The New Zealand Institute for Plant & Food Research Limited

# Fresher by Sea:
# The secret postharvest life of tomatoes

TomatoesNZ (incl T&G Covered Crops, NZ Hothouse), Vegetables New Zealand Ltd, & PFR

4 days (assembly) + 11 days (sea) + 2-3 days (arrival) + ? (retail/consumer)

New Zealand

Japan

# Fresher by Sea

- To support the development of sea-freight protocols for capsicums and tomatoes bound for Asia/Pacific markets, by:
  - summarizing the biological, technical and logistical requirements of tomatoes and capsicums sea-freighted to potential markets in Asia/Pacific region - *including the most recent relevant research and experiences of grower exporters*
  - Identifying knowledge gaps and areas of concern/risk and testing these in meaningful practical trials
  - development of suitable postharvest systems and practical guidelines
  - communication of progress and results

# Biology of ripening affects postharvest quality

- Normal ripening events
- Biological features influencing storage quality
- Postharvest technologies to extend storage quality

By Taken byfir0002 | flagstaffotos.com.auCanon 20D + Sigma 150mm f/2.8 - Own work, GFDL 1.2, https://commons.wikimedia.org/w/index.php?curid=2038647

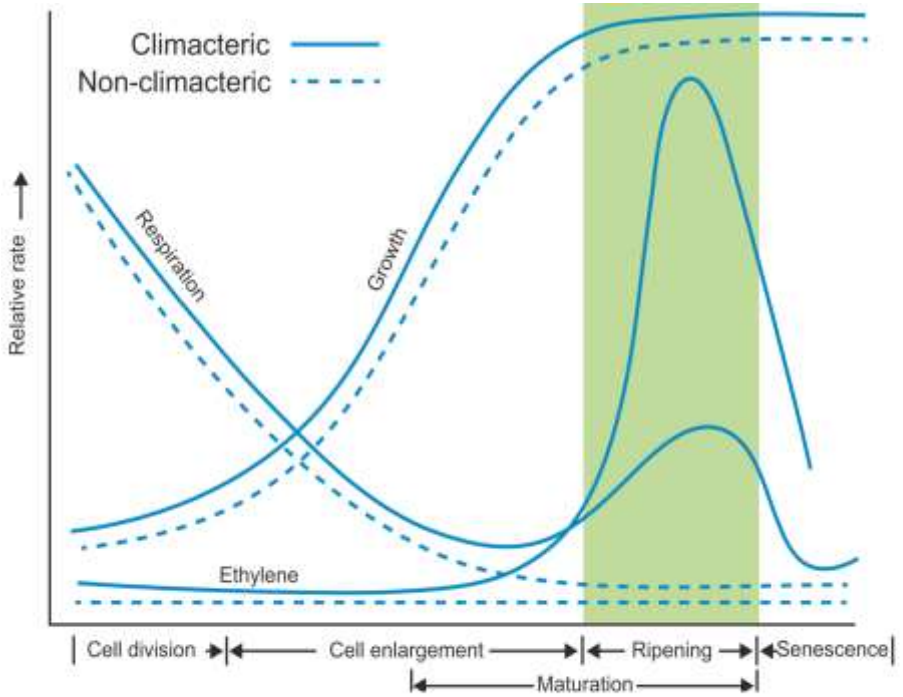


**Figure 1.1. Patterns of growth, respiration and ethylene production during fruit development.**

**Redrawn from Paul et al. (2012).**

# Colour

# Flavour


# Softening

http://www.news.cornell.edu/sites/chronicle.cornell/files/RipeTomato.jpg

# Biological factors that influence postharvest storage

- Its in the DNA (or, maybe its what ISN'T in the DNA)
- Low temperature intolerance ☹

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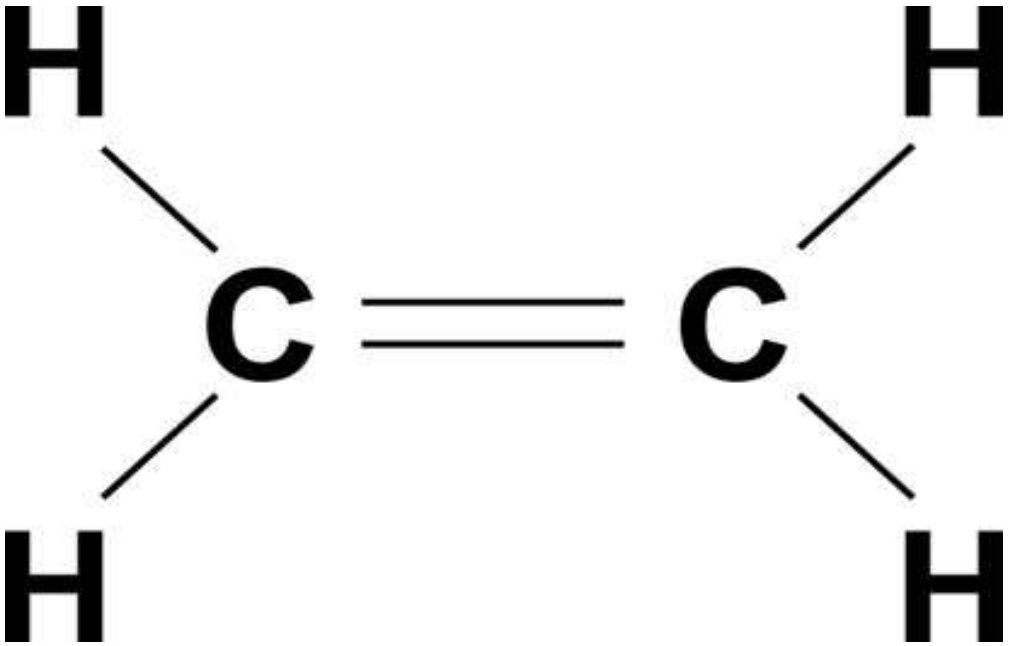
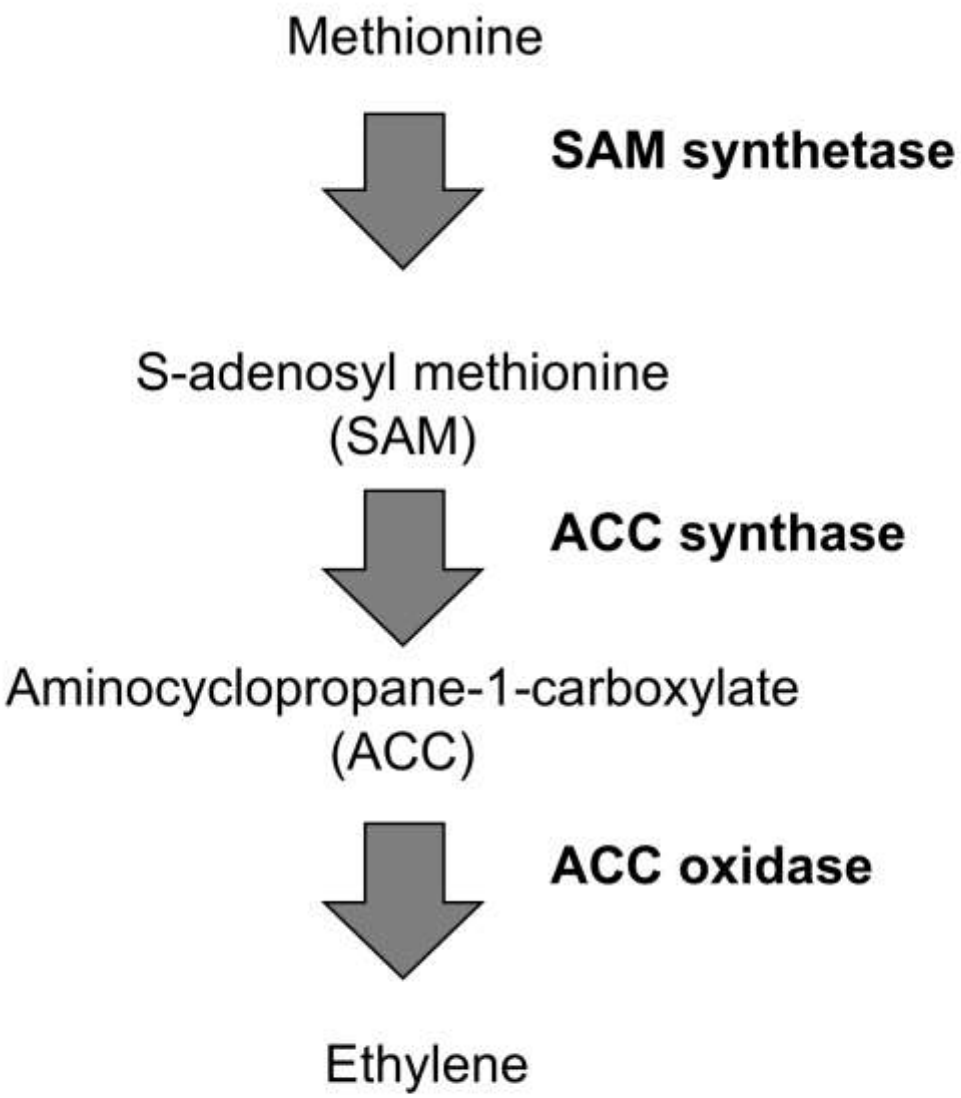
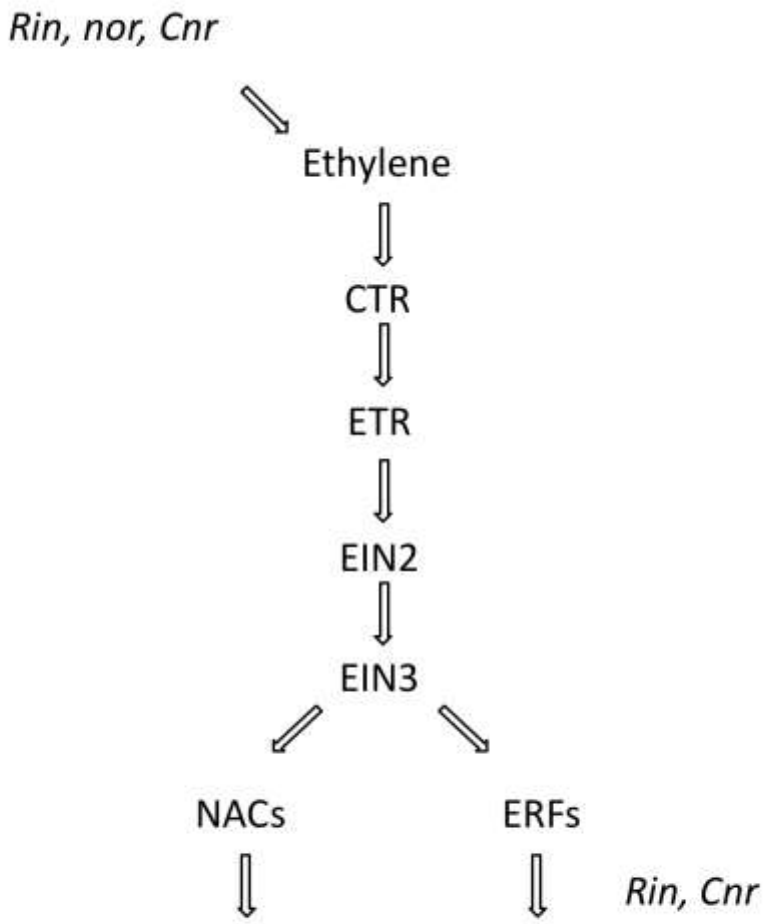



