Why Do Apples Blush?

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Topics

Pigments – biosynthesis & Genetic control

Factors controlling genes

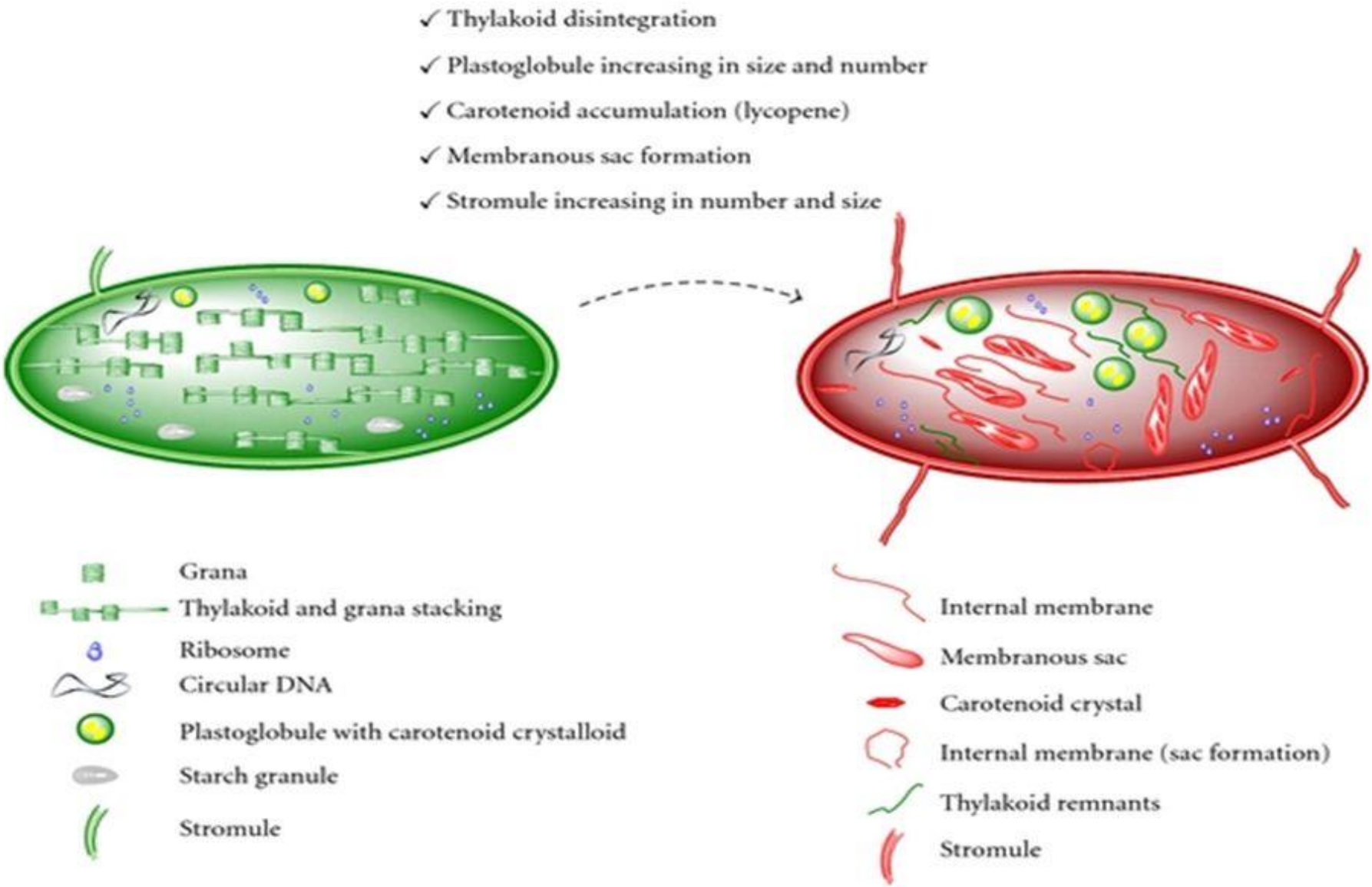
- **Mutations**
- **Environment (light, temperature, water)**
- **Crop load**
- **Nutrition**
- **PGRs**

Apple Skin Color Depends on Blends of Pigments

- Chlorophyll: in chloroplasts - green
- Carotenoids: in chloroplasts and chromoplasts - yellow, orange
- Anthocyanins: in vacuoles - red, purple, blue

