Its life ... but not as we know it

Innovations in postharvest technology to support global trade of fresh produce

Ernst Woltering (ernst.woltering@wur.nl)

Wageningen University

Food & Biobased Research & Chairgroup Horticulture

FOOD & BIOBASED RESEARCH
WAGENINGEN UR

“Aangespoelde bananen naar Dierenpark Emmen”

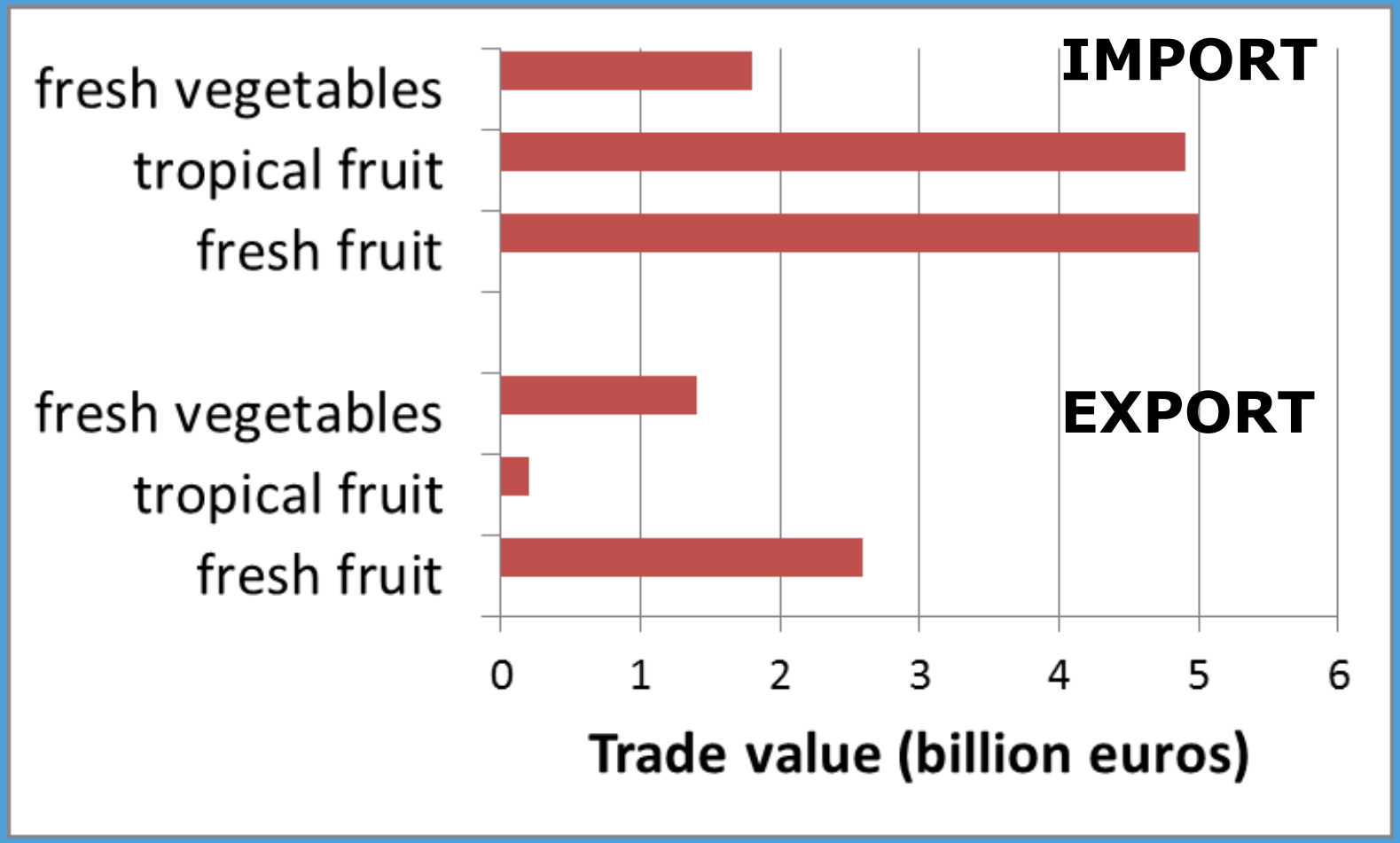

19.0 °C
HortiMax
growing solutions


DEKO


Mother's Day


EVERGREEN

European trade in fresh F&V (2011)



Value added in postharvest: search for high value markets

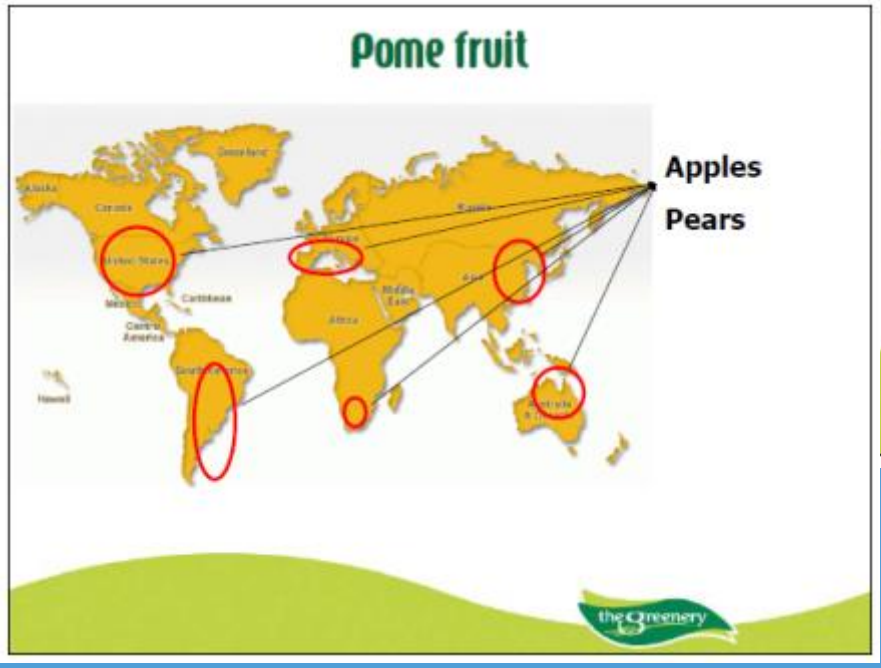
< 0.5 euro/kg
Brazil

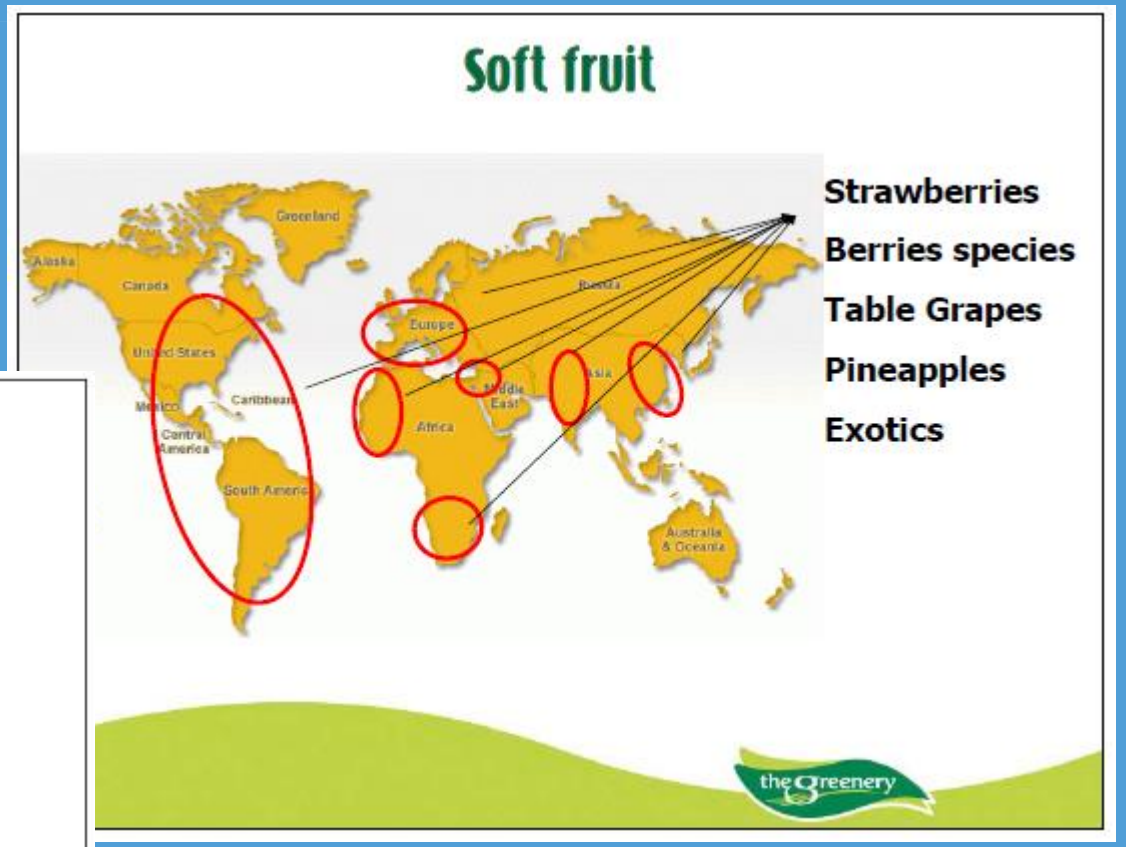
Sorting
Transport
Sorting/processing
Distribution

14 euro/kg
In UK

Egypt

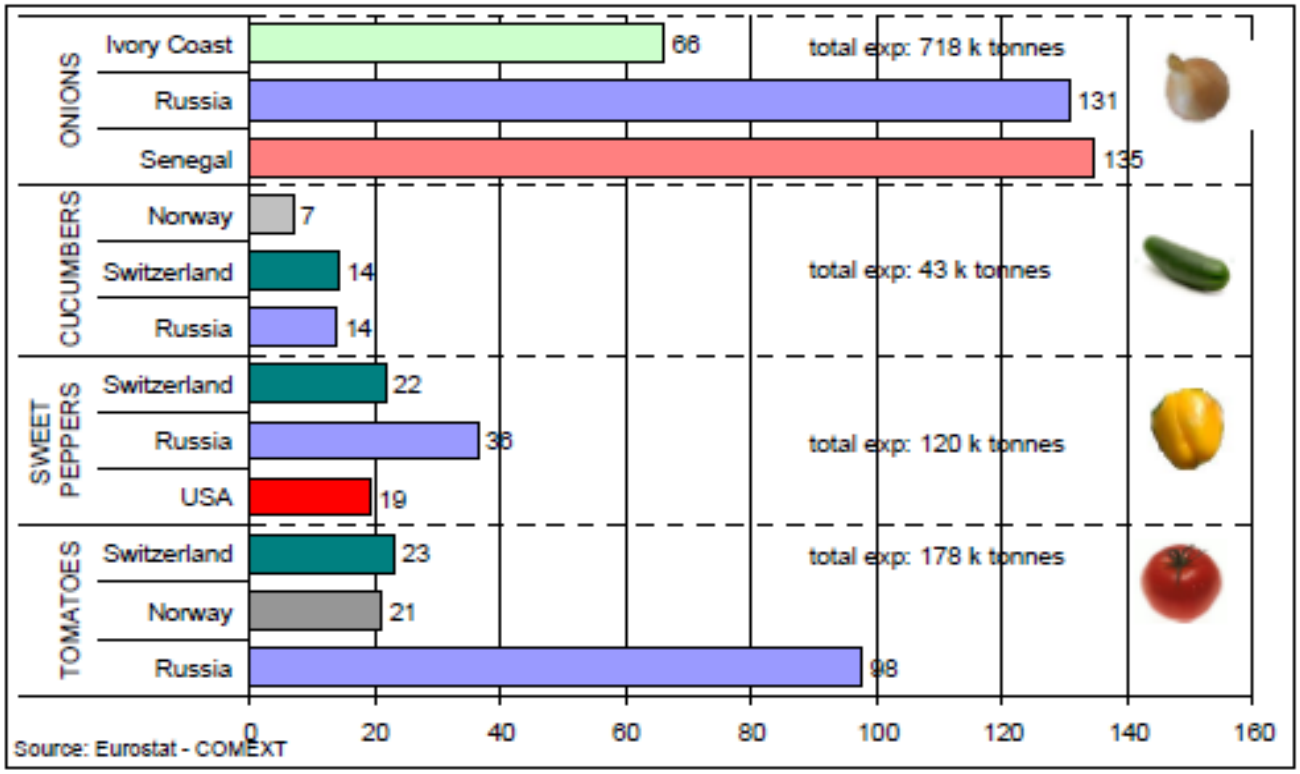
United kingdom


Pome fruit
Apples
Pears
the Greenery


Soft fruit
Strawberries
Berries species
Table Grapes
Pineapples
Exotics
Greenland
Alaska
Canada
United States
Mexico
Caribbean
Central America
South America
Europe
Africa
Middle East
Asia
Australia & Oceania
the Greenery