Colourless, odourless, tasteless…..

# Controlling ethylene synthesis



# Controlling the effect of ethylene




Ripening-related genes, e.g,
Polygalacturonase
Phytoene synthase

http://image.slidesharecdn.com/dioooperdomestication-160516134014/95/dio-oper-domestication-19-638.jpg?cb=1465406094

*Solanum lycopersicum*

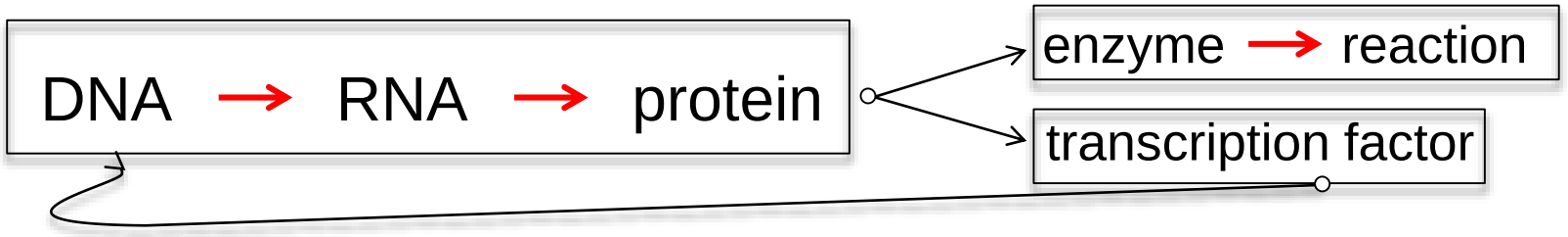
formerly
*Lycopersicon esculentum*

*Solanum pimpinellifolium*

'Original' tomato

- Domestication has resulted in a range of fruit sizes, locule number, disease resistance, shape, colour…
- These have arisen through natural breeding

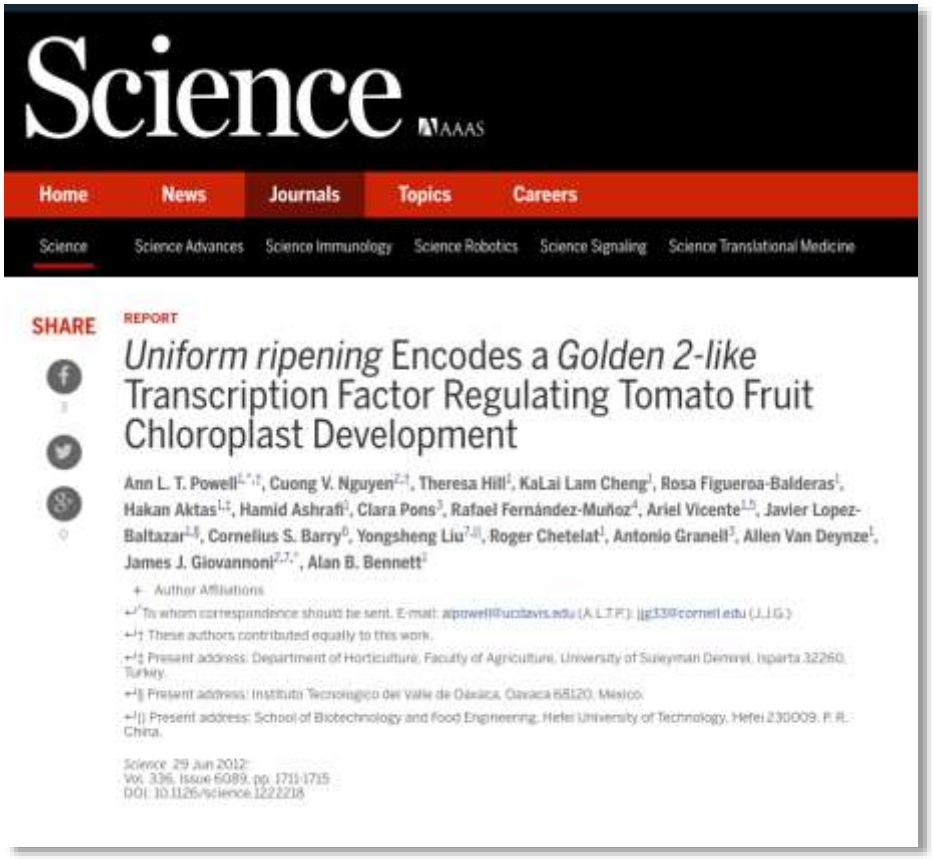
# Gene mutations




- Often arises naturally, through uncorrected errors during crossing, but can also arise on purpose through mutation breeding.
- Most mutations don't result in a phenotype.
- A mutation may not create a phenotype until it becomes homozygous through selfing.
- Consequences depend on what protein is affected; enzyme or transcription factor.
- Originally identified visually through effect on plant/fruit or through screening.
- Better information once mutation is linked to specific gene & function.

# Why don’t these tomatoes taste any good?

- Its all ‘*u*’s fault…. well some of it is
- *u*: uniform ripening locus – mutation affects a gene involved in chloroplast number and function



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REPORT

*Uniform ripening* Encodes a *Golden 2-like* Transcription Factor Regulating Tomato Fruit Chloroplast Development

Ann L. T. Powell[1,*,†], Cuong V. Nguyen[2,†], Theresa Hill[1], KaLai Lam Cheng[1], Rosa Figueroa-Balderas[1], Hakan Aktas[1,‡], Hamid Ashrafi[1], Clara Pons[3], Rafael Fernández-Muñoz[4], Ariel Vicente[1,5], Javier Lopez-Baltazar[1,§], Cornelius S. Barry[6], Yongsheng Liu[7,||], Roger Chetelat[1], Antonio Granell[3], Allen Van Deynze[1], James J. Giovannoni[2,7,*], Alan B. Bennett[1]

+ Author Affiliations

↵* To whom correspondence should be sent. E-mail: alpowell@ucdavis.edu (A.L.T.P.); jjg33@cornell.edu (J.J.G.)