As Apples Ripen

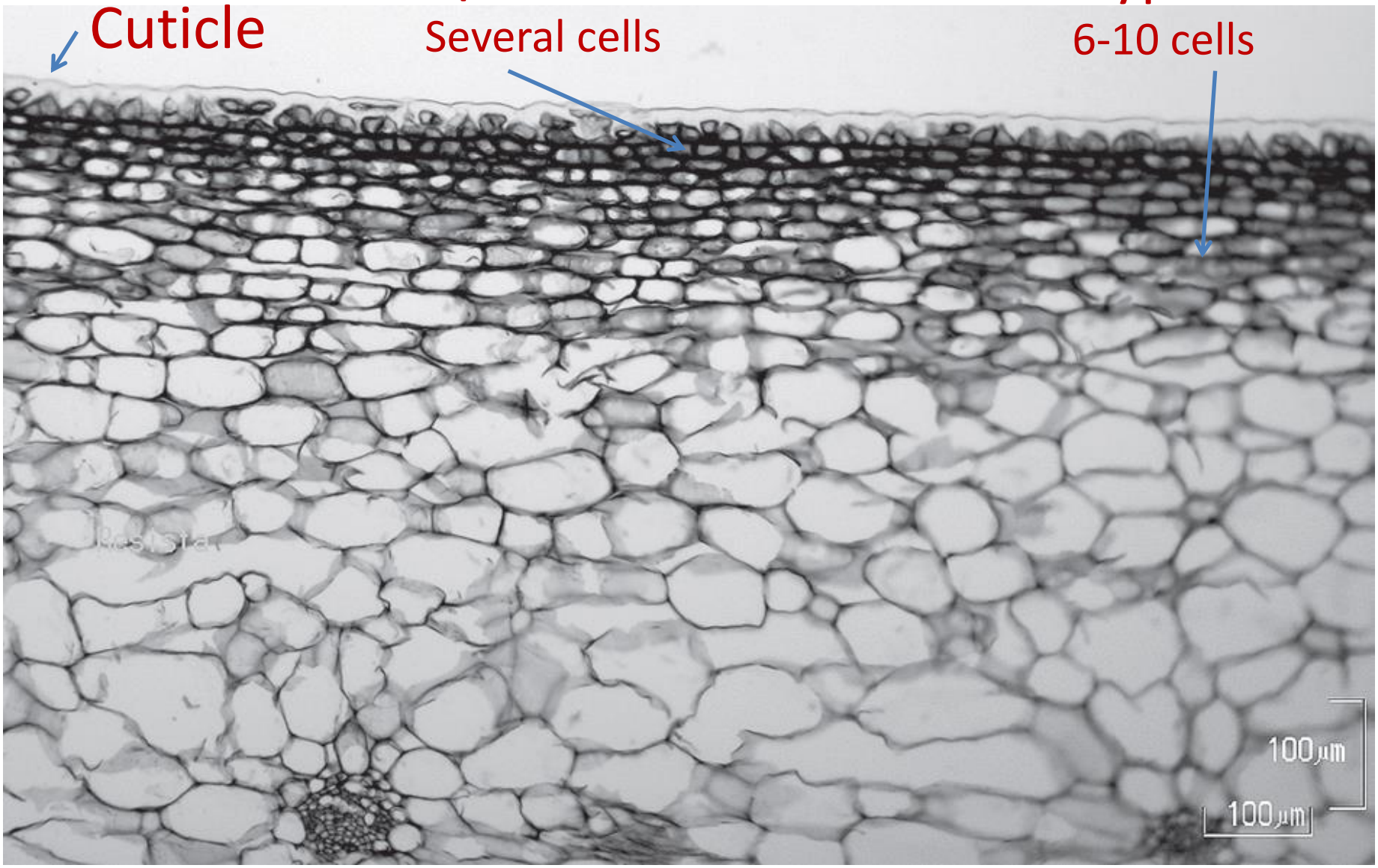
- Chlorophyll is degraded and carotenoids increase as chloroplasts transition to chromoplasts
- Anthocyanins increase up to 5-fold
- Under non-conducive conditions for anthocyanin development, anthocyanin may be destroyed and precursors shunted to other pathways



Schematic representation of the main structural changes occurring during the chloroplast to chromoplast transition.