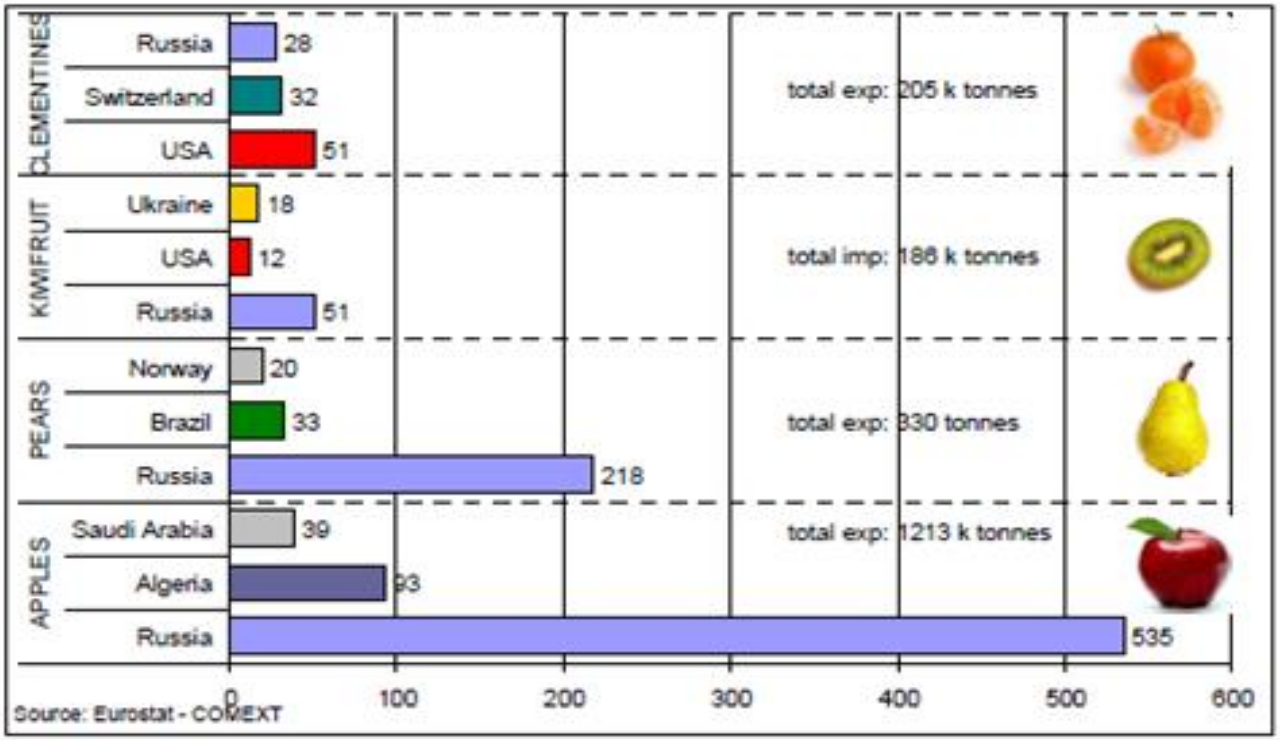
Exports Vegetables out of Europe

Graph 4: Exports of selected fresh vegetables by top destinations (average 2009-2011 in thousand tonnes)

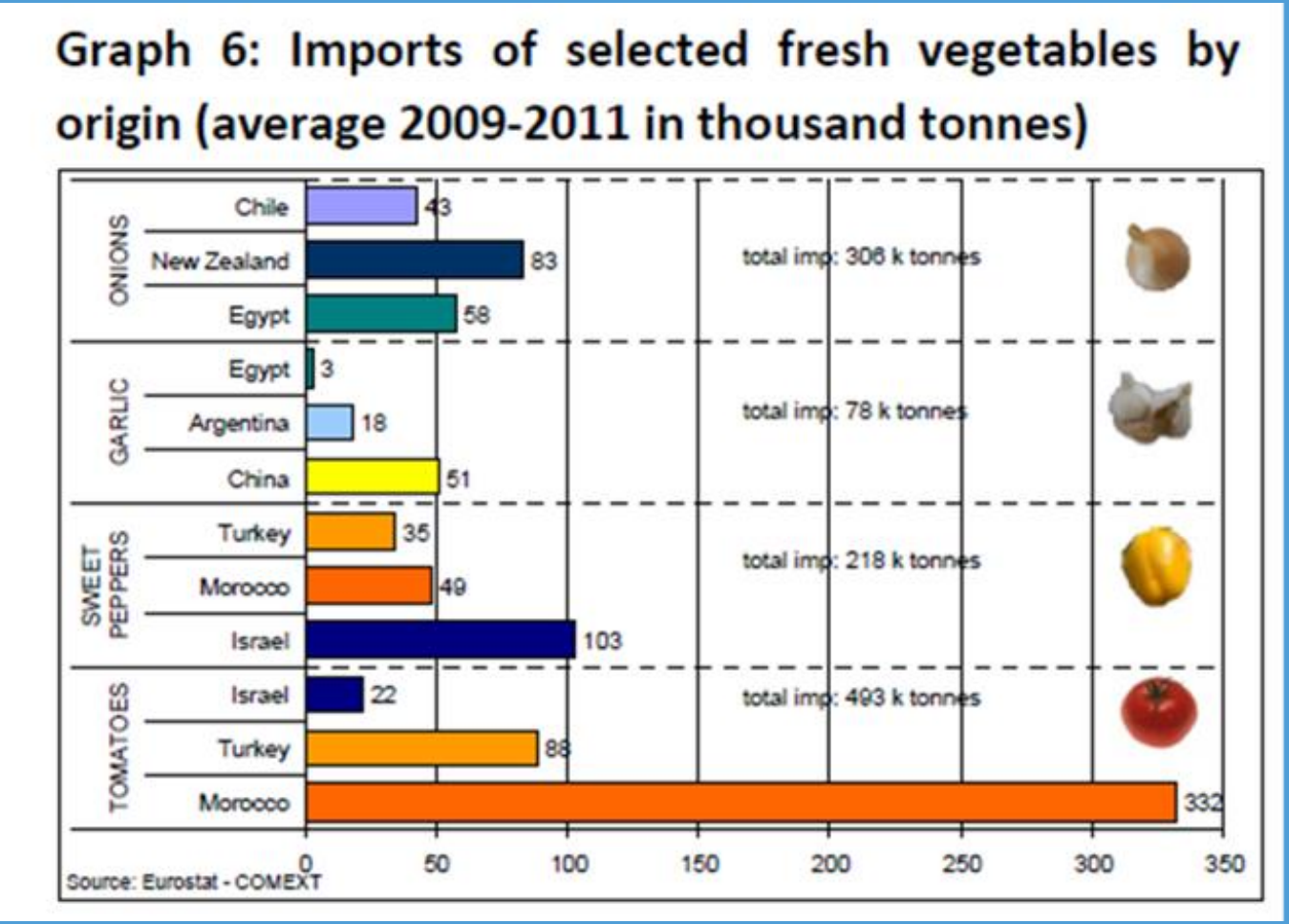


Exports Fruit out of Europe

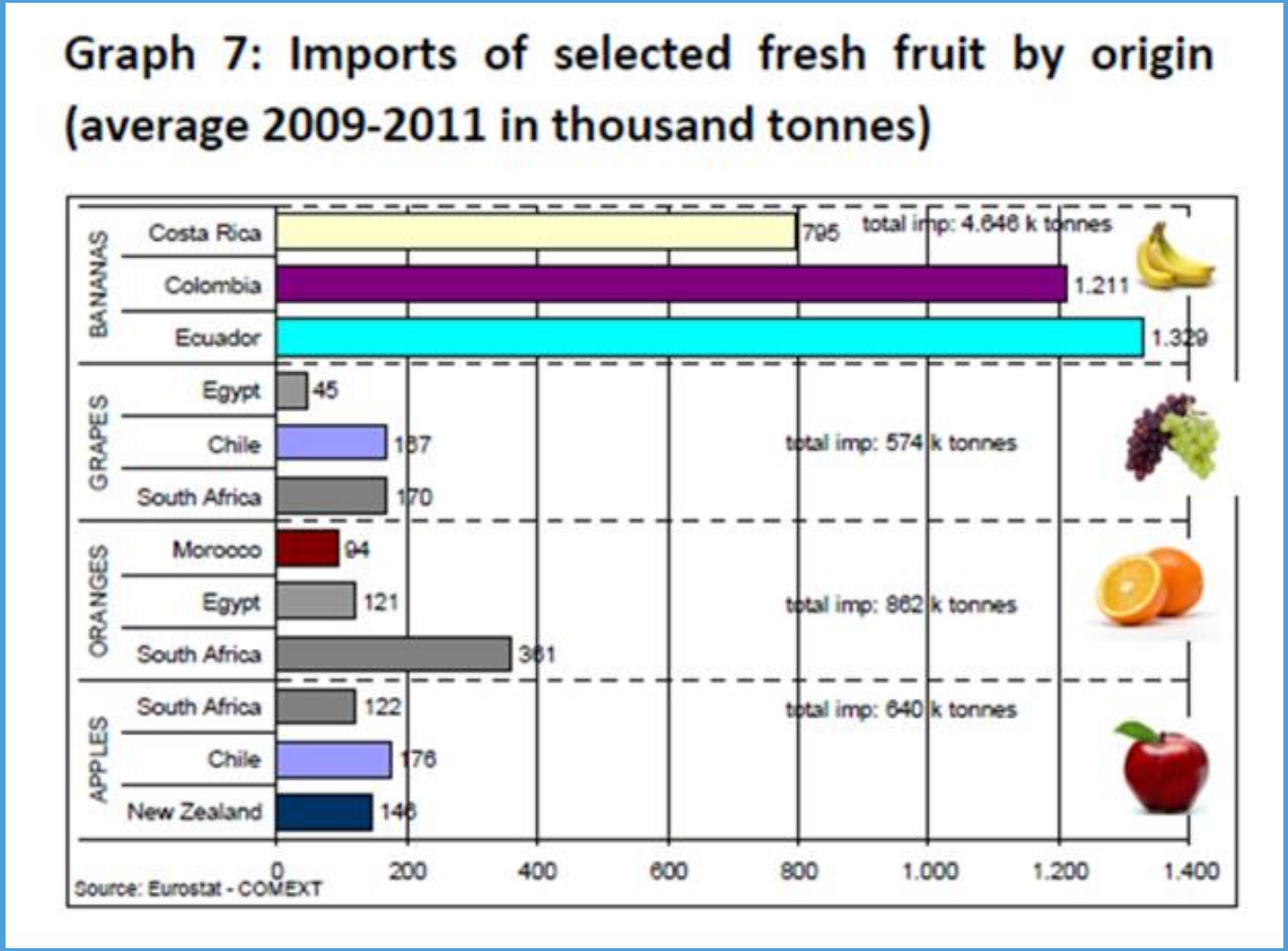
Graph 5: Exports of selected fruit to top destinations (average 2009-2010 in thousand tonnes)



Imports Vegetables into Europe



Imports Fruit into Europe



Fresh F&V is Global trade

- Extensive transportation (energy cost)
- Long storage times at low temperatures
  (up to many weeks)

- Food losses in distribution
- Quality issues (deterioration)
- Many different products
- We need protocols, methods, technologies to enable global trade!

Transport modality shift (tropical fruit)

- Standard transport modality: air freight
  - Short transport times
  - Relatively expensive; fuel surcharges

- Alternative marine (Reefer) transport
  - Long transport times
  - Less expensive

  Reefer=

  refrigerated container

Transportation energy costs

Product km per energy quotum

- Private car 1
- Air 43
- Truck 740
- Railroad 2400
- Container Ship 3800

Airplane versus Reefer:

50 - 100 x less energy and CO2 emission/kg product

One ship may contain up to 15.000 20-foot cntnrs

Attractiveness of container transport

Pro's

- Relatively cheap
- Lots of capacity
- Excellent climate control (T, RH, atmosphere)
  - also in the case of delays!
  - From farm to customer!
- Transport mode of choice for e.g. Melon, Avocado, Mango, Pineapple, Banana, some vegetables

Con's

- Takes long time (2 – 4 weeks)
- Quality of end product often disappointing!

Global trade to please the consumer

- To enable global trade, research is focussed on development of new sustainable technologies to pack, store, transport and to guarantee quality of fresh F&V

Its life ... but not as we know it

- "It's life, Jim, but not as we know it."
- **What he really said:** "No life as we know it."