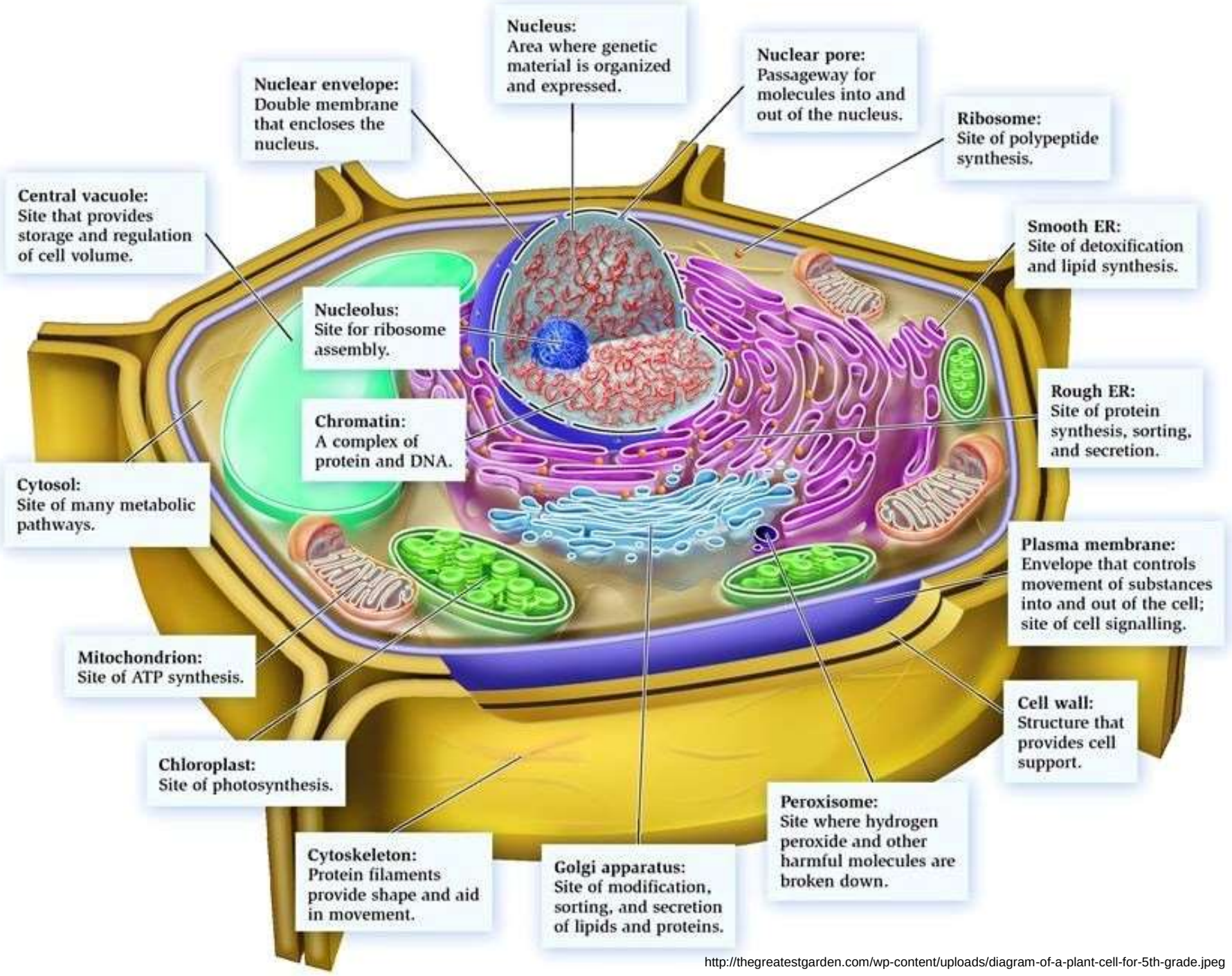
↵† These authors contributed equally to this work.

↵‡ Present address: Department of Horticulture, Faculty of Agriculture, University of Suleyman Demirel, Isparta 32260, Turkey.

↵§ Present address: Instituto Tecnologico del Valle de Oaxaca, Oaxaca 68120, Mexico.

↵|| Present address: School of Biotechnology and Food Engineering, Hefei University of Technology, Hefei 230009, P. R. China.

*Science* 29 Jun 2012:
Vol. 336, Issue 6089, pp. 1711-1715
DOI: 10.1126/science.1222218




http://thegreatestgarden.com/wp-content/uploads/diagram-of-a-plant-cell-for-5th-grade.jpeg

# Why don’t these tomatoes taste any good…

- Its all ‘*u*’s fault…. well some of it is
- *u*: affects a gene involved in chloroplast number and function
- mutation results in uniform but paler colour, and less sugar accumulation.

## Pretty or Sweet

The grocery-store tomato that looks beautiful but tastes like tart cardboard arises from selection processes favoring phenotypes that make commercial production more reliable. Significant in that selection process was a mutation that reduced the mottled color variations of unripe green tomatoes, leaving them a uniform, pale, green. **Powell *et al.*** (p. 1711) analyzed the molecular biology of the mutation. The *uniform ripening* mutation turns out to disable a transcription factor called *Golden 2-like* (*GLK2*). *GLK2* expression increases the fruit's photosynthetic capacity, resulting in higher sugar content.

**Ann L. T. Powell et al. Science 2012;336:1711-1715**

# Natural mutants with impaired ripening are the workhorses of commercial tomatoes

| Name | Phenotype | Gene |
|---|---|---|
| ***Ripening inhibitor* (*rin*)** | Fruit do not ripen fully. They yellow and soften very slowly. No climacteric rise in respiration or ethylene. Fruit lack flavour and pro-vitamin A and have long storability. | MADS box transcription factor[1] |
| ***Nonripening* (*nor*)** | Final fruit colour is pale orange. Does not ripen fully (similar to *rin*). | 2 bp deletion in NAC[9] |
| ***Never-ripe* *Nr*)** | Ripe fruit are orange. Synthesis of lycopene and polygalacturonase reduced. Fruit store a long time. | Single amino acid change in Ethylene receptor[10,11] |
| ***Colourless nonripening (Cnr)*** | Yellow fruit with a substantial loss in cell-to-cell adhesion resulting in mealy pericarp. Ripening-related carotenoid synthesis absent. | SBP-box transcription factor[6] |
| ***Delayed fruit deterioration (dfd)*** | Very thick skin and reduced water loss | Unknown |
| ***High pigment1 (hp-1)*** | Dark green immature fruits due to overproduction of chlorophyll | DDB1 (UV-damaged binding protein 1) |
| ***High pigment2 (hp-2)*** | Identical to *hp-1* | Deetiolated1 (DET1) ortholog, nuclear localized protein[2] |
| ***Green-ripe* (*Gr*)** | Reduced ethylene response. | Deletion in promoter causing ectopic expression of ethylene receptor protein interactor?[4] |
| ***Never-ripe2 (Nr-2)*** | Allelic to *Gr* | Ethylene receptor protein interactor[4] |
| ***Green flesh* (*gf*)** | Ripe fruit are red-brown because chlorophyll not totally degraded. Fruit otherwise ripen normally. | Staygreen (SGR) ortholog[3] |
| ***Yellow flesh (r)*** | Ripe fruit are yellow because lycopene is not produced. Fruit otherwise ripen normally. | Phytoene synthase[7] |
| ***Uniform ripening* (*u*)** | Pale green fruit, dark green shoulder of fruit not present | Golden 2-like transcription factor[5] |
| ***Alcobaca (alc)*** | *In planta* ripened fruit are pale red. Flavour almost normal but longer shelf life attributed to reduced polygalacturonase activity. Lycopene synthesis inhibited. Fruit picked mature green only ripen to yellow colour. | Valine to aspartic acid amino acid change at position 106 of NOR[8] |
| ***Long keeper*** | Fruit ripen to a golden orange red colour. Polygalacturonase activity, softening and carotenoid content is reduced and fruit store well | |