Chromoplast in Red Pepper

Apple Peel cross-section



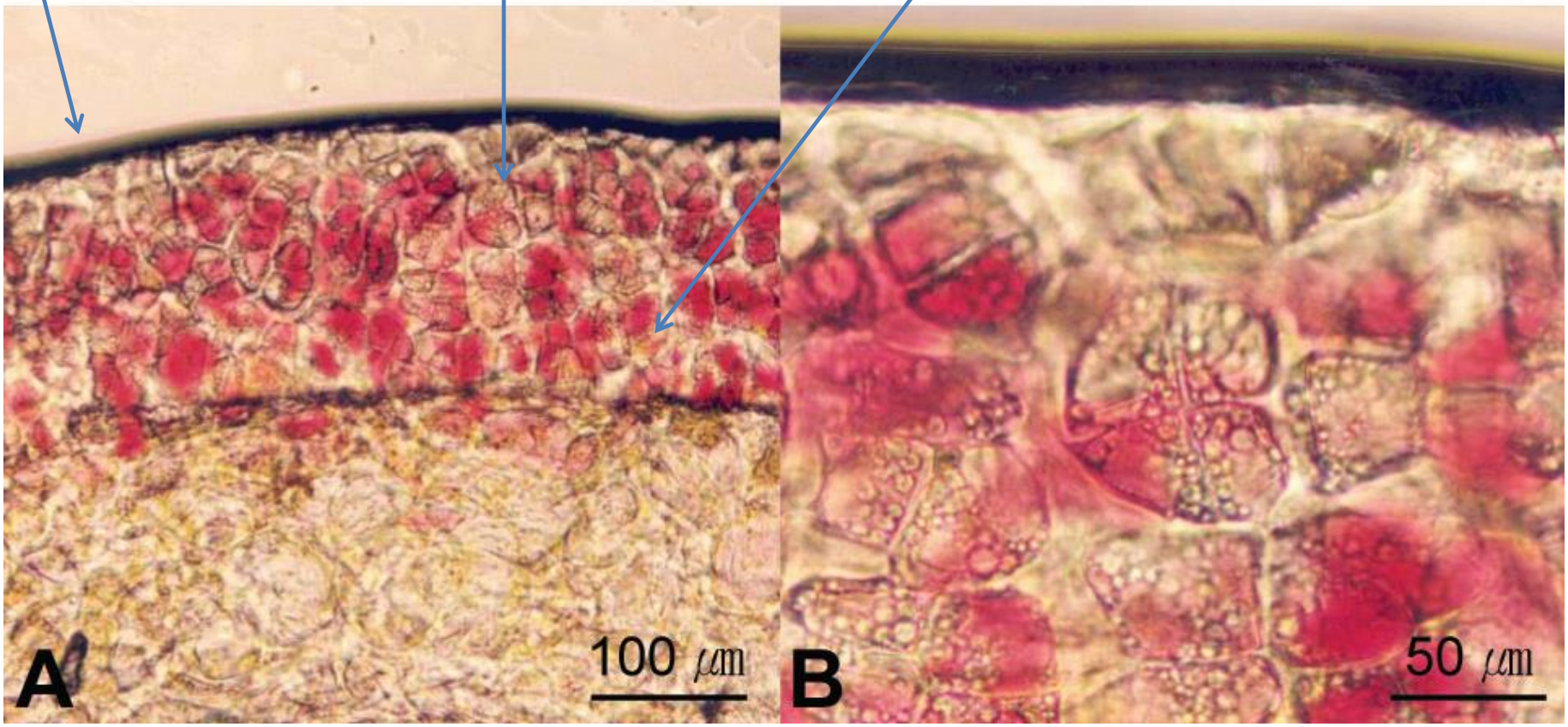
Cuticle

Epidermis

2 or 3 cell deep

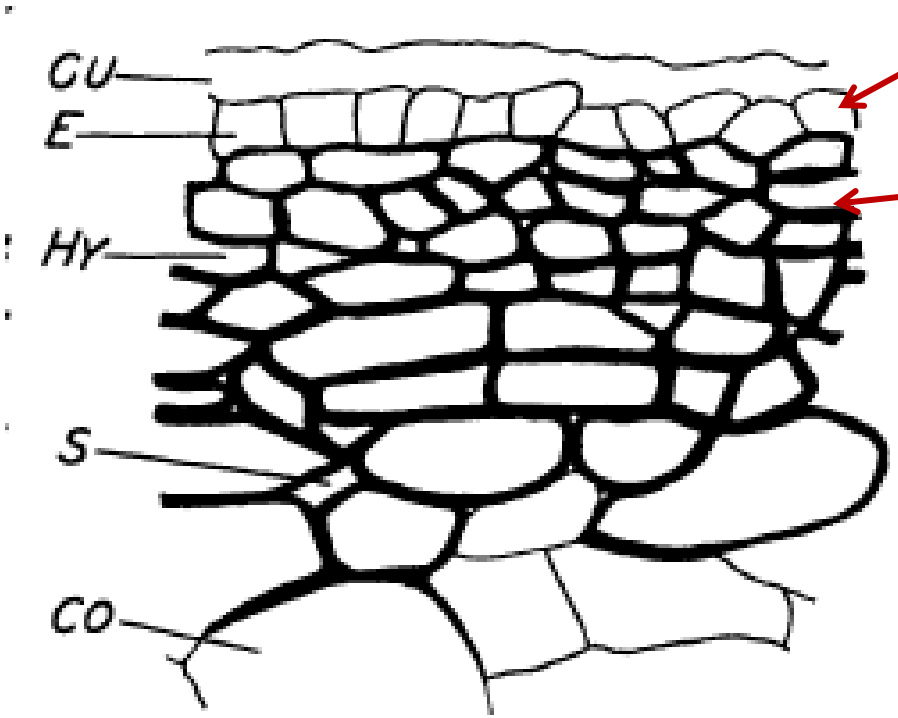
Hypodermis

6 – 10 cells deep



Red Color in apple skin

Redness depends on the proportion of epidermal and hypodermal cells containing anthocyanin



Epidermis - 2 or 3 cells deep

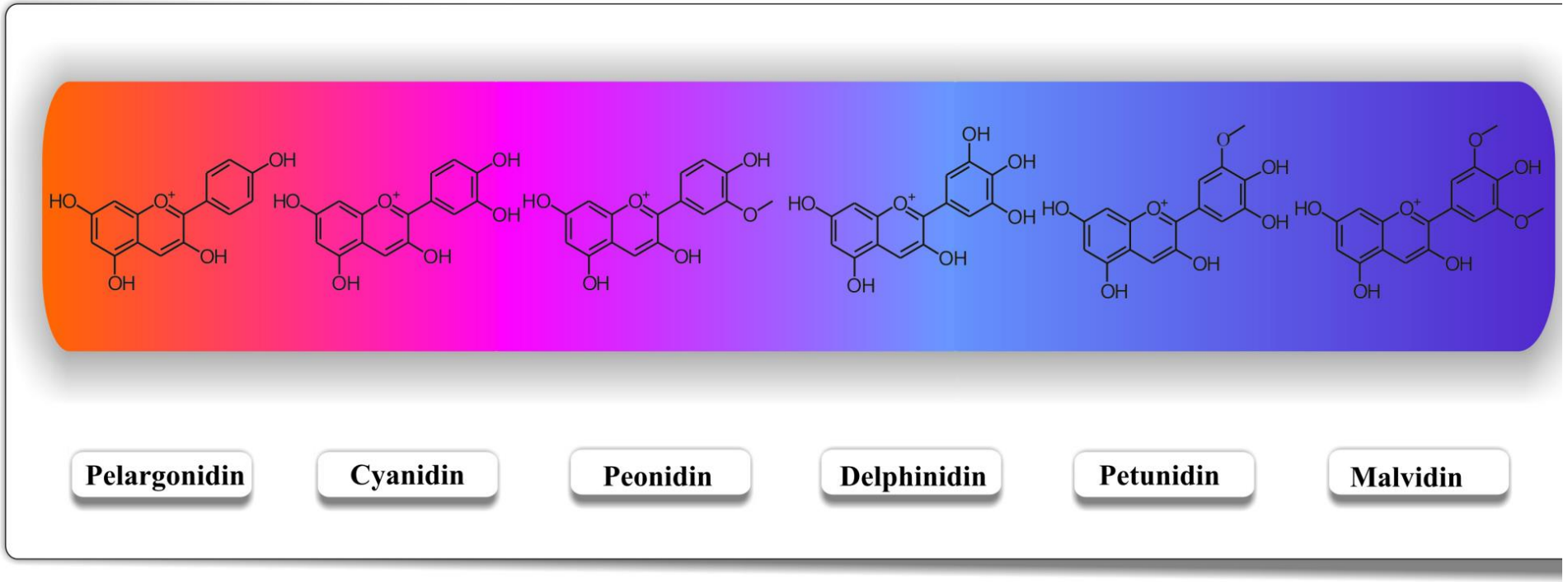
Hypodermis 6 – 10 cells deep
More on sun side of fruit