"Beam Me Up Scotty" was Never Said in the Original Star Trek

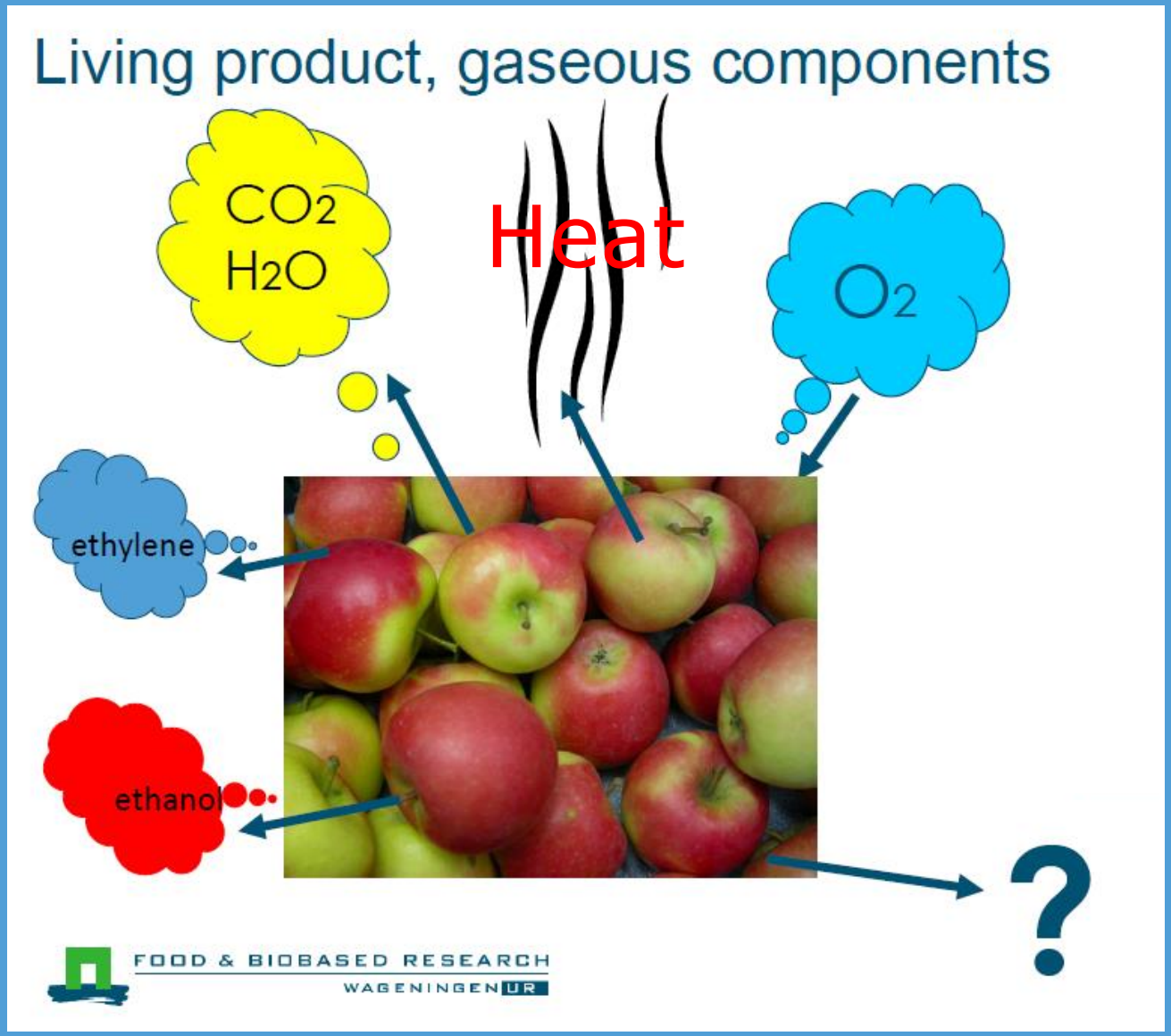
Its life … but not as we know it

- It is important to be aware of the pivotal role of storage and distribution conditions on the quality of the products
- It is important to realize that we are dealing with a living product that ages along the way
- The product is alive! It breathes and produces ethylene
  - Very different from other "fresh" products such as fresh fish or fresh meat, chicken.
  - These products are dead!

Its life … but not as we know it

- All biological processes have an intimate relation with the environmental conditions
- To preserve quality, conditions should be optimal for the products
- Products can be “put to sleep”

Its life ... but not as we know it



Pre harvest & Post harvest

Pre-harvest physiology

- Growth/developmental processes
- Biomass production
- Pest management
- Flowering/fruiting
- Photosynthesis

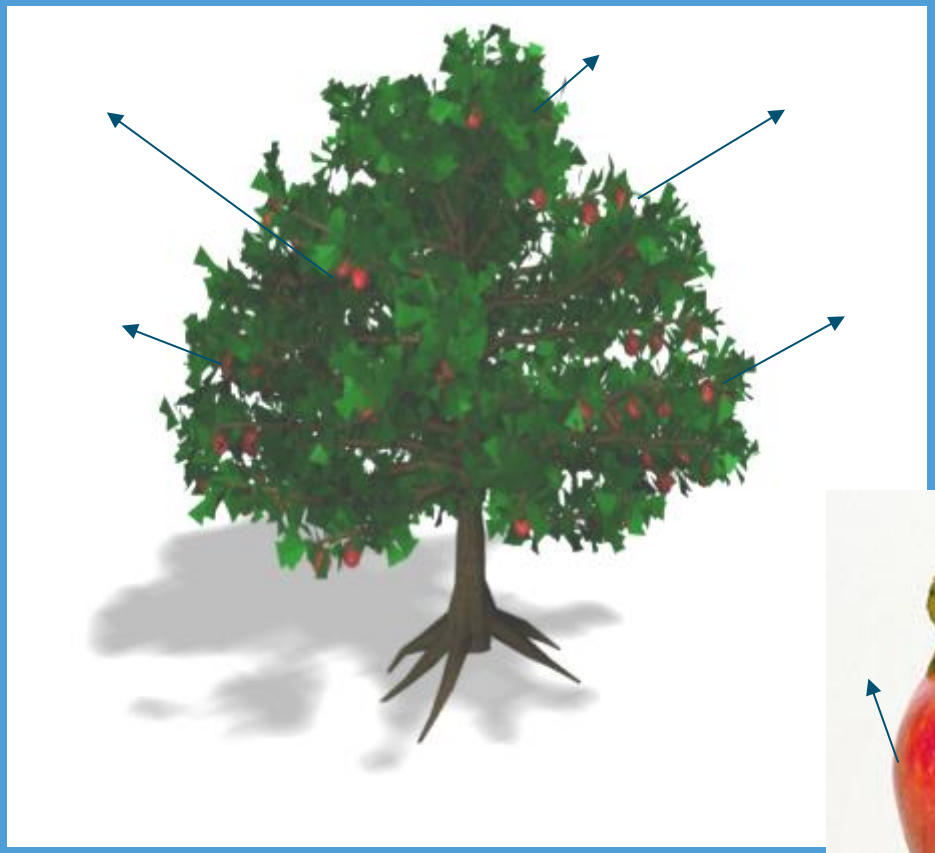
Harvest

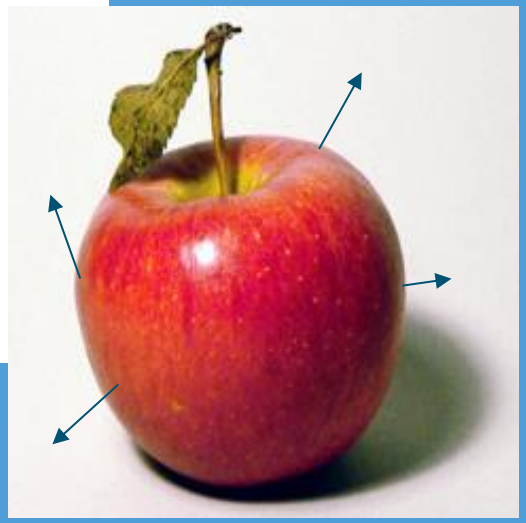
Post-harvest physiology

- Deteriorative processes (Senescence)
- Water loss (Transpiration)
- Accelerated development (Ethylene)
- Respiration

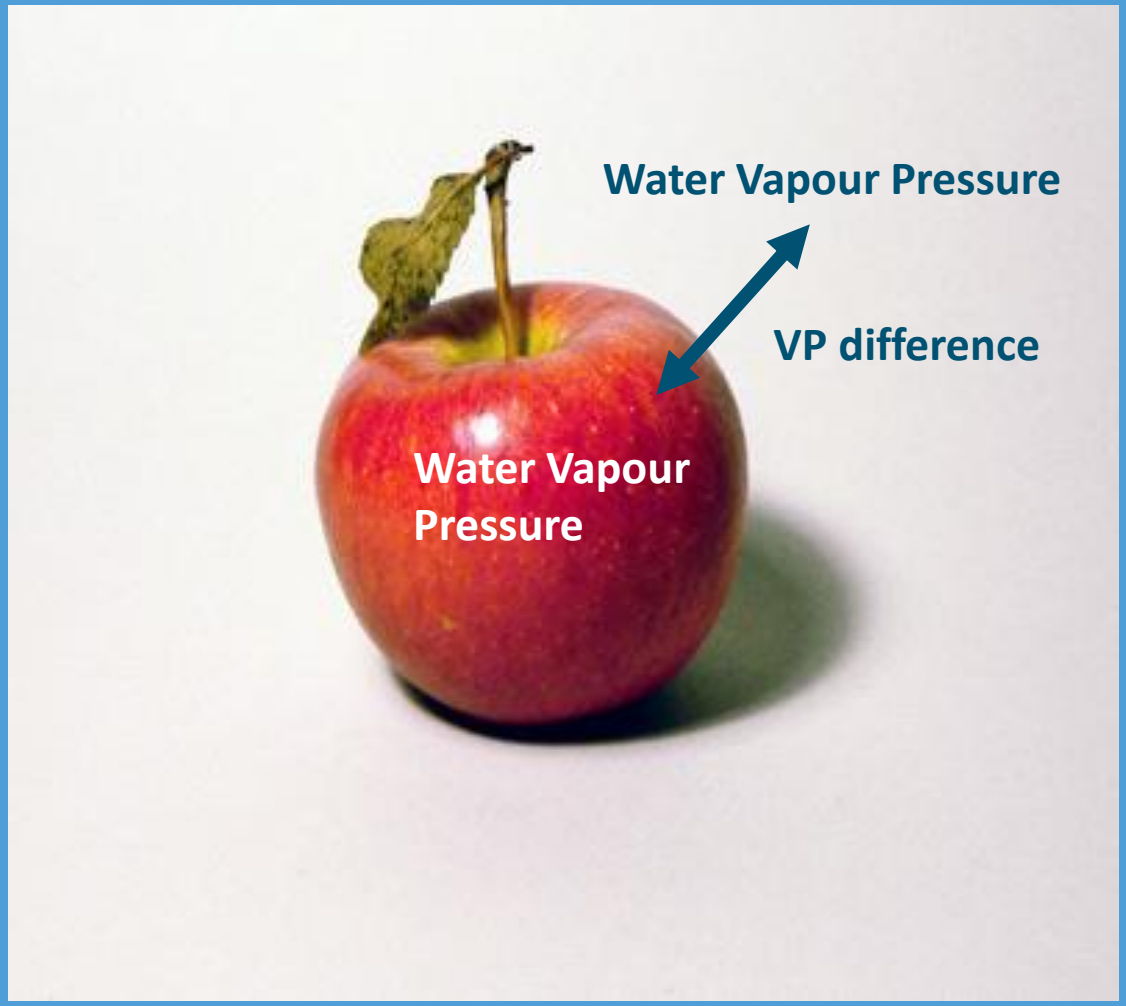
- Transpiration (product loses water)
  - VPD
  - Peel resistance to water flux
- Respiration (carbohydrate reserves are turned into heat)
  - Temperature
  - O2, CO2
- Ethylene biosynthesis (ripening and rotting hormone)
  - Temperature
  - O2, CO2
- Ripening & senescence (product becomes unusable)
  - Temperature
  - Ethylene

Water loss postharvest is not replenished





What determines transpiration (water loss)?



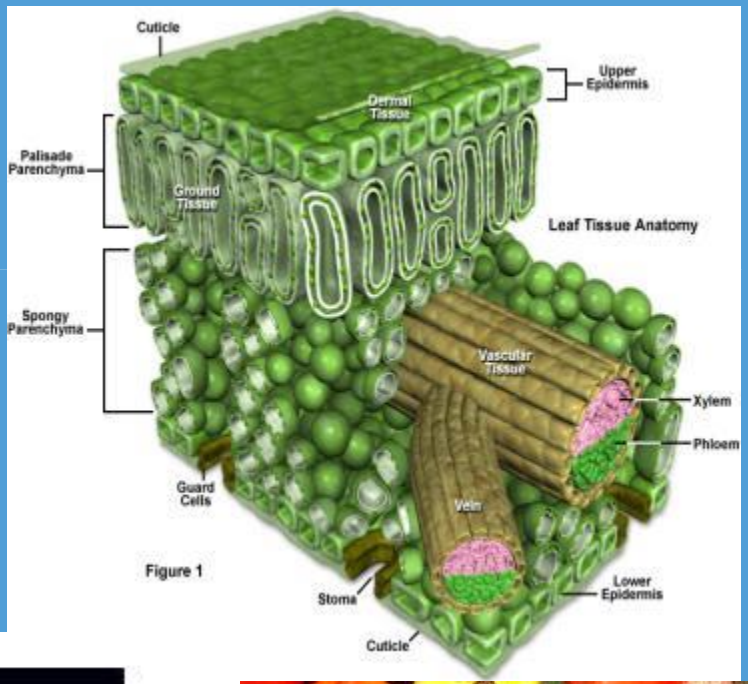
Calculate water flux

- Ohms law: V=I x R
  - Potential difference= flux x Resistance
- Flux = potential difference/resistance
- Water flux = VPdifference/ resistance to water movement

Transpiration pathways Resistancies

- Stomata (leaves)
- Other "openings"
  - Lenticells
  - Stem scar
  - injuries/lesions

- Directly through cuticula/wax layer
- Air movement will lower resistance



Loss of weight is loss of profit

- Modern storage operations
- Store 7-10 million KG of fruit
- Worth 5-7 million Euros