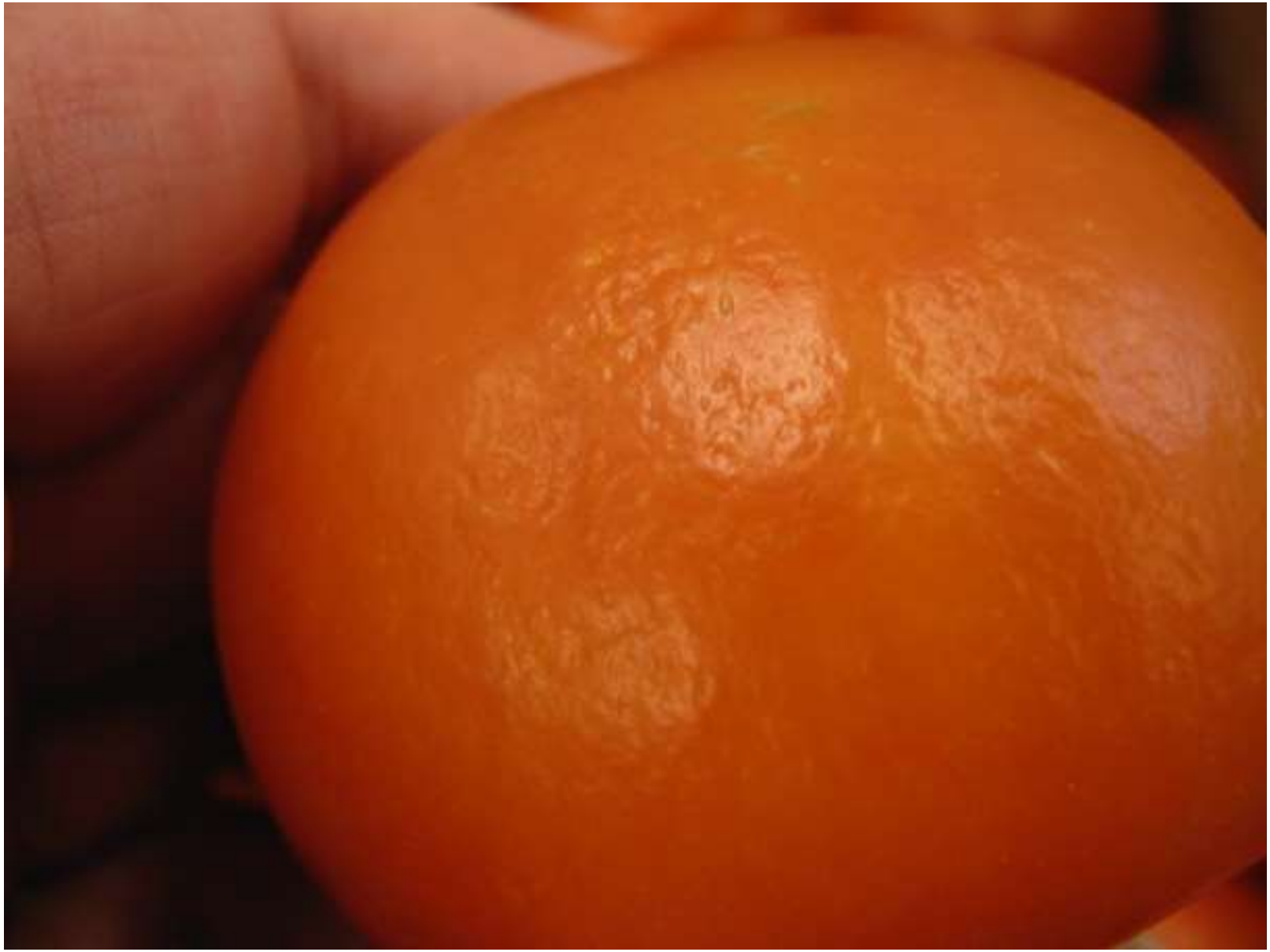
*rin*: gene controls ethylene dependent and independent aspects of ripening. Mutation results in fruit that do not ripen. Heterozygous in commercial lines, so have extended shelf-life but do ripen somewhat.

*nor/alcobaca*: same transcription factor gene mutated but different outcomes – non-ripening to delayed ripening. Affects the coordination of events downstream of ripening climacteric – fruit seem to act like they are non-climacteric (so ripen well on-plant).

# Specialty lines are the same but different….

- Grape and cherry lines carry the *rin* mutation
- May carry the *nor* mutation as well
- Better picked at ripe – to take advantage of the greater accumulation of sugar
- Brix levels are critical for customer
- Ethylene management not so critical

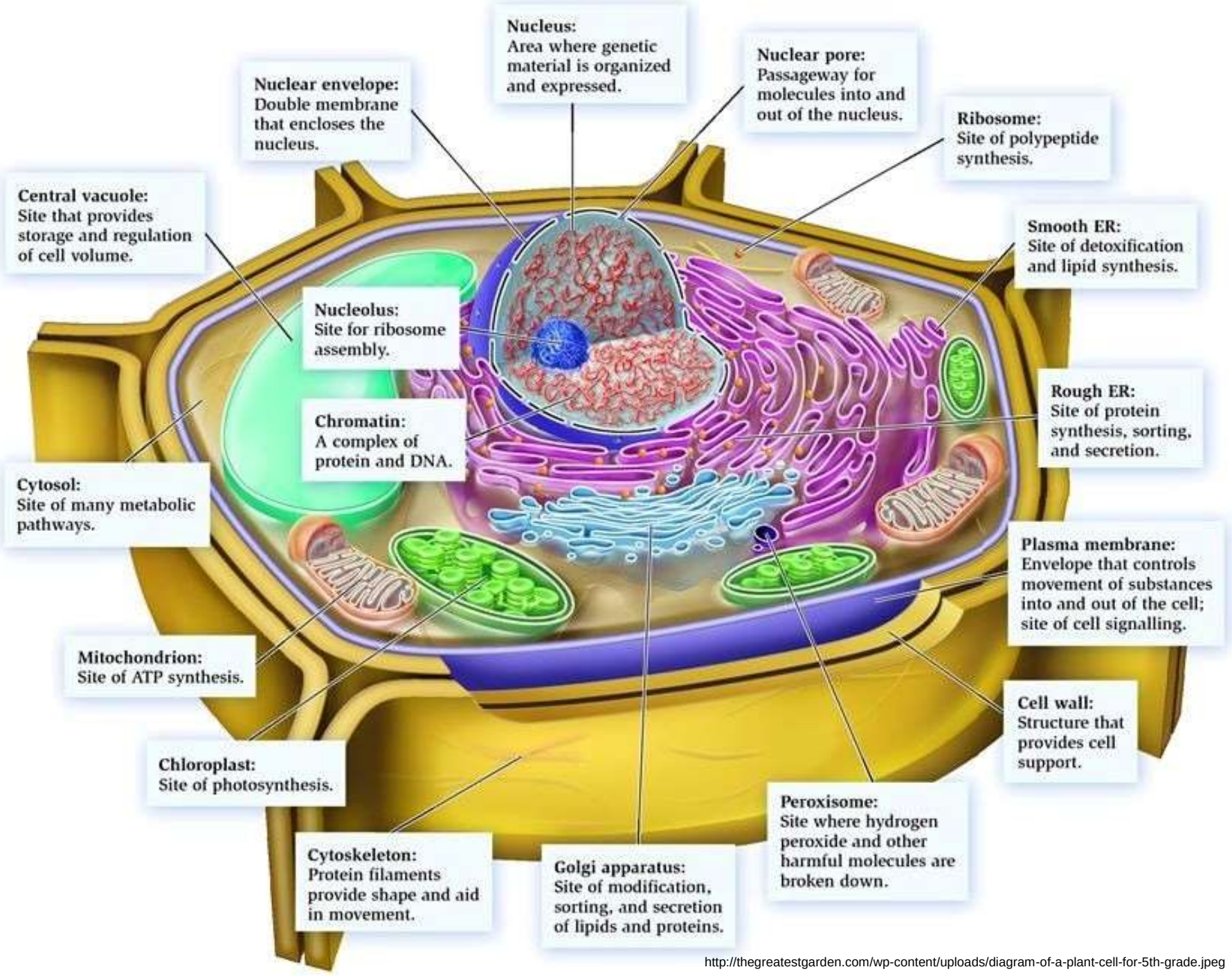
http://www.specialtyproduce.com/produce/sppics/1275.png



for Plant & Food Research Limited

# Tomatoes are susceptible to chilling injury

- Due to damage to cell membranes.
- Can’t reverse chilling damage – can accumulate with increased exposure.
- Damage not always obvious during storage but revealed as stored fruit warm up.
- Maturity dependent – unripe fruit more susceptible.
- Cultivar variation (but probably not on purpose!).
- Temperature can’t be the sole means of slowing metabolism during storage.

