruit size depends on cell number

Fruit growth summary

- Carbohydrate reserves support flower and spur leaf development but not fruit
- Post-bloom growth supported by Pn
- Spurs important in first weeks (i.e., during cell division)
- Yield depends upon light captured by spurs in first critical weeks after bloom
- Open canopies, light pruning, early thinning

Carbohydrate partitioning



Carbohydrate partitioning:

1. A tree is a collection of semi-autonomous organs and each organ has a genetically determined, organ-specific developmental pattern and growth potential
2. The genetic growth potential of an organ is activated or deactivated by endogenous and/or environmental signals
3. Once activated, genetic growth potential interacts with current environmental conditions to determine conditional organ growth capacity
4. Realized organ growth is a consequence of conditional organ growth capacity, total free resource availability, and inter-organ competition for those resources
5. Inter-organ competition for resources is a function of location relative to the sources of carbohydrates, organ sink efficiency, and organ microenvironment

T.M. DeJong. HortScience 34:1037-1040

Who cares?

- Growing points need resources
  - Called ‘sinks’
  - Resources provided by ‘sources’

- Understanding growth (meristematic activity) and development is fundamental for manipulating growth and maximizing yield/quality relationship
  - When?
  - Where?
  - What limits it?
  - What controls it?

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