- 1-2 % weight loss
- Around 100.000 Euros loss

Loss of weight = Loss of quality = loss of profit

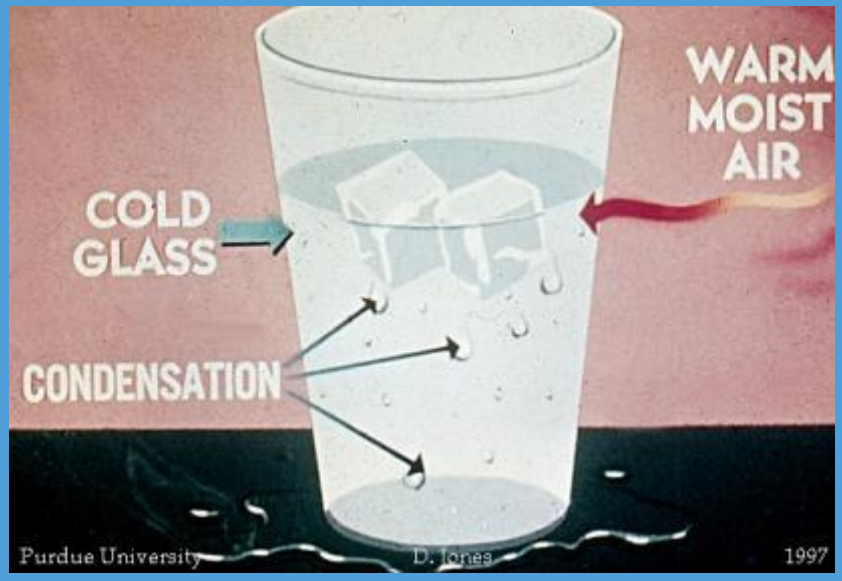
Loss of appearance

Loss of firmness

Shrivelled necks

Transpiration

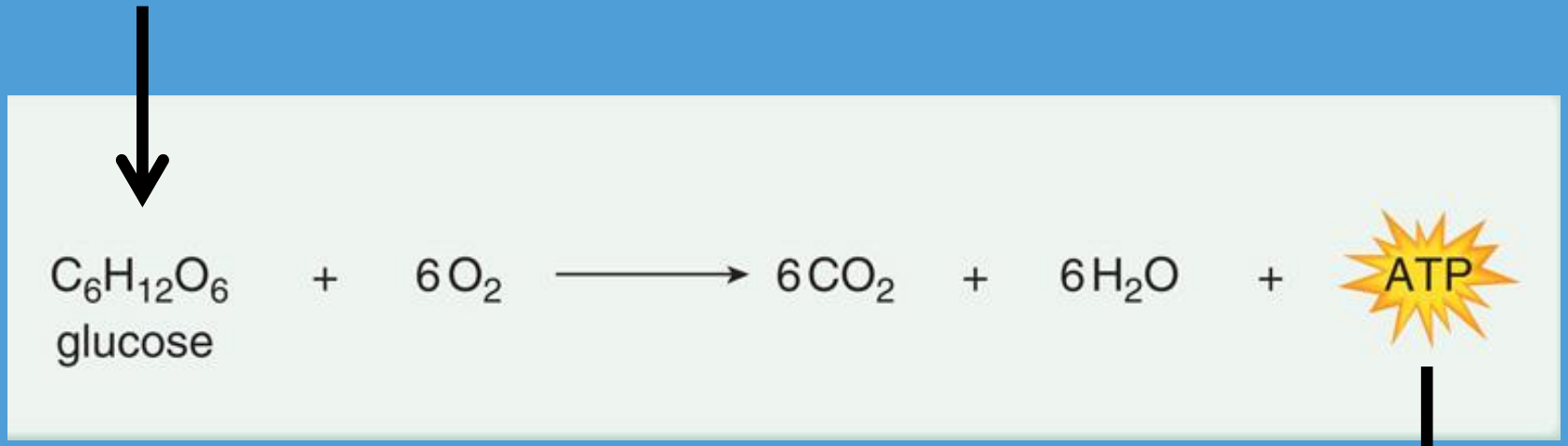
- To control transpiration, knowledge is required about physical and physiological processes, relations between product and air temperature and VP-differences
- Design of strategies to limit water loss without having excessively high relative humidities (fungal infections)
    - Smart ways to remove field heath
    - Smart ways to avoid condensation
- Sometimes "misting" is applied to bring water in the product


WARM
MOIST
AIR
COLD
GLASS
CONDENSATION
Purdue University
D. Jones
1997

- Transpiration (product loses water)
  - VPD
  - Peel resistance to water flux
- Respiration (carbohydrate reserves are turned into heat)
  - Temperature
  - O2, CO2
- Ethylene biosynthesis (ripening and rotting hormone)
  - Temperature
  - O2, CO2
- Ripening & senescence (product becomes unusable)
  - Temperature
  - Ethylene

Respiration

Photosynthesis

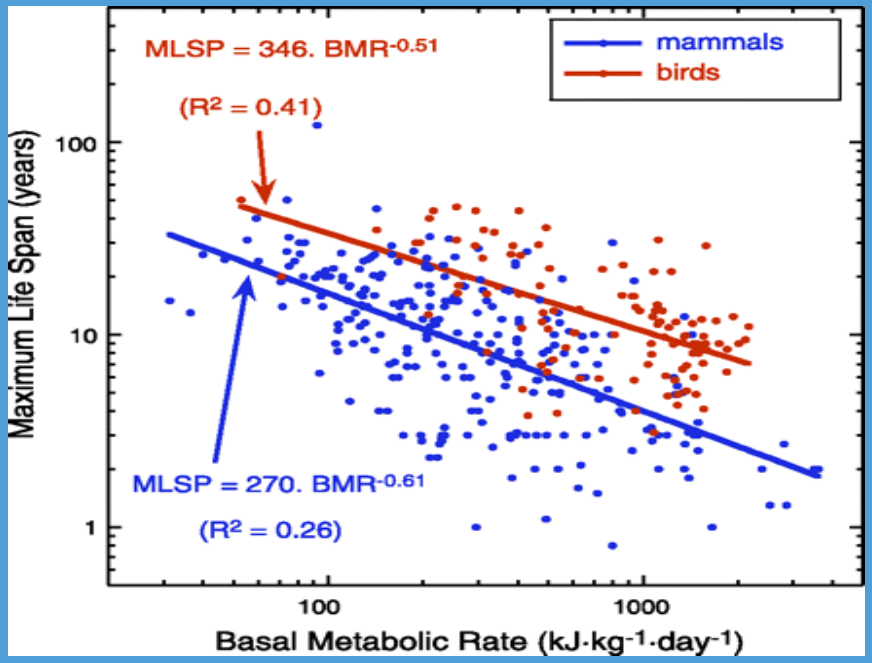


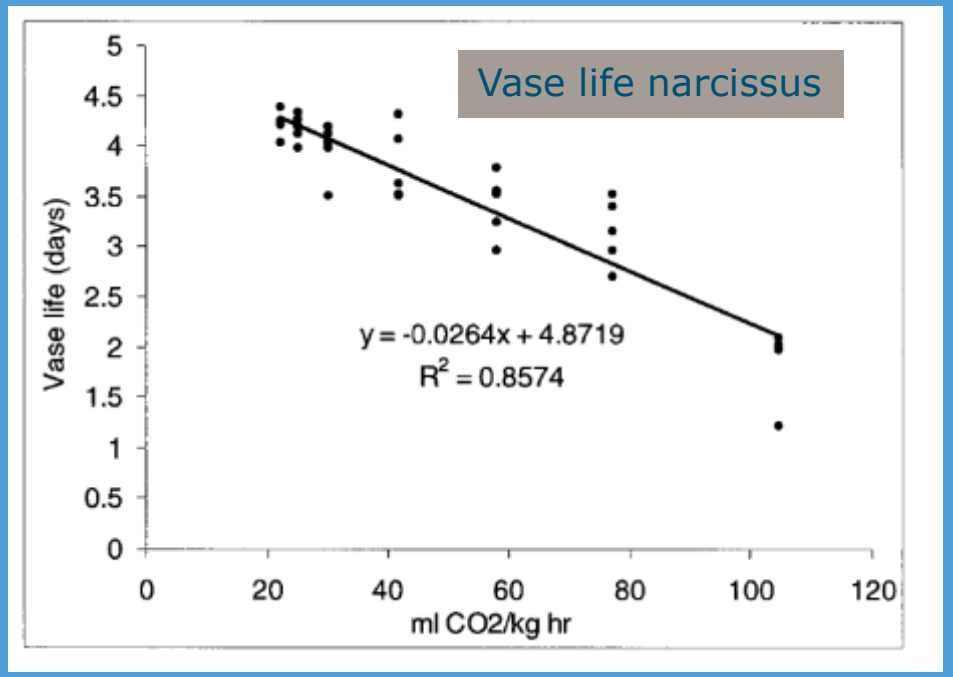
Heat

The respiratory machinery also produces Reactive Oxygen Species (ROS)

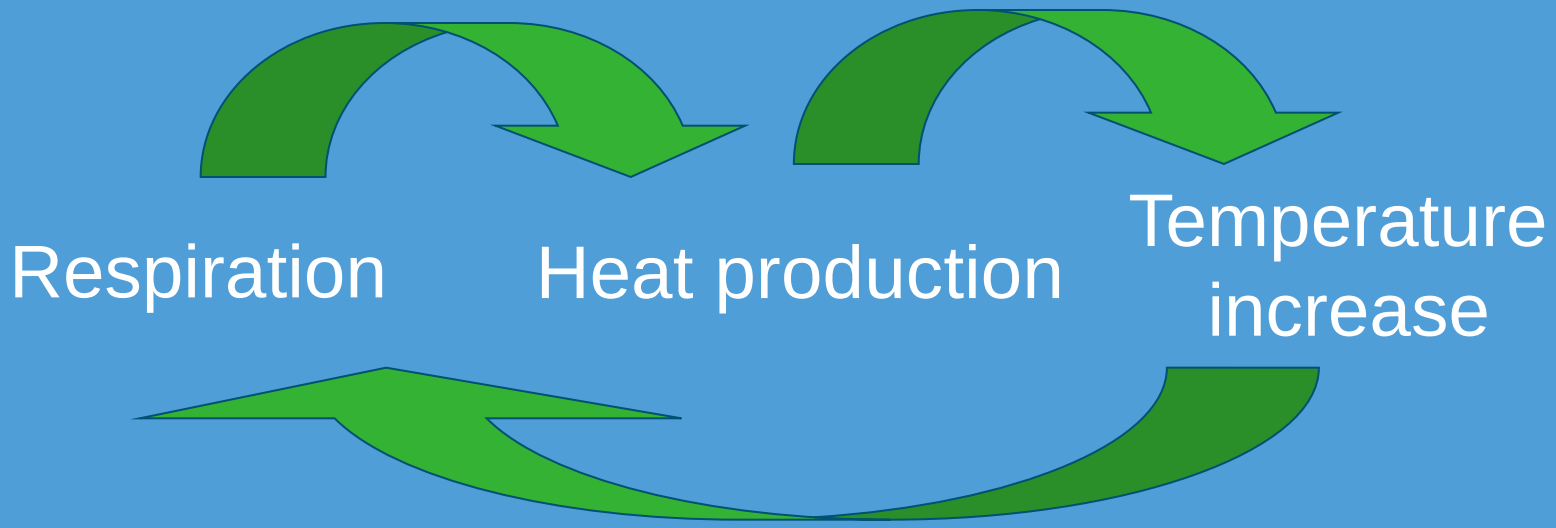
Respiration

- There is a good correlation between respiratory activity and the length of the life of an animal!
- This also is true for horticultural produce
- Storage strategies should suppress respiratory activity as much as possible (low T, low O2, elevated CO2)



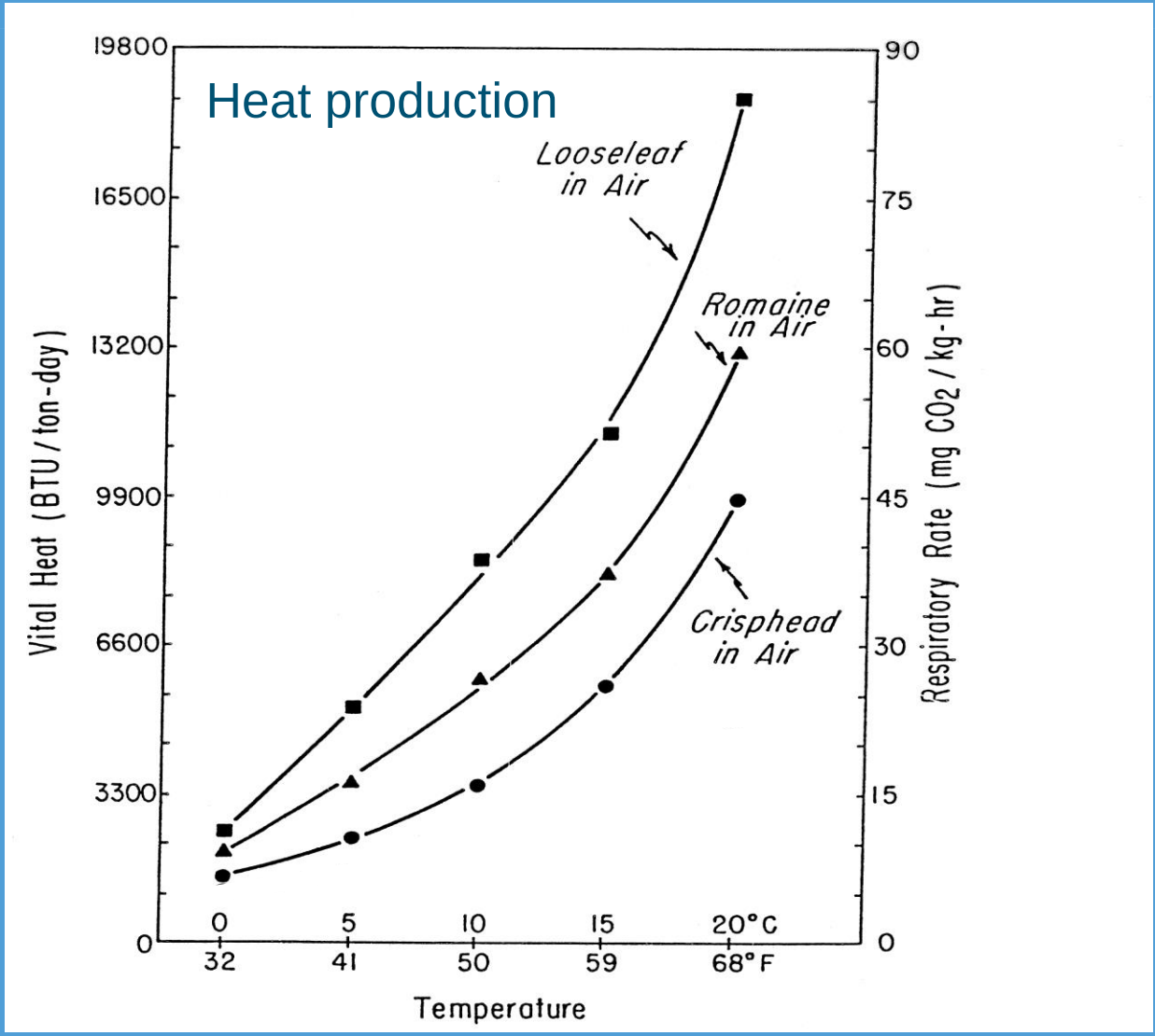


Respiration is temperature dependent



Trucks do not have sufficient cooling capacity to lower product temperature!!
Products should be pre-cooled !!