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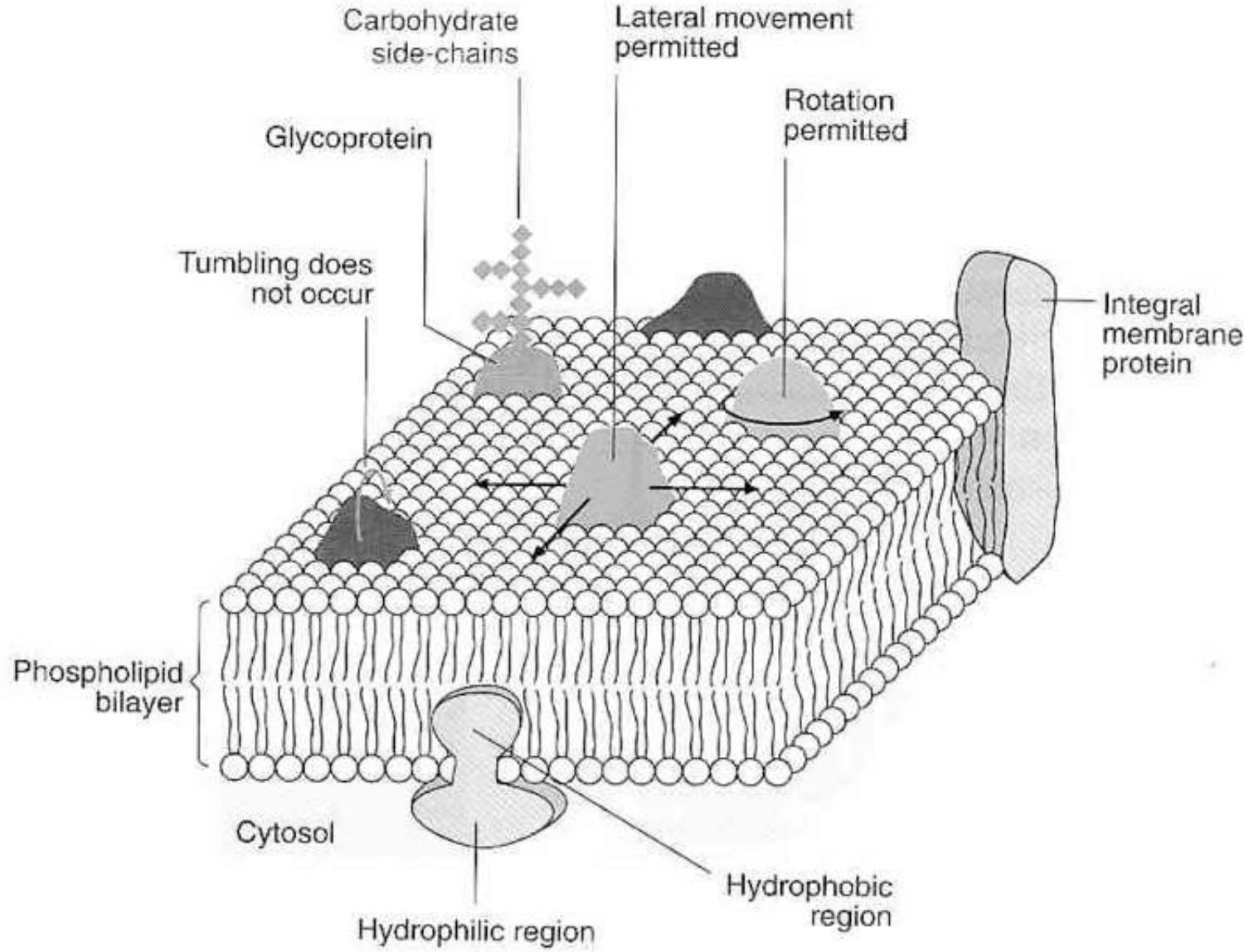
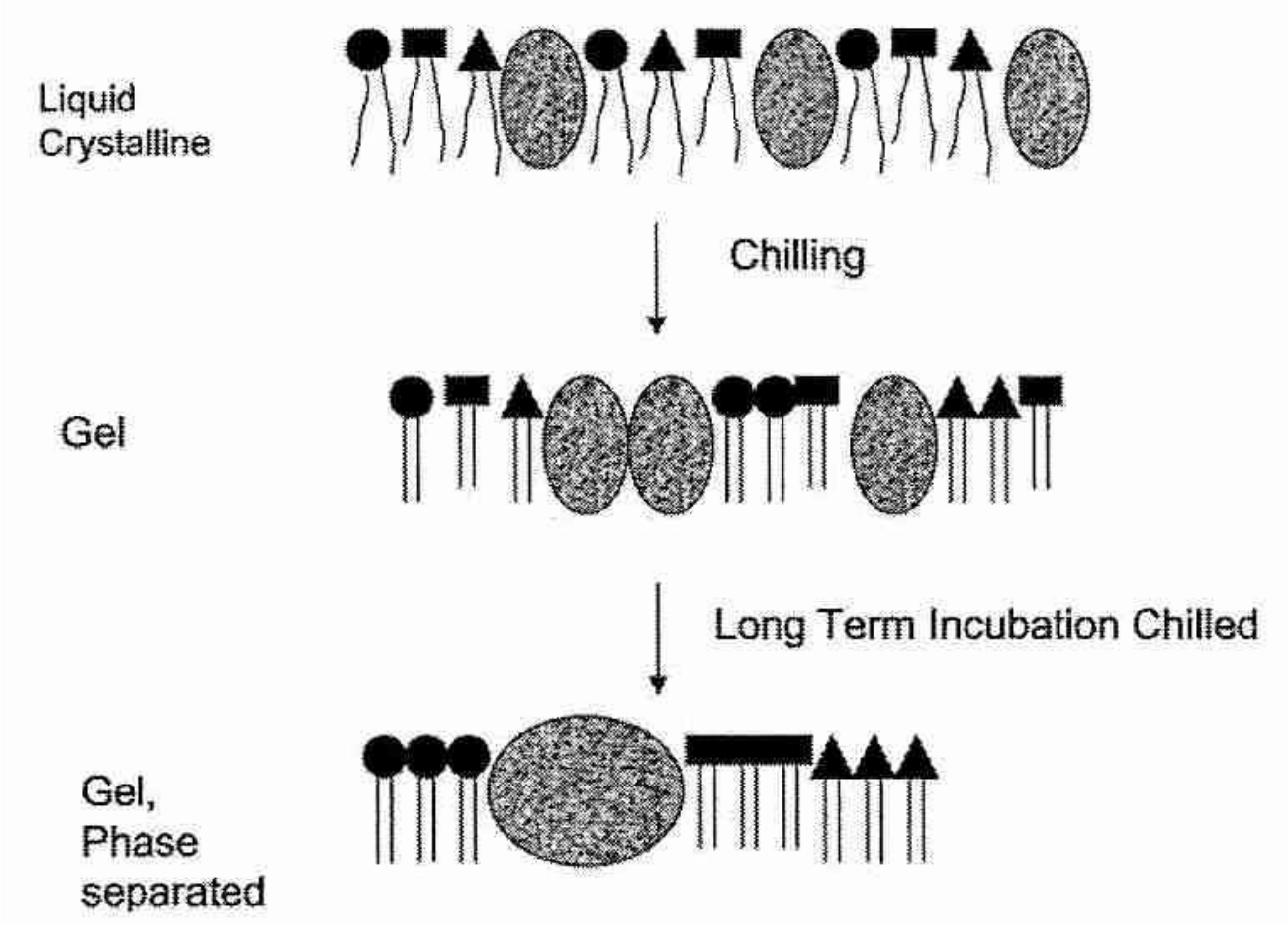



http://www.benbest.com/cryonics/Bilayer.jpg

# Low temperature intolerance




http://www.benbest.com/cryonics/rafts.jpg

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# Postharvest technologies to extend storage

- Manage ethylene, manage ripening….(but not for all tomatoes)
- Temperature …. (need to find the best one for the job)

- Heat shock
- UV-C

- Controlled atmosphere?
- Methyl salicylate, methyl jasmonate?

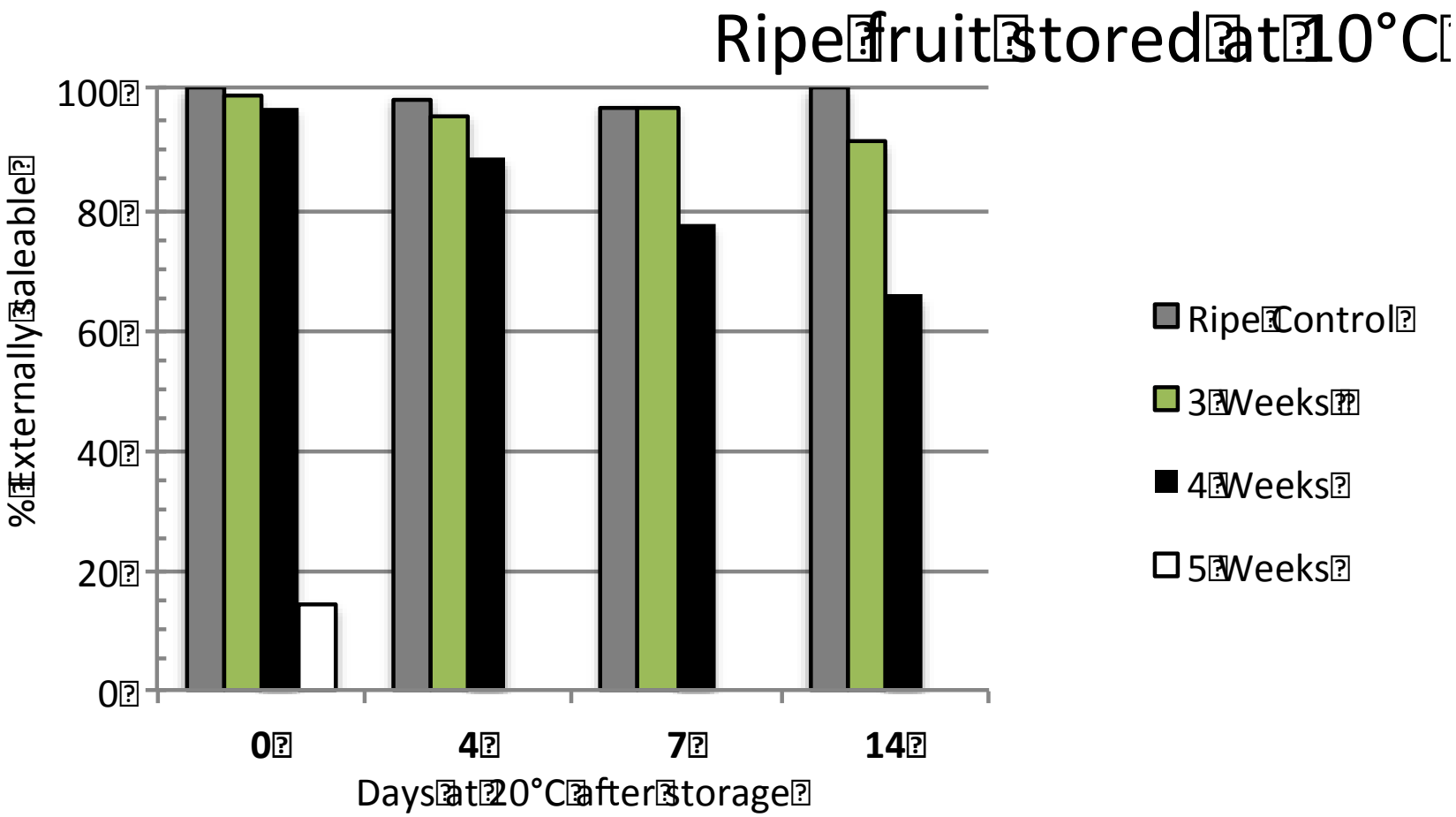
http://www.profitableplantsdigest.com/wp-content/uploads/2013/12/HeirloomTomato_opt-.jpg