What are Anthocyanins

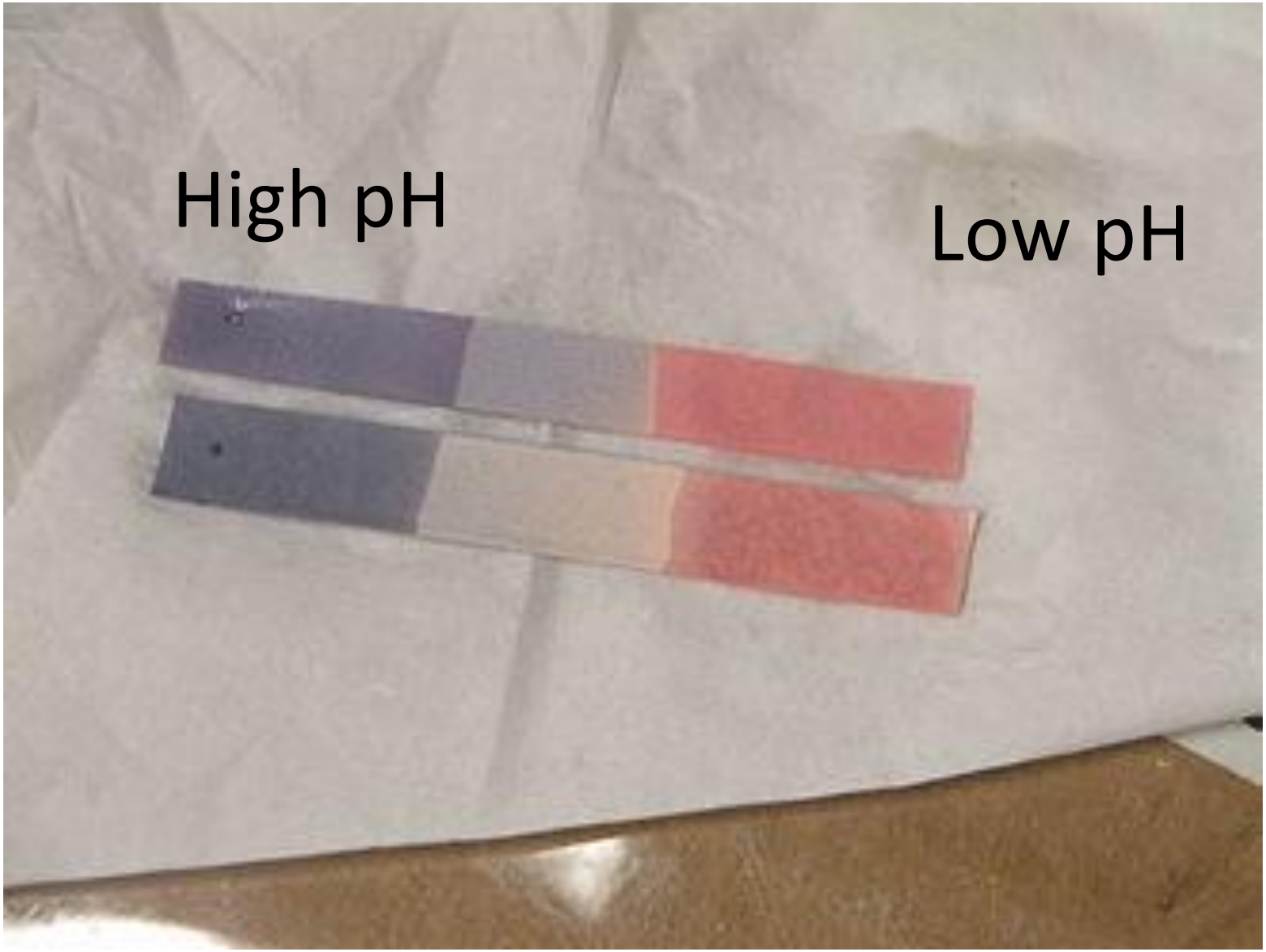
- Water soluble pigments in vacuoles of epidermal and hypodermal cells of apple skin
- Belong to a class of odorless molecules called flavonoids, taste moderately astringent
- They are antioxidants and may protect tissues from UV light and high temperatures
- Of the 6 common glycosides, cyanidin-3-galactoside
- Glycosides – organic molecules