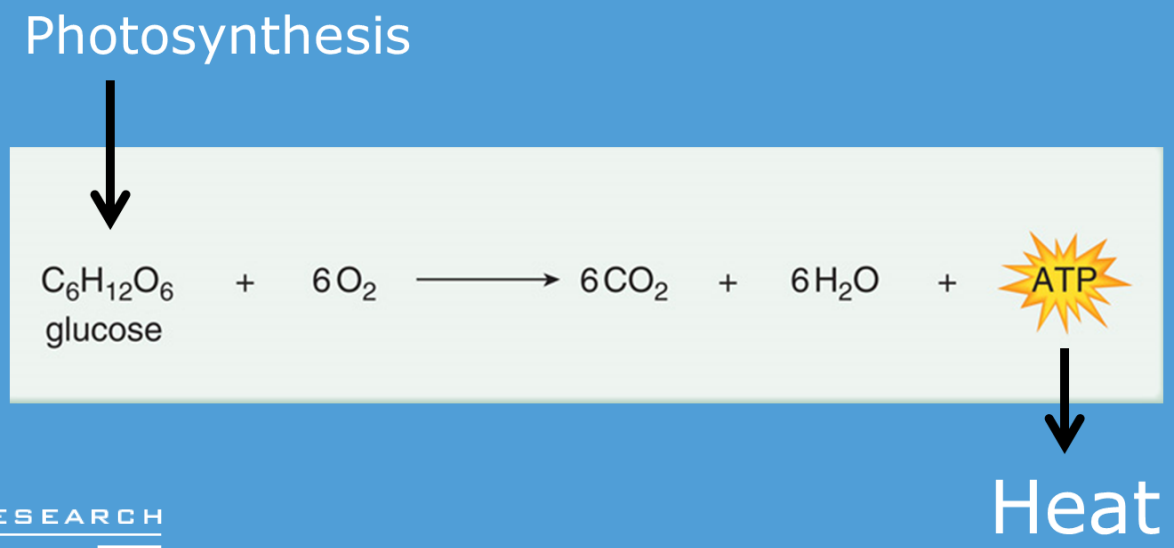
Temperature and heat production



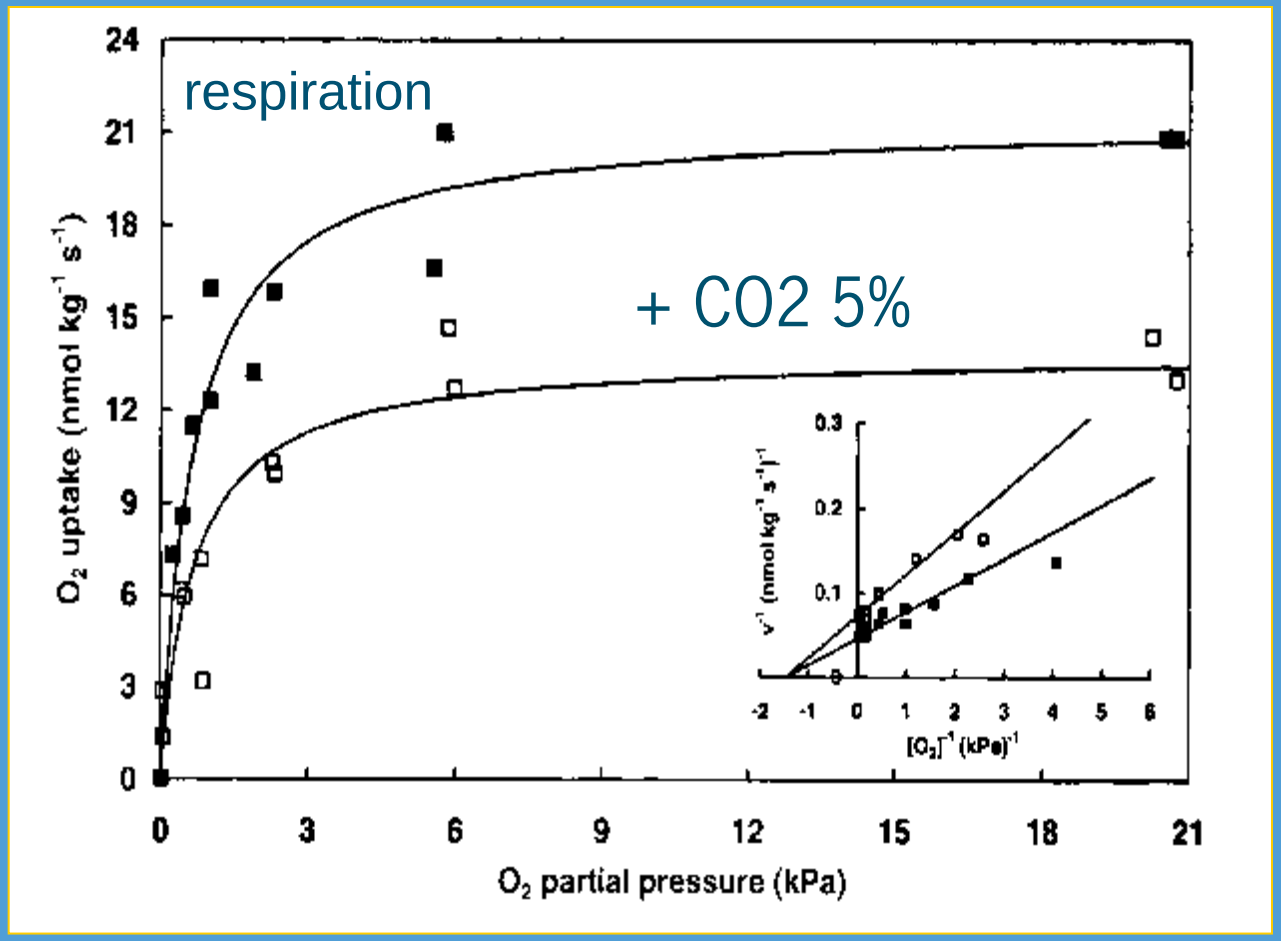
Controlled atmosphere to lower respiration

- Decreased O2
- Increased CO2
- On top of the low temperature

- Effects of CA: Lower respiration



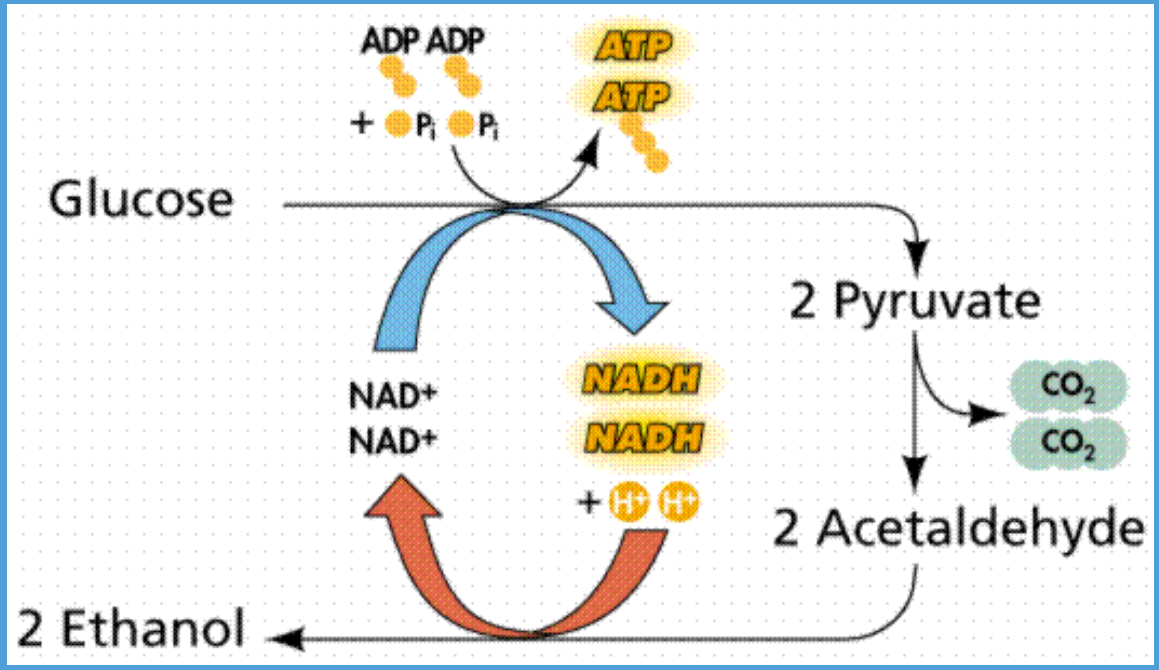
Effect oxygen and carbon dioxide on respiration pear



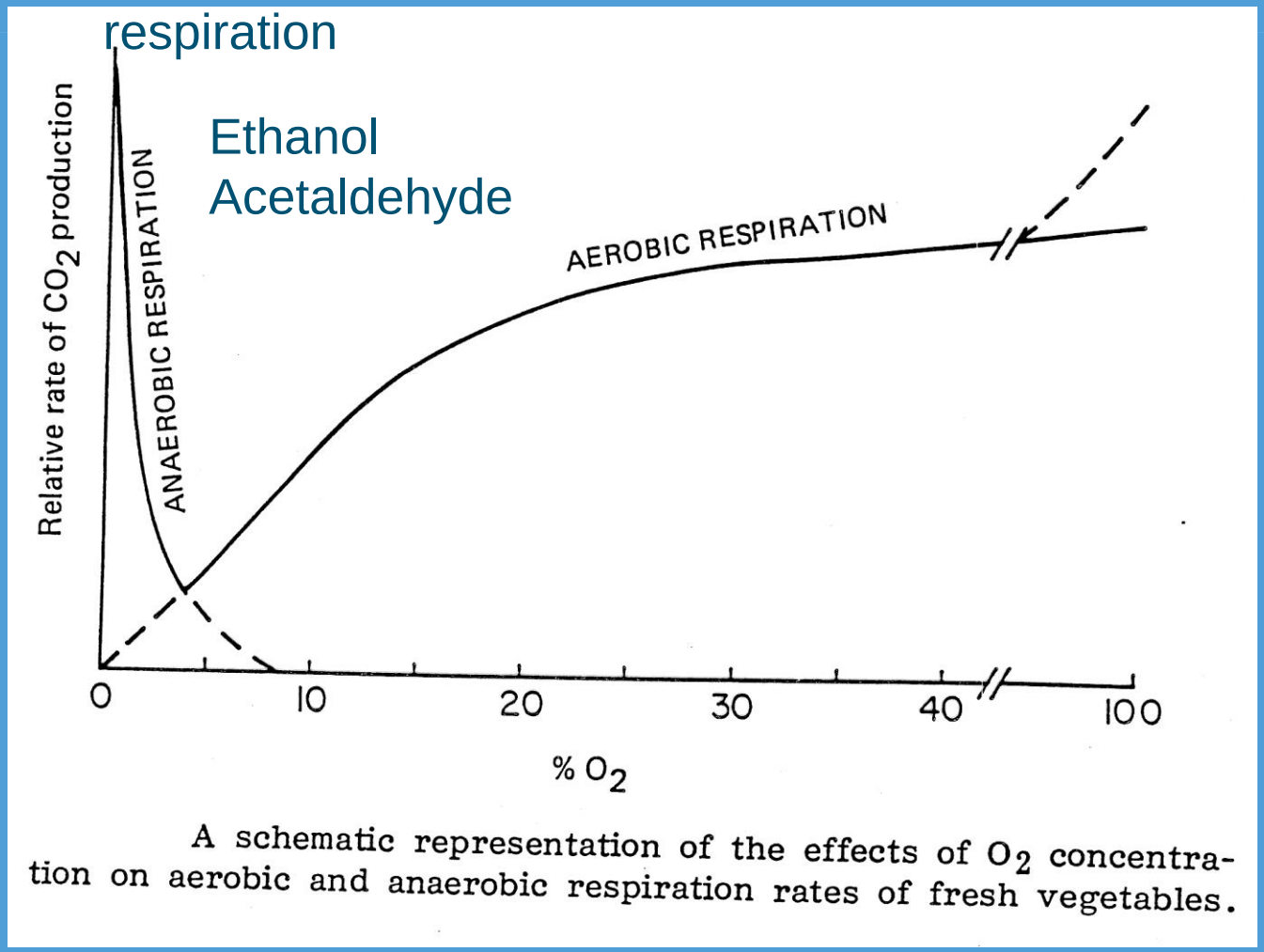
Positive effect of CA storage

Fermentation

- Too low oxygen and too high CO2 lead to fermentation
- The switch-points are not fixed and dependent on type of product and product history