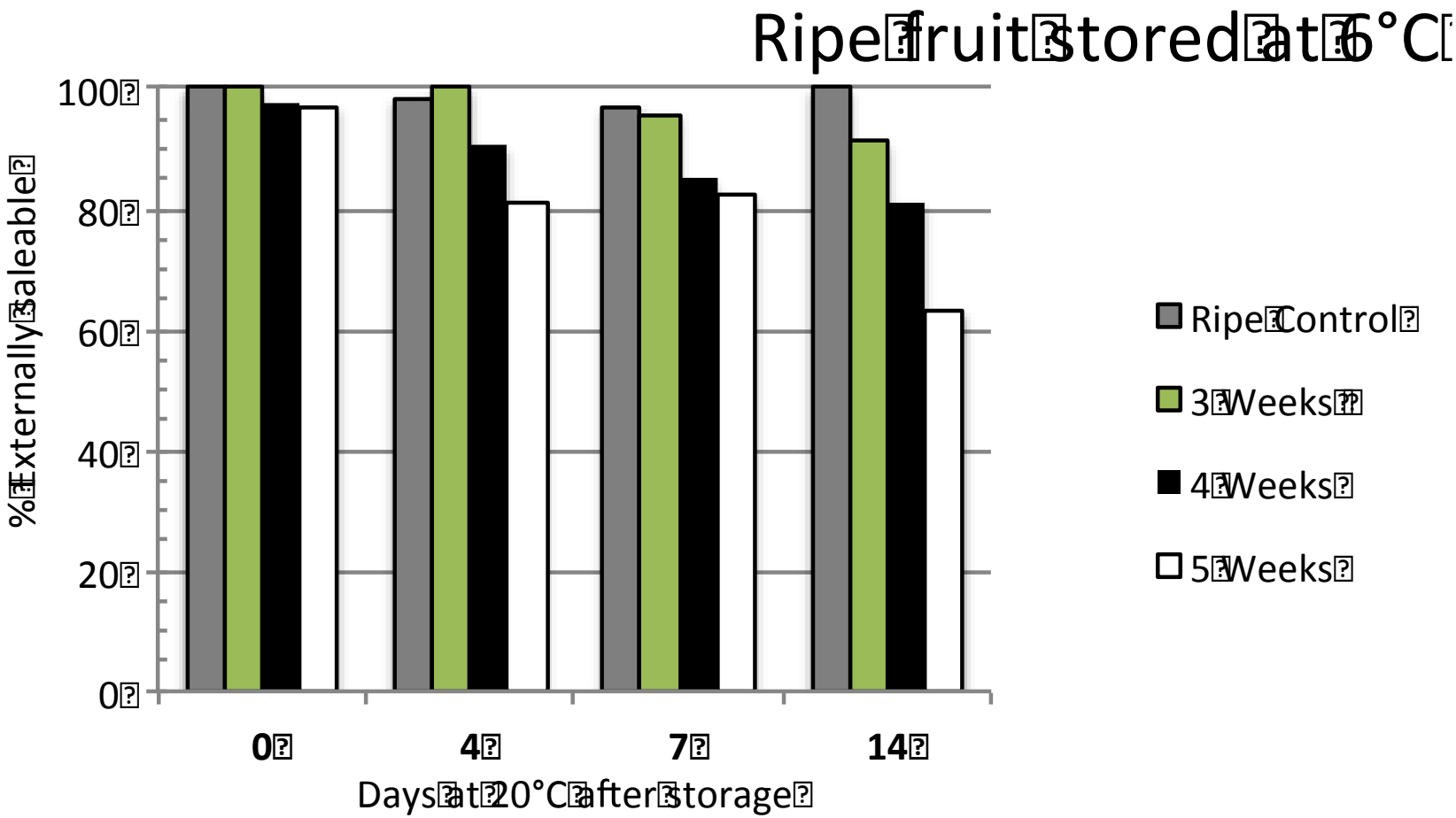
# Specialty line storage: maintaining quality AND delivering Brix

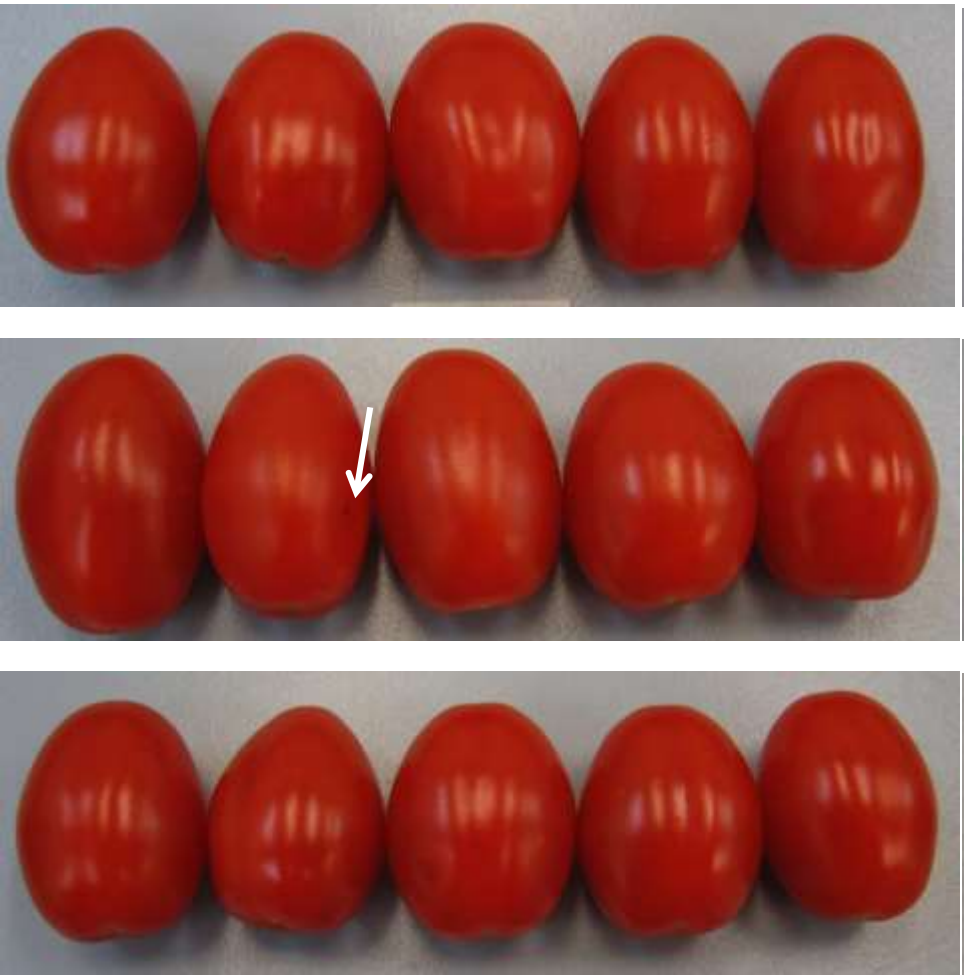

# Grape-type specialty tomatoes

- Pick ripe.
- °Brix declines during storage.
- Can last 3 weeks with extra days of shelf life.
- More robust than standard tomatoes but not bullet-proof.