containing sugar molecules

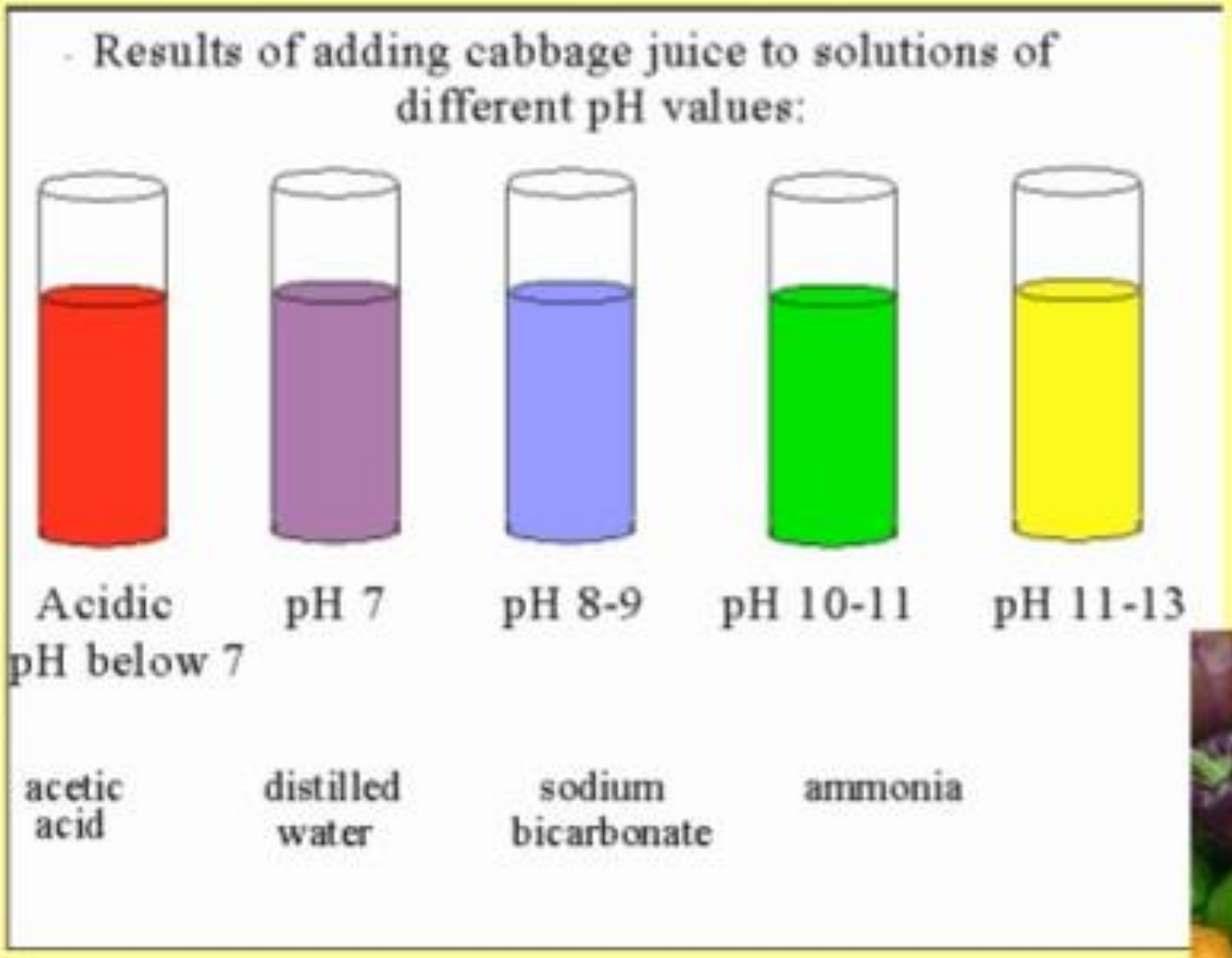
Anthocyanins vary in color



Anthocyanin is Like Litmus Paper



Anthocyanin at different pH



Hydrangia color and pH

A Family of Genes Control Anthocyanin Synthesis in Apple skin and Flesh

- MdMYB10 – controls red pigment in flesh, skin and foliage
- MdMYB1 and MdMYB17 – control red pigment in skin only
- MdMyB17 may repress anthocyanin
- MdMYB1 is induced by light
- Two variants (alleles, Rf & Bl) on a gene may be associated with striped vs. blush skin color patterns

Anthocyanin Biosynthesis

Phenylalanine

PAL-*MYB1* – Light & Temp, *MYB10*

Coumaryl-Co-A

CHS – *MYB1* - Light

Chalones

CHI – *MYB1* – Light & Temp.

Flavones

F3H – *MYB1* - Light

Dihydroflavonals

DFR - *MYB1* - Light

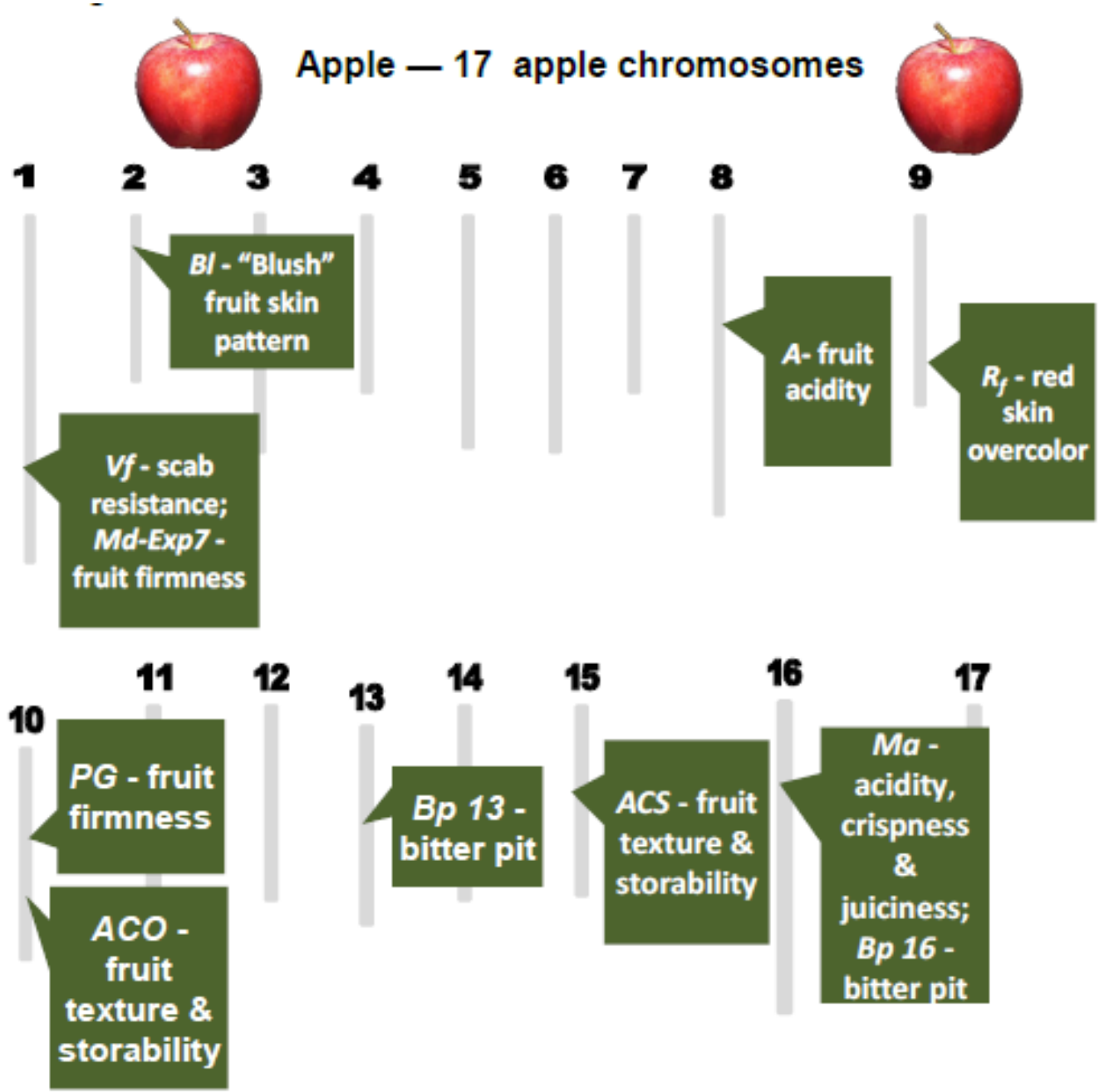
Leucoantocyanidins

LDOXv- *MYB1* – Light & temp

Anthocyanadins

Anthocyanins

UFGT – *MYB1* & *MYB10* – temp.



https://www.rosbreed.org/jewels-in-the-genome

Rf – Functional Genotypes

" PercOvrClr" = "% red / overcolor color of skin"