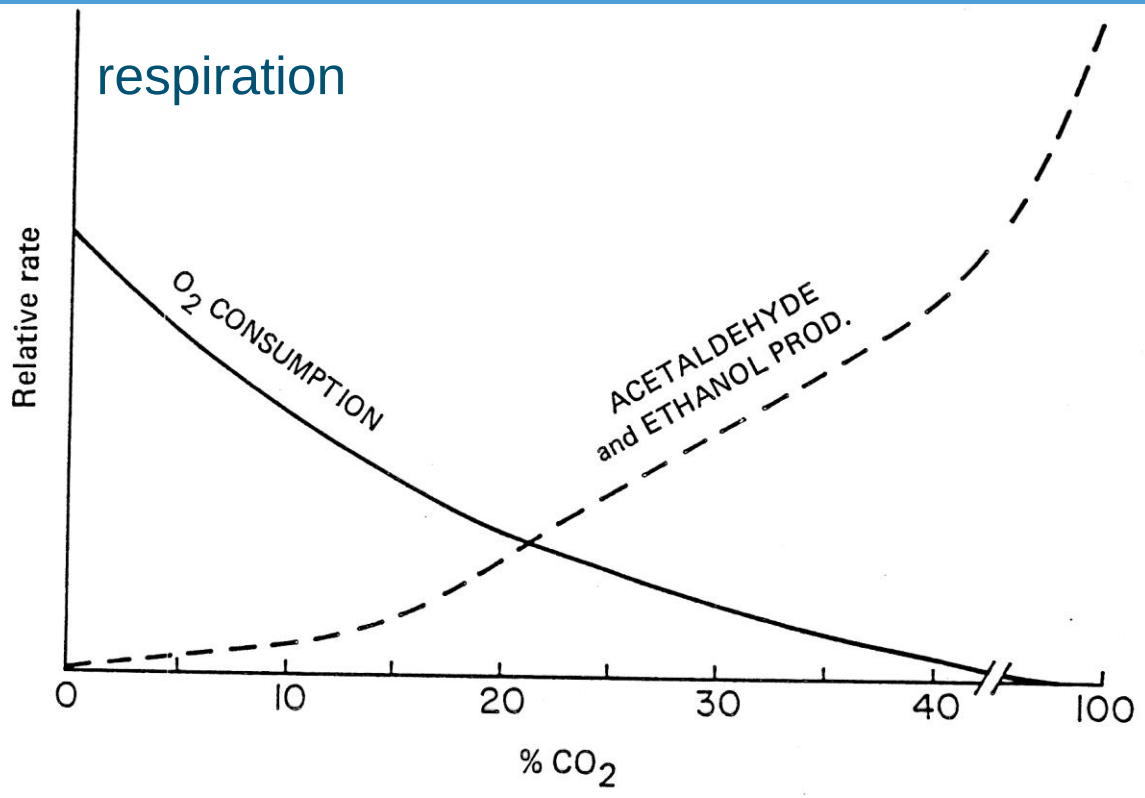


Low O2



A schematic representation of the effects of O_2 concentration on aerobic and anaerobic respiration rates of fresh vegetables.

High CO_2



Schematic representation of the effects of CO_2 concentration on aerobic respiration (O_2 consumption) and anaerobic respiration (acetaldehyde and ethanol production) rates of fresh vegetables.

Dynamic control of CA conditions: Optimise setpoints through monitoring product response

CO2 removal unit

O_2

CO_2

O_2

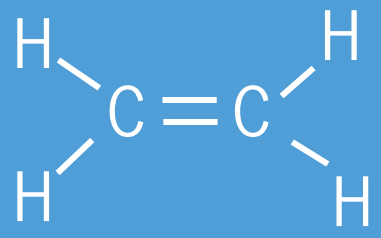
CO_2

Ethanol

- Transpiration (product loses water)
  - VPD
  - Peel resistance to water flux
- Respiration (carbohydrate reserves are turned into heat)
  - Temperature
  - O2, CO2
- Ethylene biosynthesis (ripening and rotting hormone)
  - Temperature
  - O2, CO2
- Ripening & senescence (product becomes unusable)
  - Temperature
  - Ethylene

Ethylene

- Ethylene is a plant hormone
- All plants produce ethylene
- Ethylene is a gas
- Ethylene affects developmental processes
- Ethylene affects growth
- Ethylene causes ripening and deterioration
- Ethylene act as a signalling molecule between plants



Ethylene and ripening/deterioration

Ethylene is involved in ripening (softening, coloration and taste/flavor production) in:

- apple
- pear
- mango
- tomato
- banana
- melon
- Avocado

Ethylene causes ripening but also deterioration

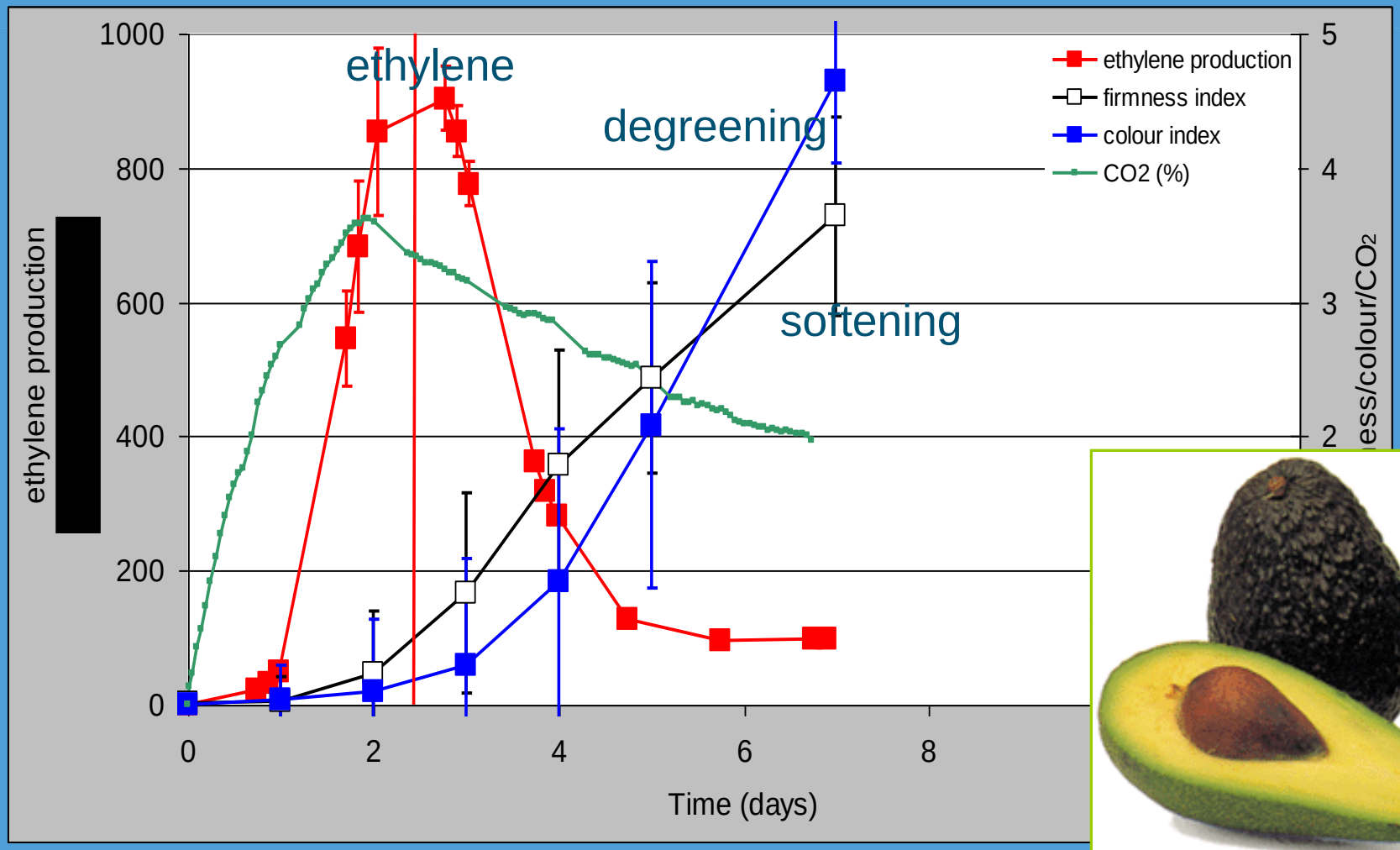
Ethylene and ripening/deterioration

Ethylene is involved in degreening/pigment synthesis/softening but not so much in taste and flavor in:

- strawberry (and other berries)
- broccoli
- grapes
- bell pepper
- artichoke
- lemon
- star fruit
- Oranges
- cucumber

Ethylene is mostly negative for quality

Avocado ripening

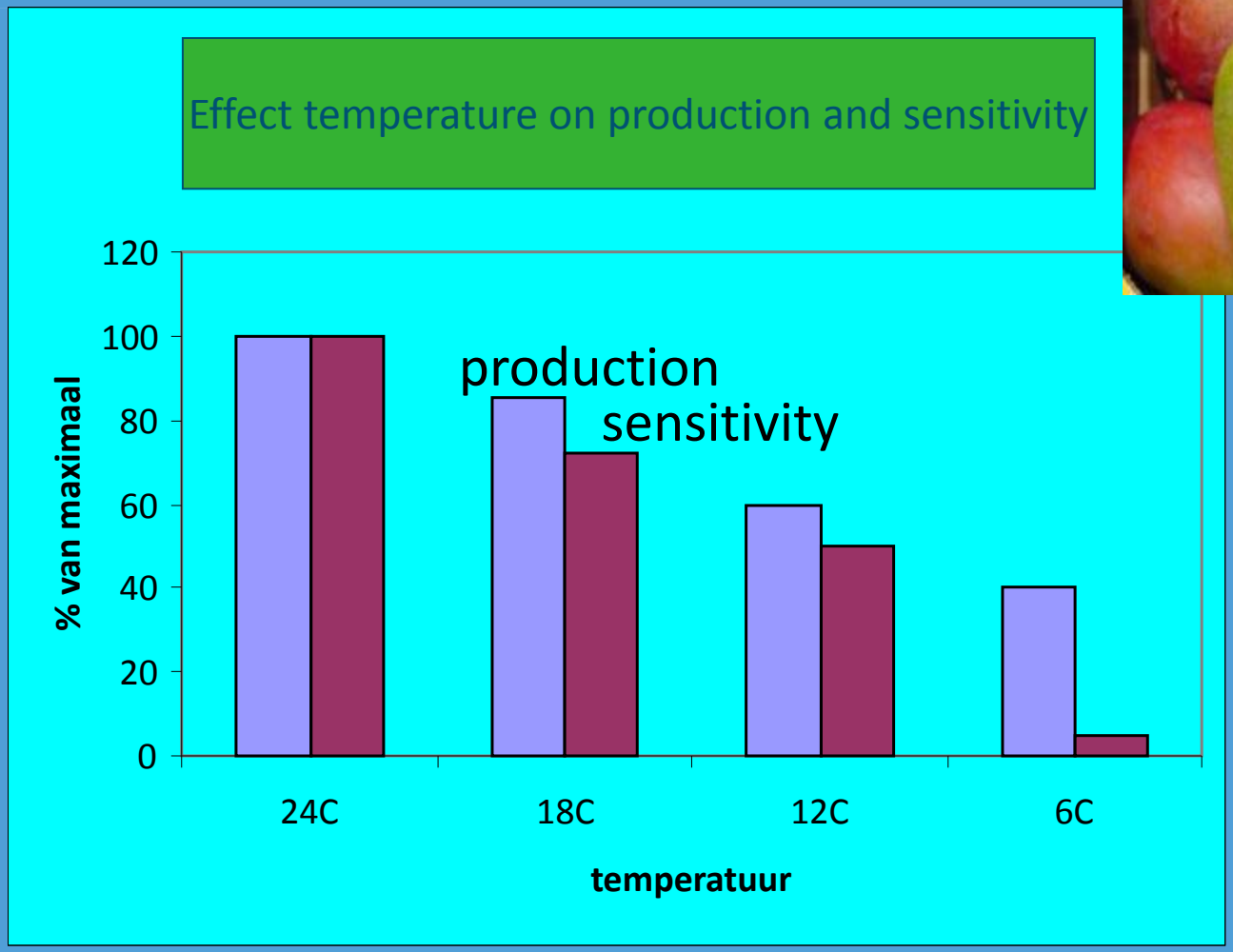


How to avoid ethylene problems?

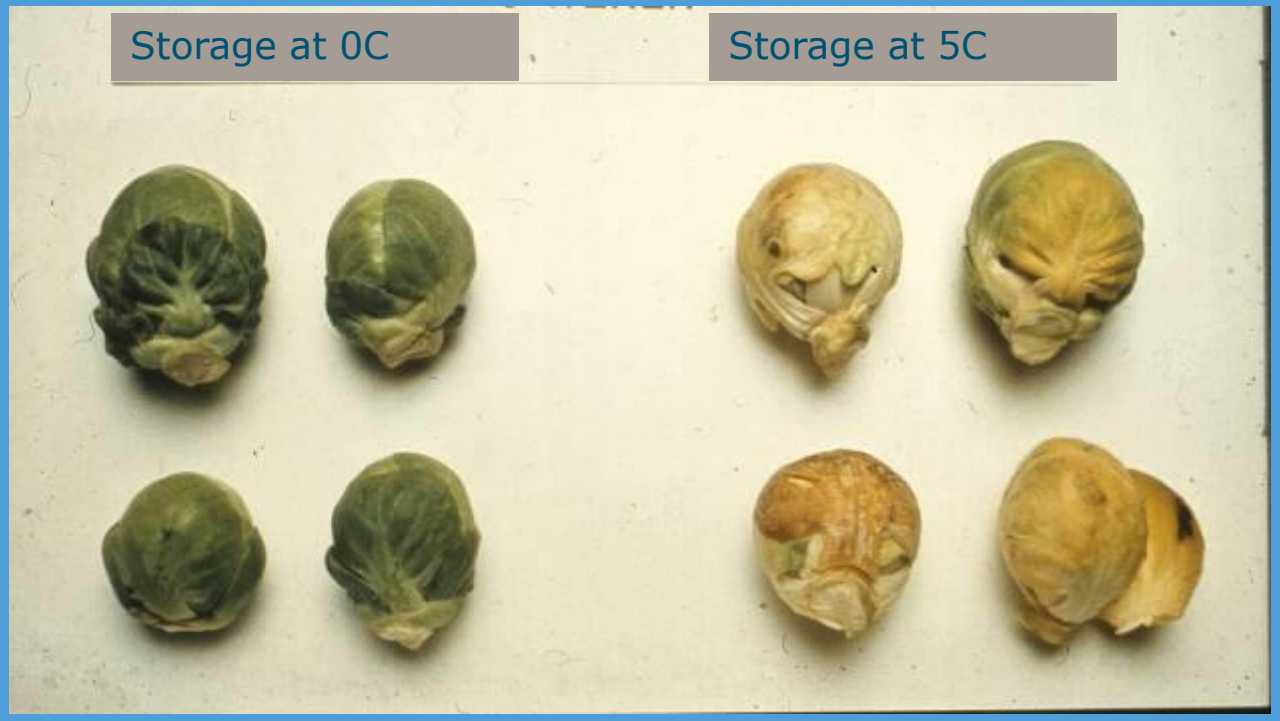
- Lower the temperature, it lowers both ethylene production and the ethyelne sensitivity
- Use 1-MCP > It blocks the ethylene receptor