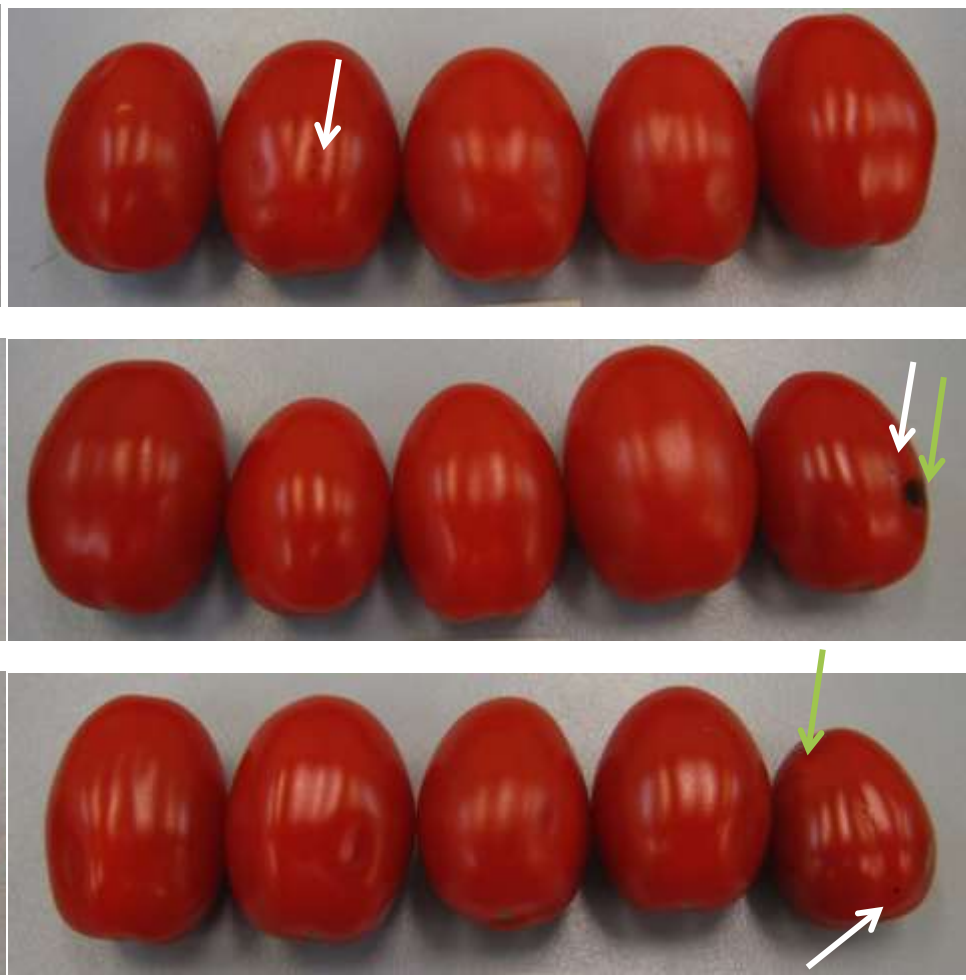
http://www.specialtyproduce.com/produce/sppics/1275.png


Ripe fruit stored at 10°C
% Externally saleable
100
80
60
40
20
0
0
4
7
14
Days at 20°C after storage
Ripe Control
3 Weeks
4 Weeks
5 Weeks


Ripe fruit stored at 6°C
% Externally saleable
100
80
60
40
20
0
0
4
7
14
Days at 20°C after storage
Ripe Control
3 Weeks
4 Weeks
5 Weeks



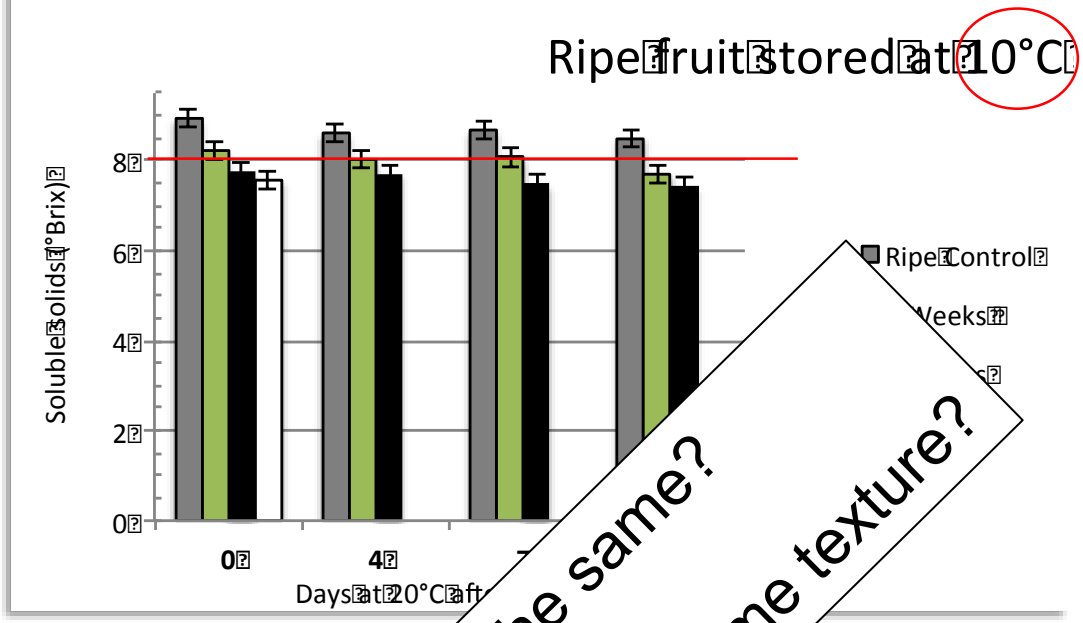
Ripe, 6°C 3 weeks + Day 4



Ripe, 10°C 3 weeks + Day 4

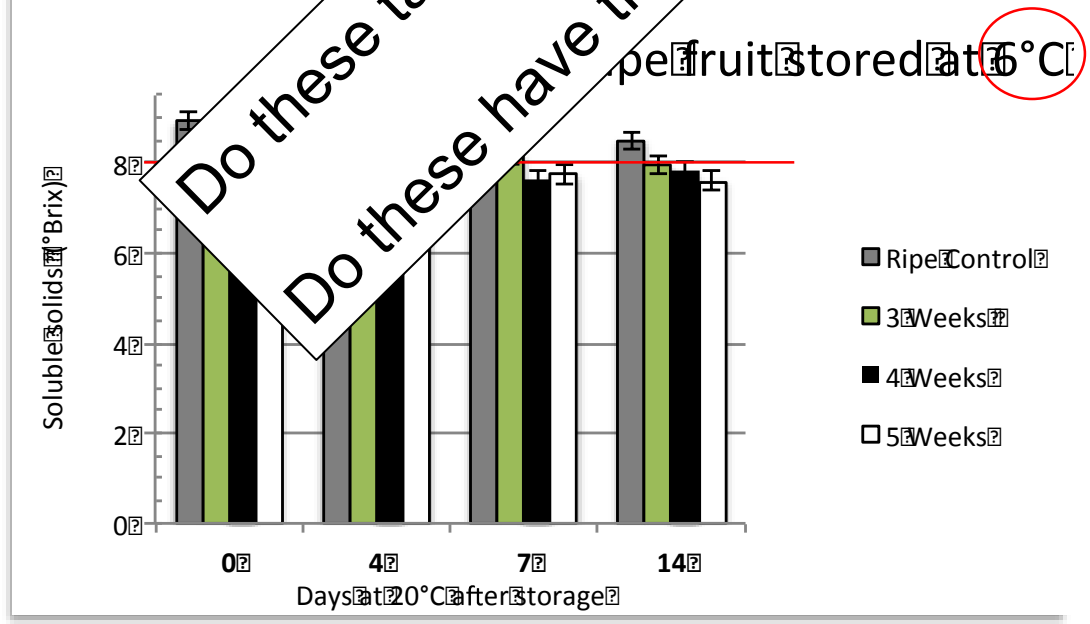
# Ripe fruit stored 3 weeks at 10C, + 4 days of shelf life

# Ripe fruit stored 3 weeks at 6C, + 4 days of shelf life




Do these taste the same?

Do these have the same texture?



# Postharvest treatments: Heat shock, UV-C

- Heat shock
  - brief exposure to temperatures in the range 40-52°C.
  - reported to reduce postharvest decay, induce pathogen resistance responses, induce synthesis of new proteins that protect membranes against chilling injury, prevent loss of flavour
- UV-C
  - reported to reduce incidence of postharvest rots, delay ripening and reduce chilling injury symptoms
  - application difficult – whole surface must be exposed
- Both treatments shown to be somewhat effective in a research context
- Time/temperature/cultivar: important to optimize; uniformity of heating important; integration into current handling systems???