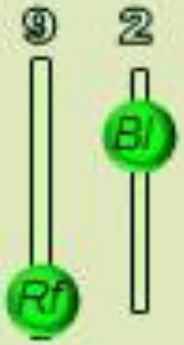
rfrf Golden Delicious, Granny Smith, Aurora Golden Gala

Rfrf Honeycrisp, Gala, Zestar, Pacific Rose, Braeburn, Pinova, McIntosh, Cripps Pink, Splendour, Cameo, Red Delicious

RfRf Jonathan, Jonamac, Empire, Scired

RosBREED

Enabling marker-assisted breeding in Rosaceae



Rf – Has a Friend

- Another locus, on LG2, is nicknamed the "blush" locus (*Bl*) because on its own it is associated with degree of blushiness vs. stripiness

blbl
is more often
← like this

BlBl
is more often
like this →

- But the "*Bl*" locus also interacts with *Rf* to influence apple skin blush amount (PercOvrClr) – blbl less blush than BlBl

This Explains Why . . .

- Some ‘Honeycrisp’ trees produce only blushed fruit, some produce only striped fruit, and some produce both types (controlled at genetic level).
- Proportion of striped fruit can vary with season (also effected by environment)
- Fruit in close proximity likely to be similar
- Sometimes fruit on same spur differ
- Striped areas of skin have higher activity of *MdMYB10* and *MdMYB17*

Factors Affecting Anthocyanin

- Fruit physiological stage
- Tree nutrition
- Environment
  - Light
  - Temperature
  - Water

Physiological Development

- Some cultivars lack ability to turn red –genetics
  - Some non-red cultivars can synthesize anthocyanin at maturity following bagging
- Stage influences genetic programing for color
- Two peaks of anthocyanin accumulation
  - During cell division – even in non-red cultivars
  - At fruit maturity for red cultivars

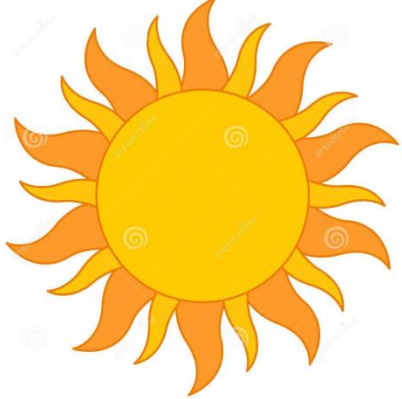
Red Delicious Fruit 40 DAFB

2’ into canopy

Periphery

Interior

Light



- Triggers genes involved in anthocyanin accumulation
- Sugars needed to convert anthocyanidins to anthocyanin
- Depends on stage of development - Mature ‘McIntosh’ require longer exposure than early harvest
- Critical level depends on cultivar and stage
- Blue-violet and UV are most important wavelengths

Enhancing Light

- Summer prune about 2 weeks before harvest
- Reflective mulch

Reflective Mulch on ‘Fuji in California

Effect of Debagging time on color development of ‘Golden Delicious’ and ‘Qinguan’ Apple. Jing et al. 2016.

- Bagged fruit at 45 DAB
- Bags removed at 90, 108, 122, 138, 145, 152,and 160 DAB
- Fruit were harvested on the day of debagging and on each of the other dates.