- Controlled Atmosphere Storage
  - Lower the oxygen concentration
  - Increase the CO2 concentration

Temperature

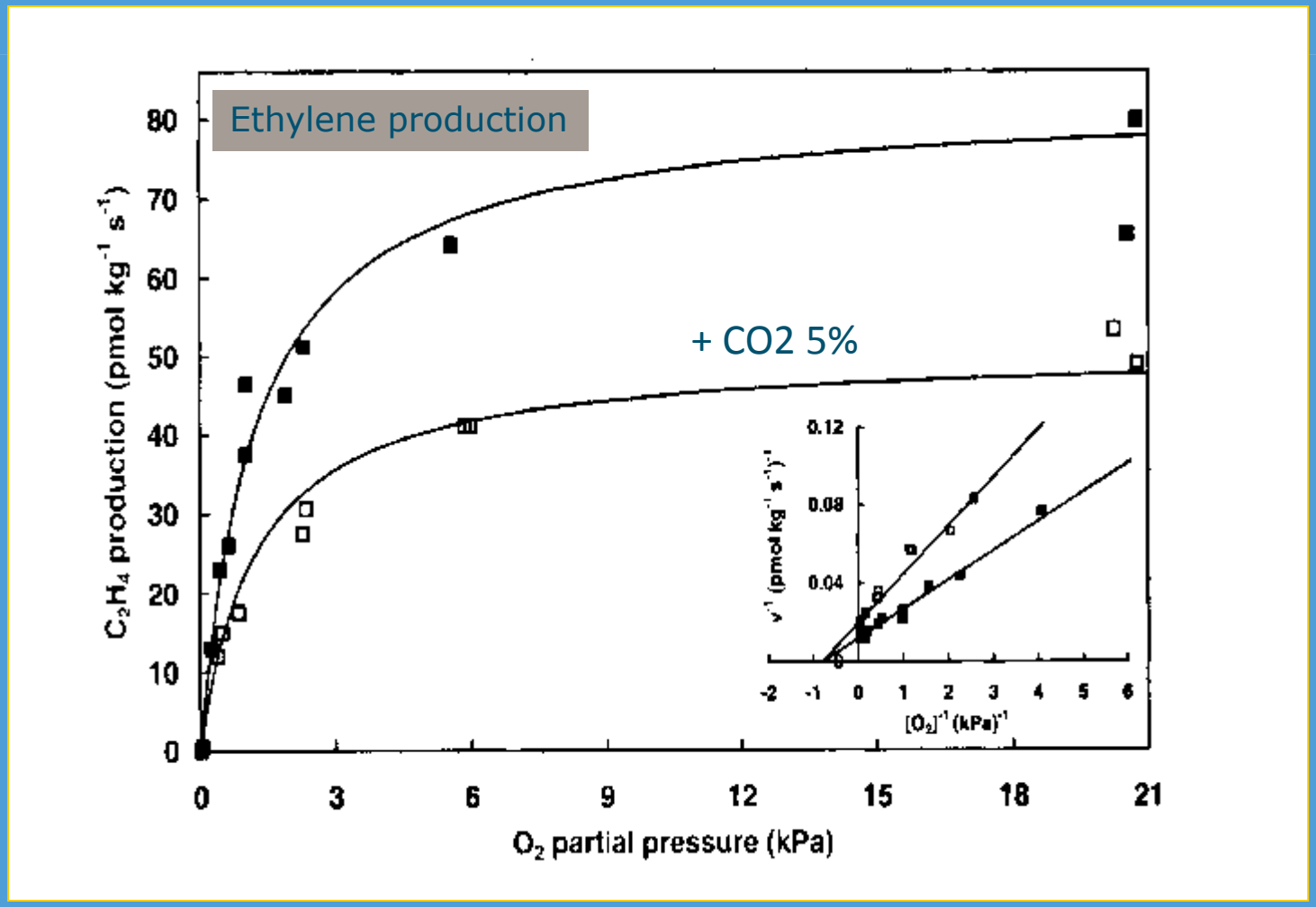


Brussels sprouts stored at 0 and 5C



Damage because of ethylene produced by the sprouts themselves; storage for 3 weeks at 2 temperatures.

Oxygen and carbon dioxide dependent ethylene production pears

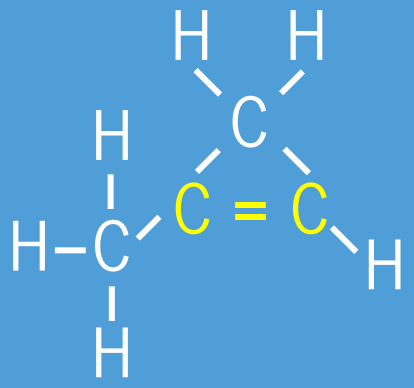


SmartFresh

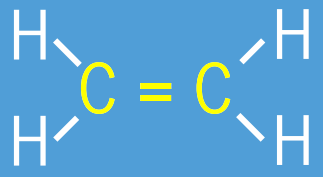
SmartFresh quality Crop Overview

- The SmartFreshSM Quality System ensures that packers and shippers of fresh produce and their retail customers can offer consistently high-quality produce to consumers with total confidence. Consumers enjoy the benefits of these best-quality fruits and vegetables for longer.

Ethylene and 1-MCP



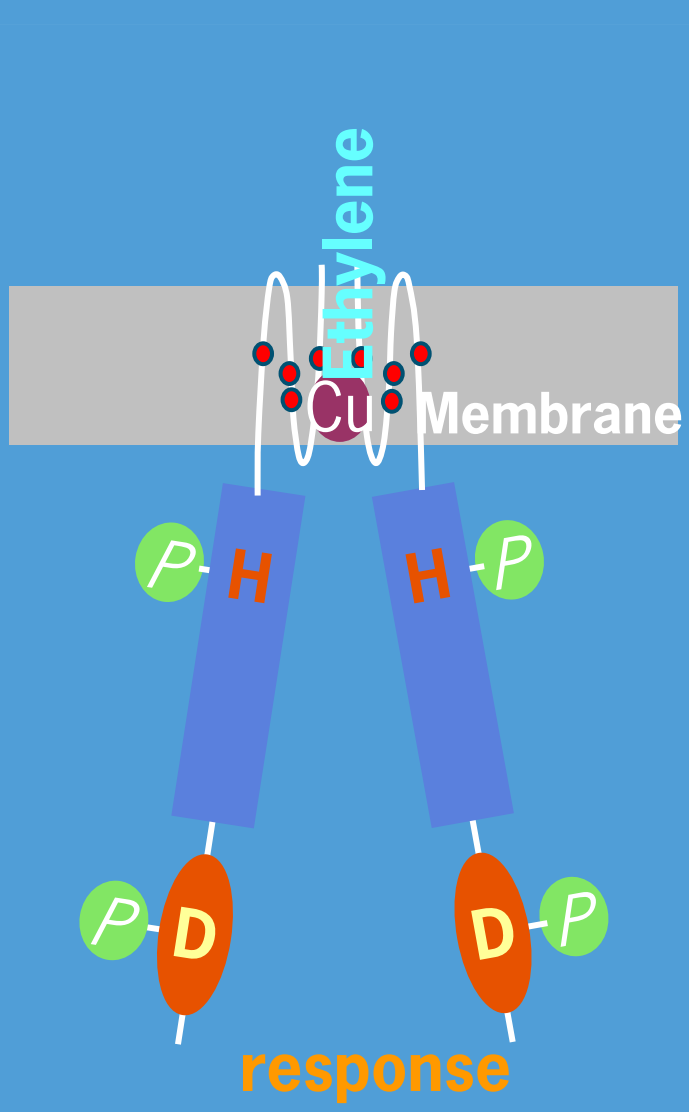
1-Methylcyclopropene (1-MCP)