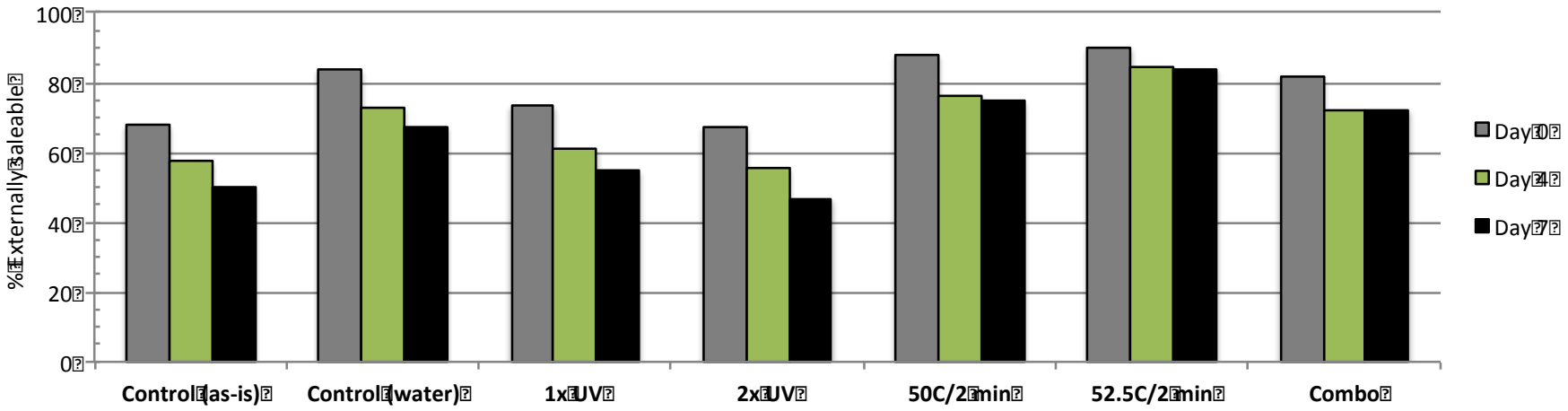
# Grape-type specialty tomatoes were treated….

1. Control (as-is)
2. Control (water washed)
3. 1x UV (in water)
4. 2x UV (in water)
5. Heat treatment 50°C for 2 min
6. Heat treatment 52.5°C for 2 min
7. Combination of heat (50°C for 2 min) plus 1x UV

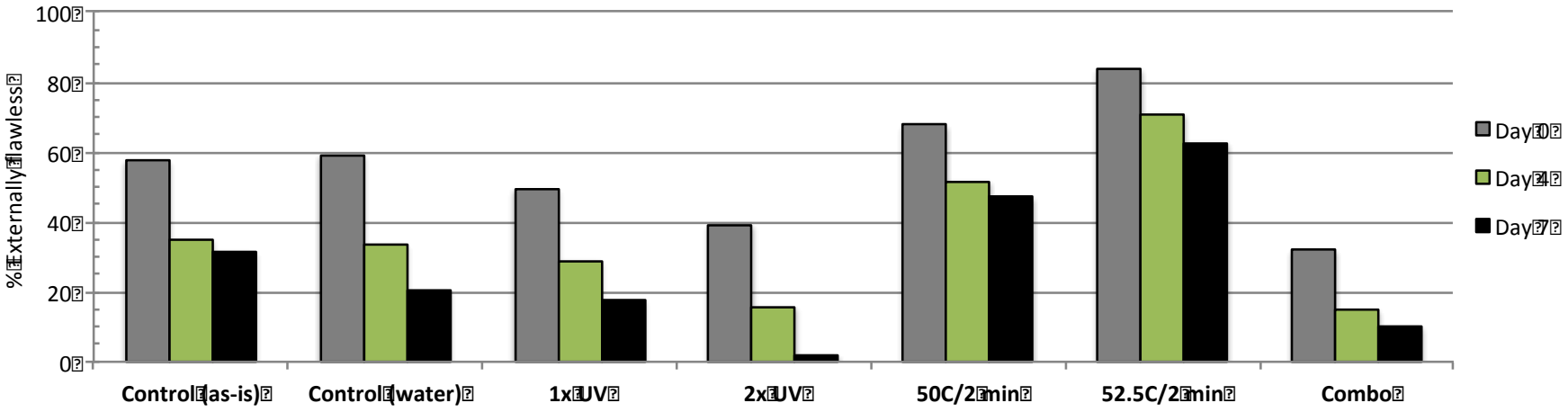
… then stored for 4 weeks at 10°C…

… then evaluated at 20°C for 7 days

# % Saleable fruit



# % Flawless fruit

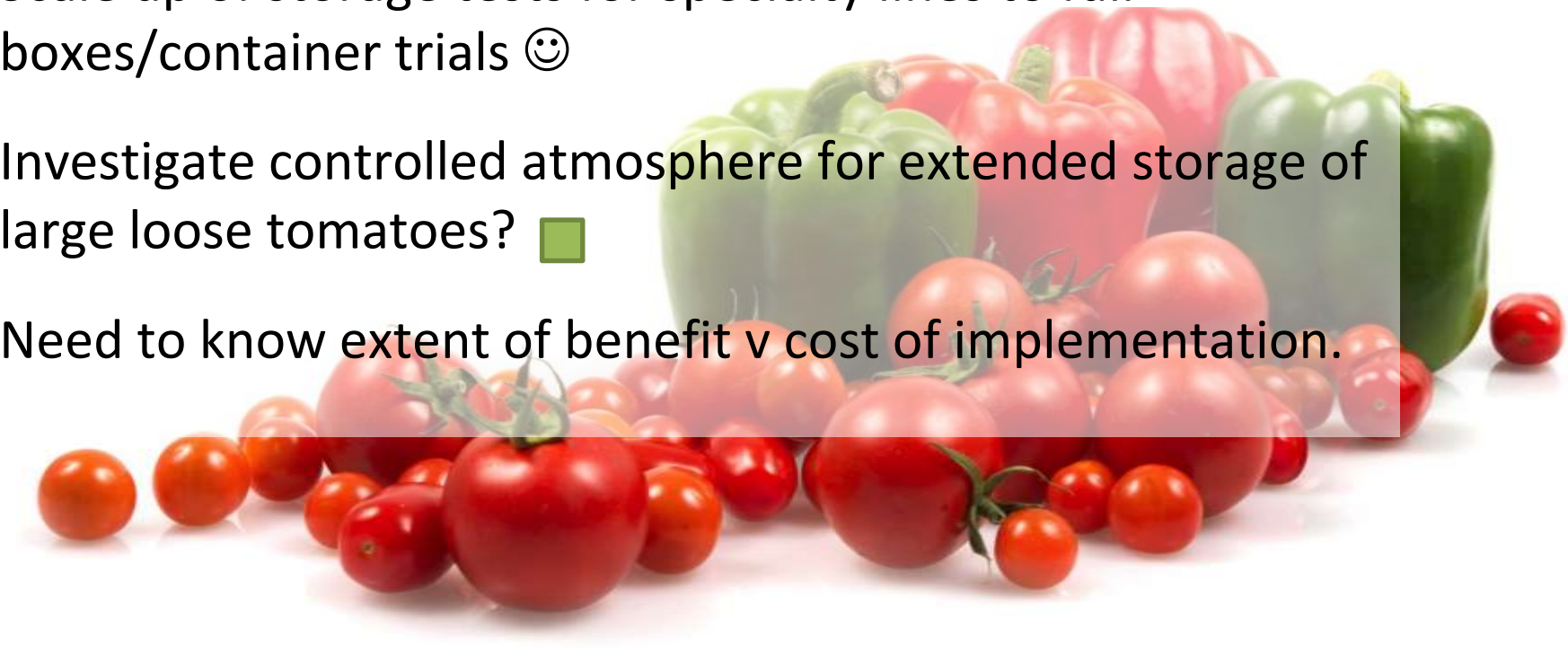


4.2

6.3

# Things to consider

- Investigate impact of heat shock on specialty lines?
- Get more certainty with temp/time for cherry tomatoes.
- Ethylene management benefits of new films?
- Scale up of storage tests for specialty lines to full boxes/container trials ☺
- Investigate controlled atmosphere for extended storage of large loose tomatoes?
- Need to know extent of benefit v cost of implementation.



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# Thanks to PFR colleagues

Sheryl Somerfield, Ross Lill, Allan Woolf, Shane Olsson, Agam Nangul, Simon Redpath

David Brummell, Donald Hunter, Marian McKenzie

Duncan Hedderley

www.plantandfood.co.nz

Plant & Food RESEARCH
RANGAHAU AHUMĀRA KAI

# Thanks to ‘Fresher by Sea’ grower-exporters!

T&G Covered Crops – Ben Smith, Murray Adam, Anthony Stone, Satwant Grewal et al.

NZ Hothouse – Simon Watson, Lex Dillon, Bevan Thorby et al.