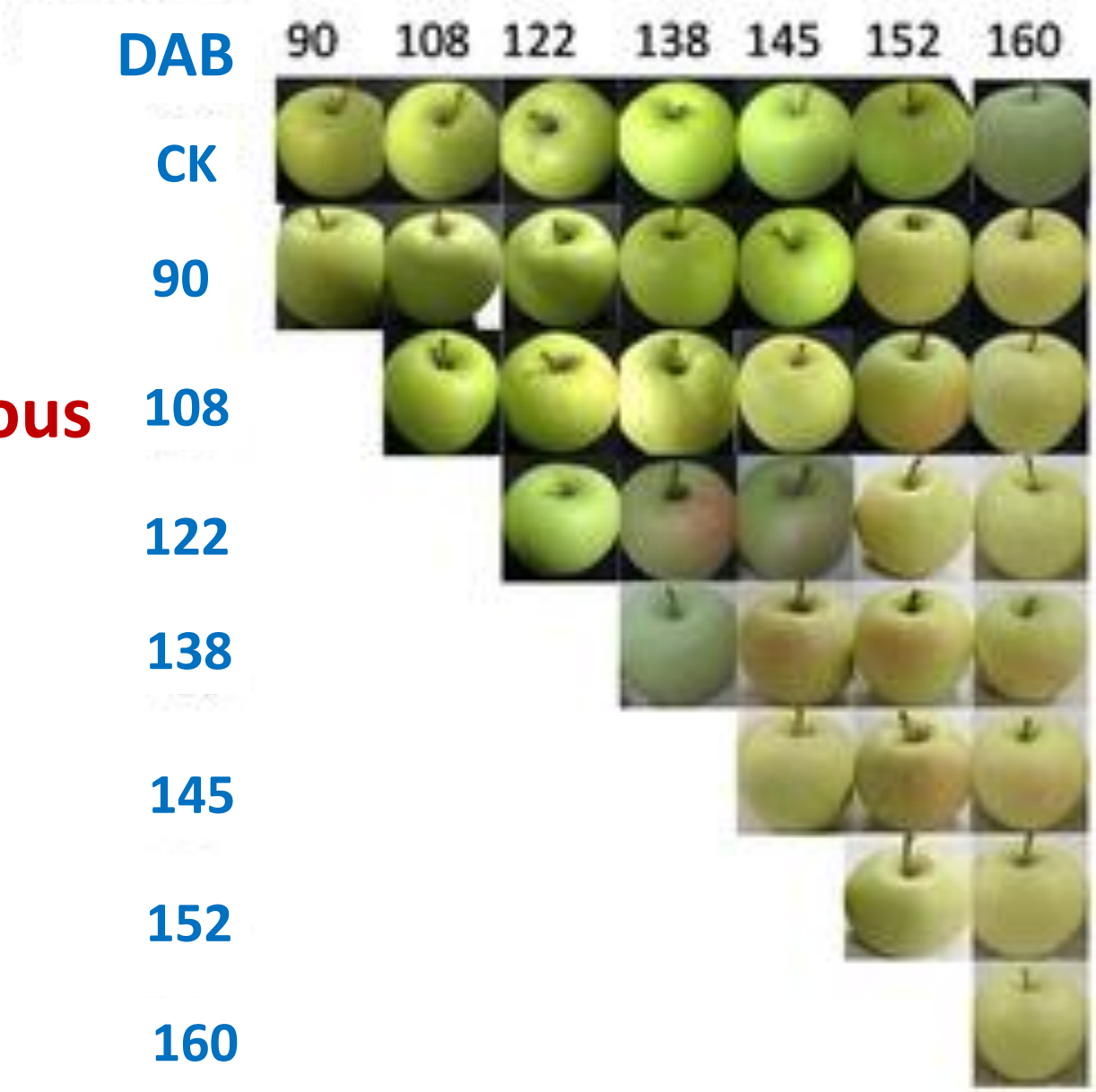
Fruit Bagging

- Outer layer of light-blocking paper (yellow)
- Inner layer of translucent colored paper (red or green)
- Apply after June-drop
- Remove outer bag 21-14 days before harvest
- Remove outer layer 4 to 7 days later
- Late debagging may cause soft
- fruit and superficial scald

Debagged

Date of Harvest

Golden Delicious

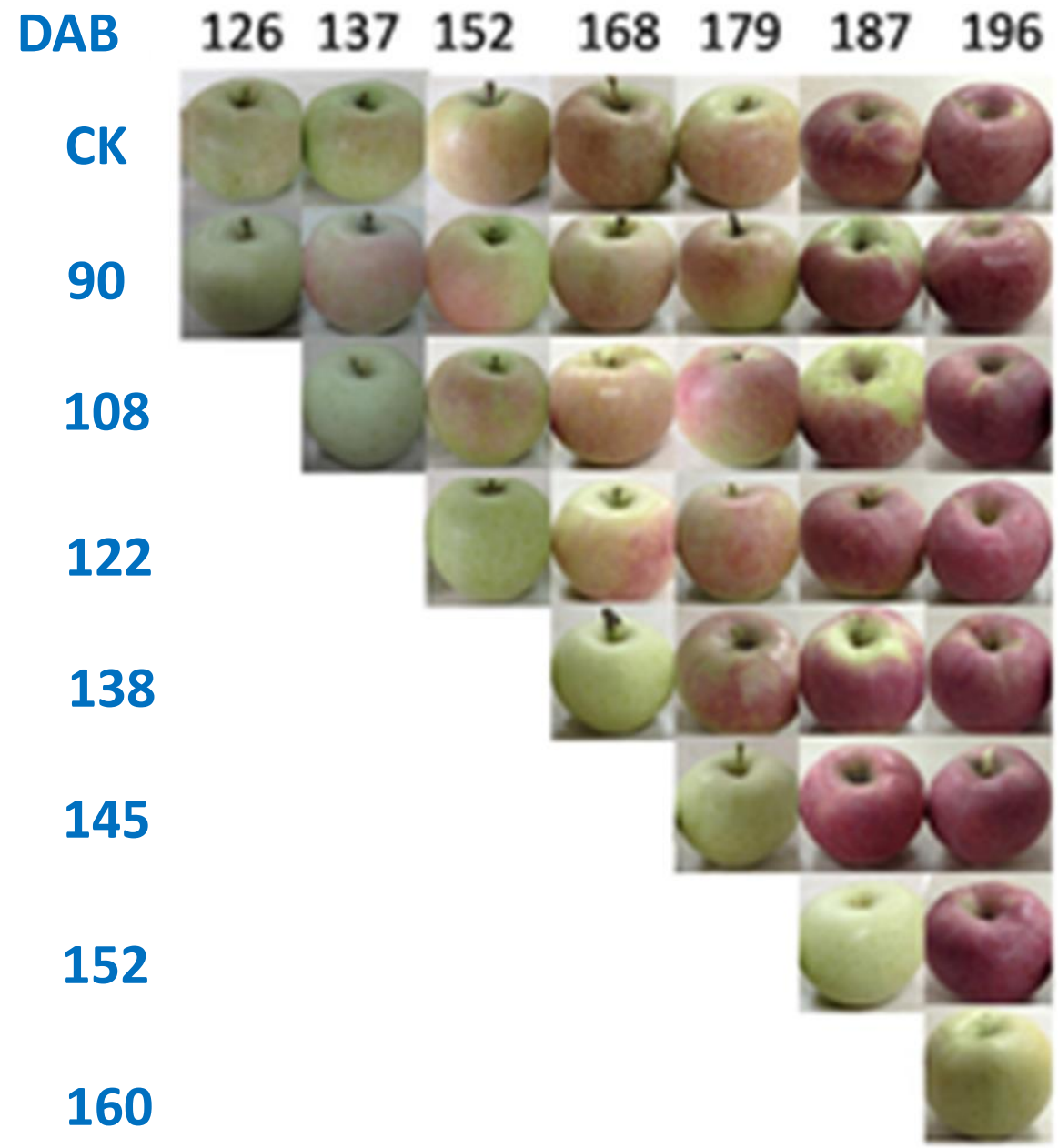


Jing et al. 2016

‘Qinguan’

Debagged

Date of Harvest



Low Temperature Promotes 3 Genes

- Optimum temp varies for cultivar and maturity
- Reduces respiration = high sugar
- Need 2 to 3 nights followed by warm days
- ‘McIntosh’ need temps below 70°
- Night temps more important than day temp
- ‘Red chief’ - 52° better than 72°
- One day at 89°negates several cool nights

‘Fuji’

- ‘Fuji’ best color at 64°
- Gene expression controlling PAL activity decreased within 24 hours after exposure to 93° but was less effective at later stage of ripening