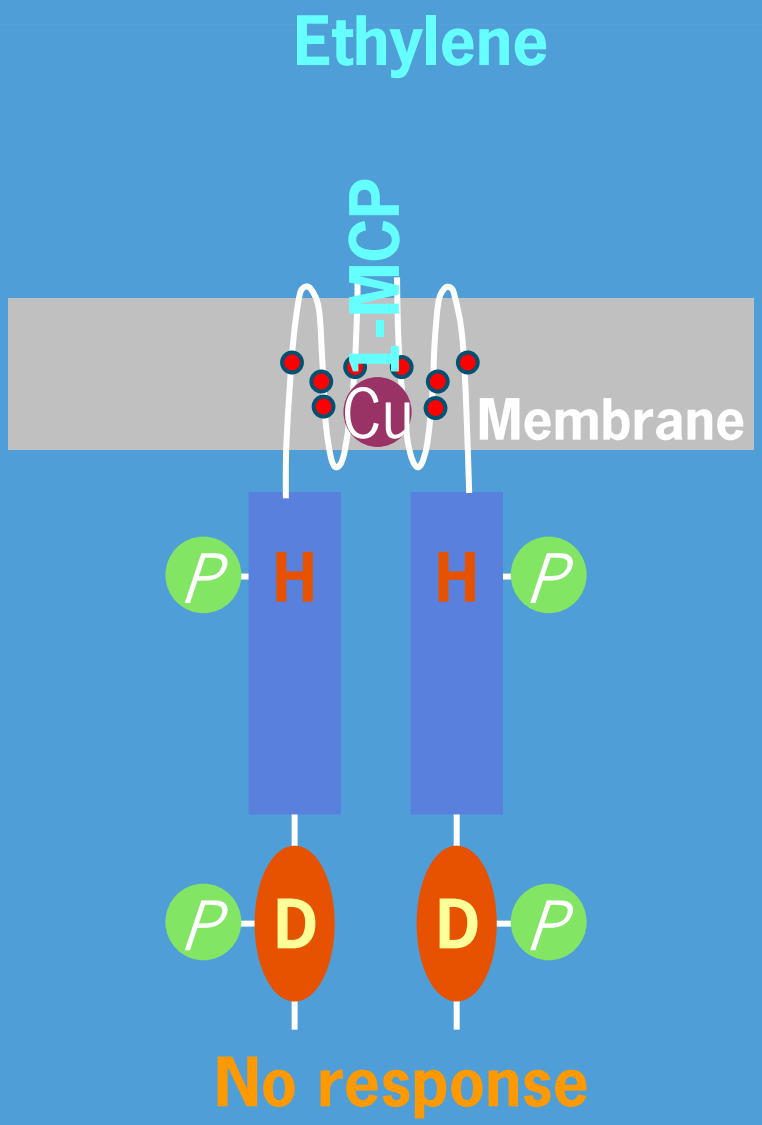


Ethylene

1-MCP prevents ethylene from occupying the receptor

1-MCP

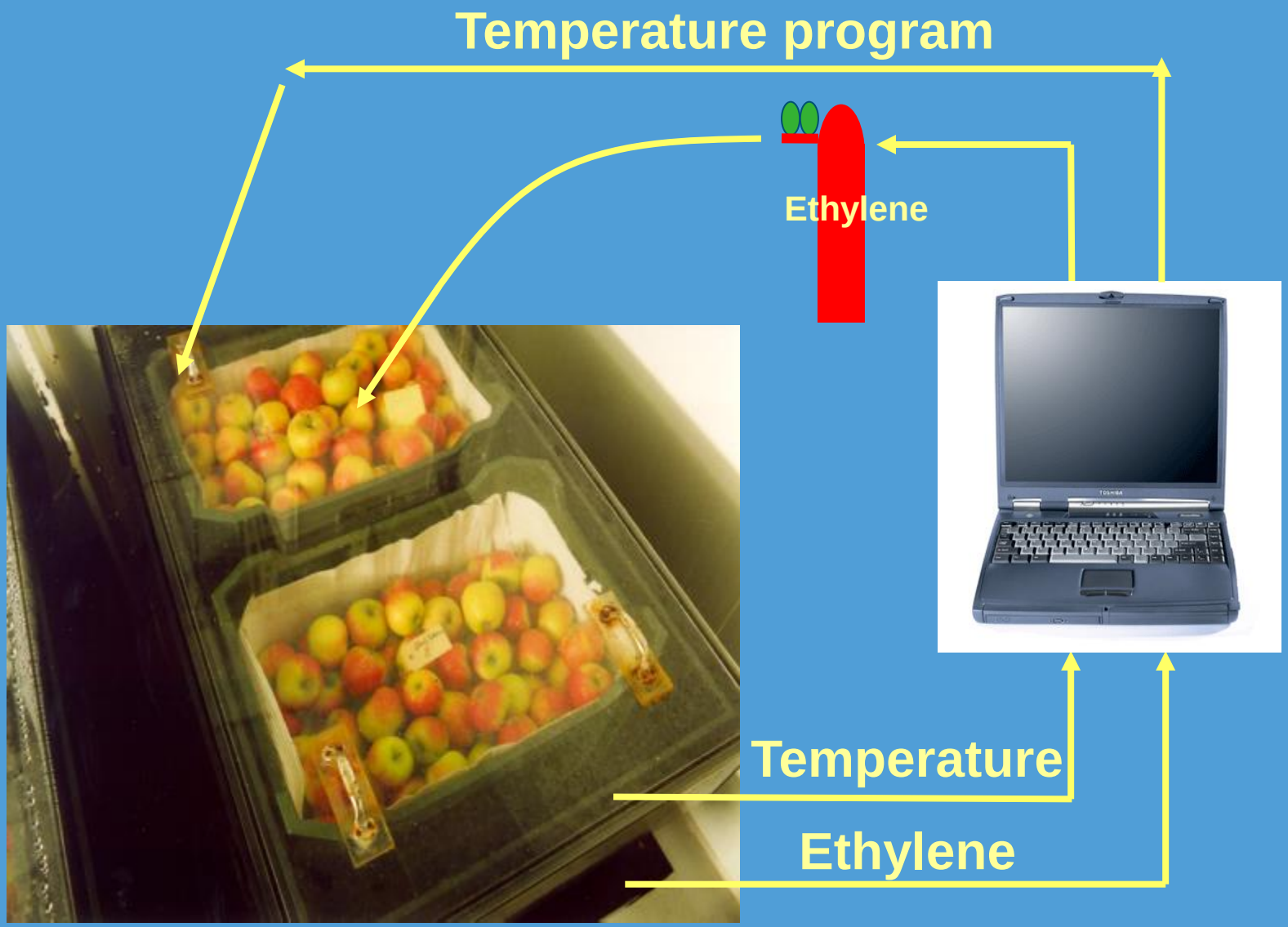

Ethylene
Cu
Membrane
P
H
H
P
P
D
D
P
response


Ethylene
1-MCP
Cu
Membrane
P
H
H
P
P
D
D
P
No response

Ethylene & storage technology

- Ethylene causes ripening and senescence
- Keeping the temperature low prevents ethylene problems
- CA conditions block ethylene sensitivity & production
- 1-MCP blocks ethylene sensitivity
- Ethylene can be removed from the atmosphere by
  - Ventilation
  - Absorbents
  - Catalytic breakdown
  - Breakdown reaction with Ozone

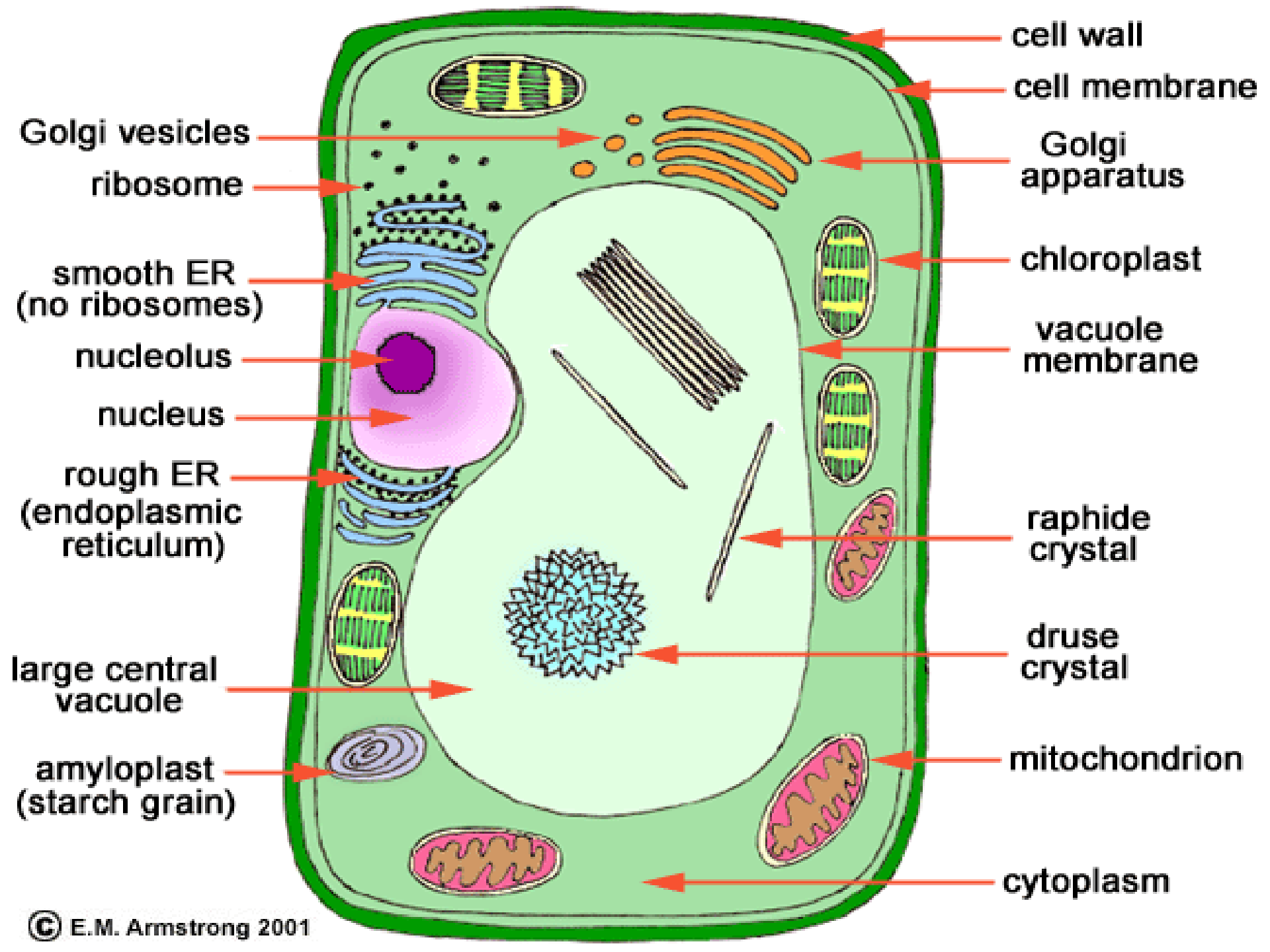
Ripening-in-transit concepts



- Transpiration (product loses water)
  - VPD
  - Peel resistance to water flux
- Respiration (carbohydrate reserves are turned into heat)
  - Temperature
  - O2, CO2
- Ethylene biosynthesis (ripening and rotting hormone)
  - Temperature
  - O2, CO2, “stress”
- Ripening & senescence (product becomes unusable)
  - Temperature
  - Ethylene

Senescence (ageing)

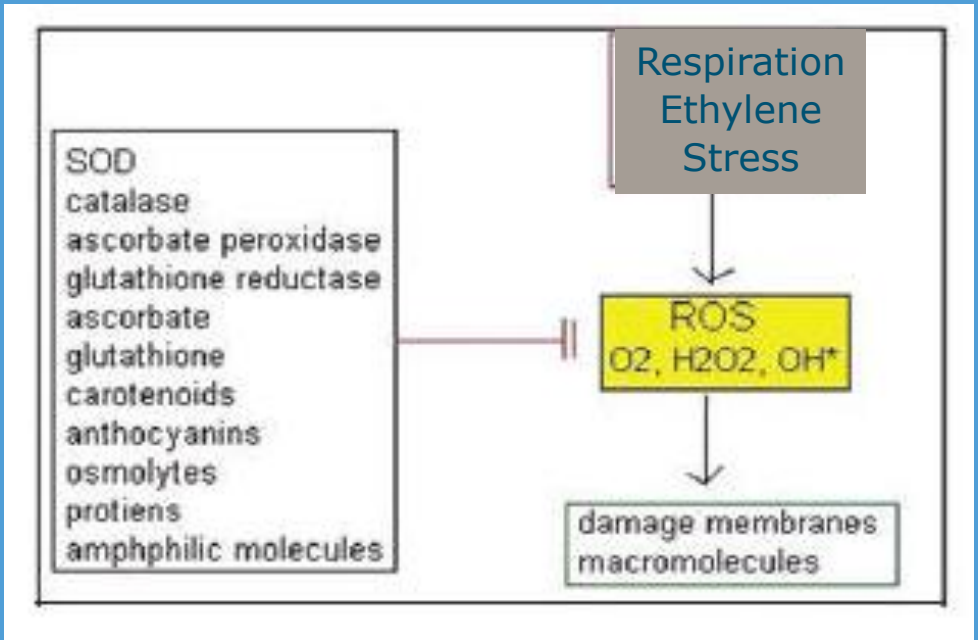
- High respiration rate and ethylene stimulate ripening processes and over-ripening (senescence)
- Senescence or ageing is a process that leads to internal breakdown and death of the plant cells, often reflected as loss of tissue structure, glassiness, browning
- The integrity (quality, functioning) of biological membranes is important
- Senescence is an “active” process which is slowed down at lower temperature


cell wall
cell membrane
Golgi vesicles
Golgi apparatus
ribosome
chloroplast
smooth ER (no ribosomes)
vacuole membrane
nucleolus
nucleus
rough ER (endoplasmic reticulum)
raphide crystal
druse crystal
large central vacuole
amyloplast (starch grain)
mitochondrion
cytoplasm
© E.M. Armstrong 2001

Senescence

- In the respiratory processes there are Reactive Oxygen Species produced (ROS)
- Ethylene stimulates ROS production
- "stress" stimulates ROS production
- ROS damage the membranes >>> Cells die!

- Balance between:
  - ROS activity
  - Scavenger activity



Over-ripening, senescence

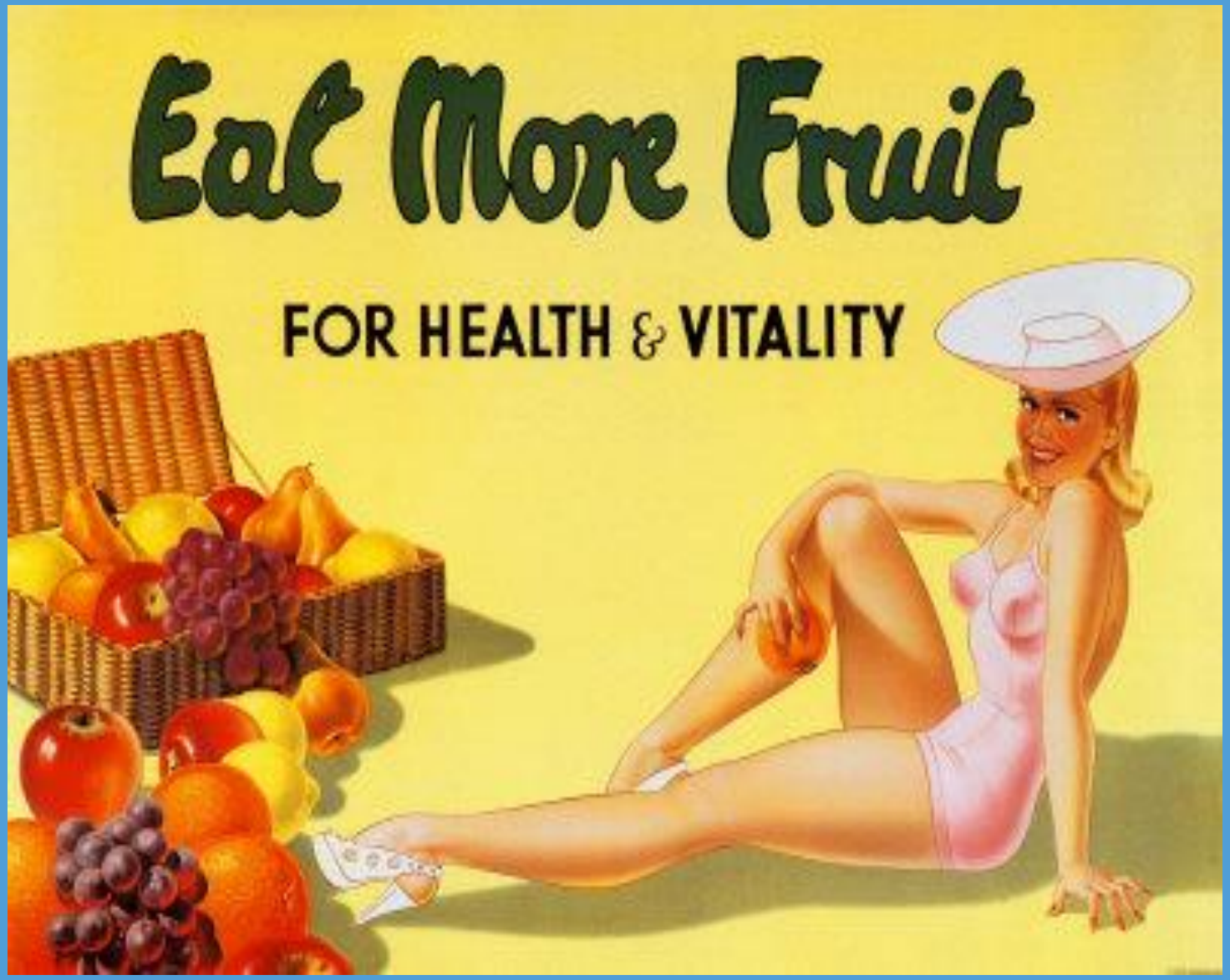
Over-ripening, Senescence

- To slow down ripening and ageing (senescence) processes it is important to:
  - Lower respiration
  - Prevent ethylene action
  - Prevent stress (such as too low or too high temperature, too low O2 or too high CO2)

Mango transport & ripening

mango ripening models

- Models were developed to support delivery of Ready to Eat (R2E) and Ready to Enjoy (R2N) fruit
  - Better ripening protocols
  - Greater % fruit R2E or R2N
  - Less waste!
  - Guaranteed quality!
  - Allows product segmentation
  - More sales?
- Models are based on firmness decay (R2E) and sugar levels (R2N)


Eat More Fruit
FOR HEALTH & VITALITY