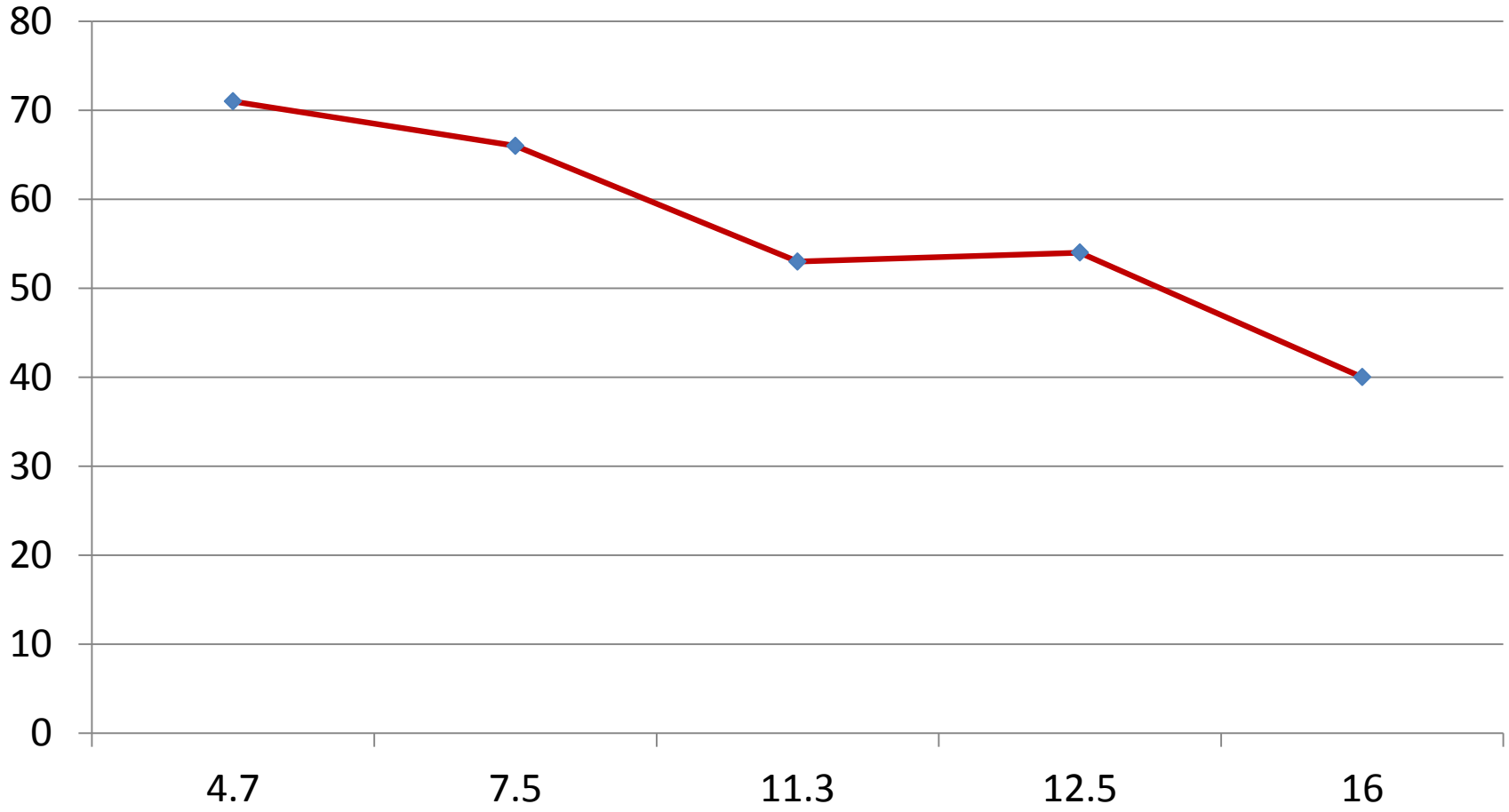
Orchard Nutrition

- Late-season high N inhibits anthocyanin accumulation , also increases shade
- High N causes precursors of anthocyanin to be converted to proteins rather than phenylalanine
- Deficient K inhibits anthocyanin accumulation, applications may partially compensate for high N
- Effect of other elements are inconsistent

High Leaf Nitrogen = Poor color

1.5% 2.4% 2.6% 3.0%

Crop Load Affect Honeycrisp Red Blush (%)



Other factors

- Water stressed trees develop poor color – low sugars, high temperatures
- Wounding increases color, due to ethylene
- Detached fruit color better than on tree
- Some evidence that fruit on dwarf rootstocks color better, not totally due to light

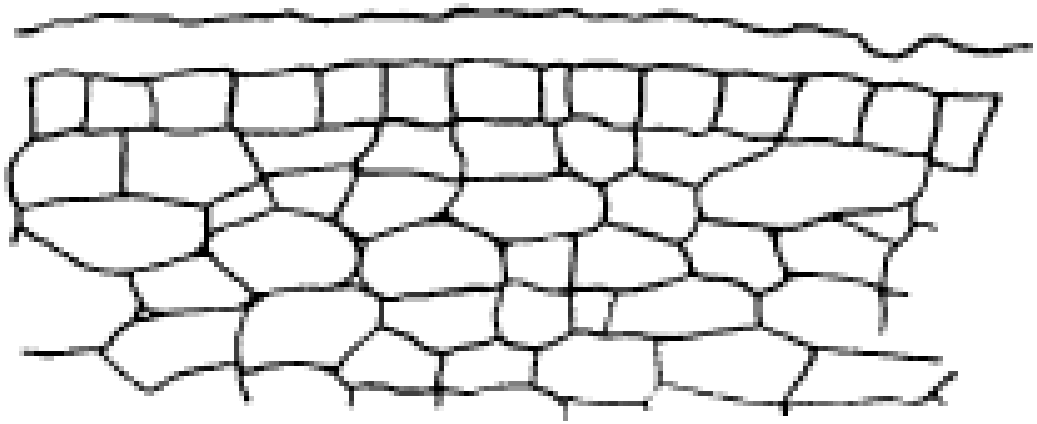
Plant Growth Regulators

- Alar – no longer available
- Ethrel – advances maturity
- Apogee – suppresses shoot growth
- Harvista (MCP) – May delays color
- ReTain – May delay color

Questions?

Anthocyanins

- A type of flavonoid and is an antioxidant
- In apple the primary anthocyanin is cyanidin 3-galactoside
- Flavones and flavonols are flavonoids that are invisible to humans – may protect tissues from UV-B radiation and attract insects.
- Develop in the epidermal and hypodermal cells
- Redness depends on proportion of cells and cell layers with anthocyanin



McIntosh apple skin development
Epidermis + Hypodermis