Respiration is tied to many metabolic process within a cell

- Thus:
  - It is an accurate indicator of the general metabolic state of a cell
  - The rate of respiration is influenced by many internal and external factors that affect general metabolism
Internal Factors

- Genotype of a commodity
- Type of plant part
- Stage of development at harvest
- Respiratory substrate
- Preharvest factors

Class (mg CO₂/kg-hr) at 5°C (41°F) Commodities

<table>
<thead>
<tr>
<th>Class</th>
<th>Range</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>&lt; 5</td>
<td>Dates, dried fruits and vegetables, nuts</td>
</tr>
<tr>
<td>Low</td>
<td>5 - 10</td>
<td>Apple, beet, celery, citrus fruits, cranberry, garlic, grape, honeydew melon, kiwifruit, onion, papaya, pineapple, potato (mature), sweet potato, watermelon</td>
</tr>
<tr>
<td>Moderate</td>
<td>10 - 30</td>
<td>Apricot, banana, blueberry, cabbage, cantaloupe, carrot (topped), kiwifruit, lettuce (head), mango, nectarine, olive, peach, pear, plum, potato (immature), radish (topped), summer squash, tomato, watermelon</td>
</tr>
<tr>
<td>High</td>
<td>20 - 40</td>
<td>Artichoke, blackberry, carrot (with tops), cauliflower, leeks, lettuce (leaf), lima bean, radish (with tops), raspberry</td>
</tr>
<tr>
<td>Very High</td>
<td>40 - 60</td>
<td>Arthritis, bean sprouts, broccoli, Brussel sprouts, collard blooms, endive, green onions, kale, okra, snap bean, watercress</td>
</tr>
<tr>
<td>Extremely High</td>
<td>&gt; 60</td>
<td>Asparagus, mushroom, parsley, peas, spinach, sweet corn</td>
</tr>
</tbody>
</table>
Internal Factors

- Stage of development at harvest
  - Maturing plant organs usually have declining rates of respiration

<table>
<thead>
<tr>
<th>Respiration Rate</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapidly senescing</td>
<td></td>
</tr>
<tr>
<td>Slowly senescing</td>
<td></td>
</tr>
</tbody>
</table>

Climacteric Commodities

- Have a “ripening phase” (e.g. soften, become sweeter & less acidic, develop characteristic aromas, etc.).

Climacteric
- Apple
- Apricot
- Avocado
- Banana
- Breadfruit
- Carnation
- Cherimoya
- Feijoa
- Fig
- Guava
- Jackfruit
- Kiwifruit
- Mango
- Musk melon
- Nectarine
- Papaya
- Passion Fruit
- Peach
- Pear
- Persimmon
- Plum
- Quince
- Rambutan
- Sapodilla
- Sapote
- Soureap
- Tomato
- Blueberry
- Cacao
- Carambola
- Cherry
- Cucumber
- Grape
- Grapefruit
- Lemon
- Lime
- Lenggan
- Loquat
- Lychee
- Olive

Non-Climacteric
- Orange
- Pepper
- Pineapple
- Pomegranate
- Passion Fruit
- Passion Fruit
- Peach
- Pear
- Persimmon
- Plum
- Quince
- Rambutan
- Sapodilla
- Sapote
- Sourap
- Tomato
**Climacteric Commodities**

- Have increased respiration & ethylene production during ripening

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**Phases of the Climacteric**

1. The preclimacteric
2. The preclimacteric minimum
3. The climacteric rise
4. The climacteric peak
5. The postclimacteric phase
Internal Factors

- Respiratory Substrate – carbohydrates, lipids, and organic acids

Respiratory quotient (RQ) = \frac{\text{CO}_2 \text{ evolved}}{\text{O}_2 \text{ consumed}}

- RQ range from 0.7 to 1.3 for aerobic (with O₂) respiration
- RQ is much greater if tissue goes into anaerobic (without O₂) respiration

Internal Factors

- Respiratory quotient (RQ) when the cell utilizes different types of substrates for respiration
  - Carbohydrates: RQ = 1
  - Lipids: RQ < 1
  - Organic Acids: RQ > 1

Internal Factors

- Preharvest factors such as:
  - Plant nutrition
    - e.g. nitrogen & calcium
  - Water supply
  - Pruning, training and thinning
  - Insect & Pathogen pressures
  - Climate and weather patterns
    - Temperature
    - Humidity
    - Wind
    - Light intensity, etc.
Environmental Factors

- Temperature
- Atmospheric composition
  - Oxygen concentration
  - Carbon dioxide concentration
  - Ethylene
- Physical stresses
- Pathogen attack
- Other plant growth regulators
- Radiation
- Light
- Chemical stress
- Water stress

Respiration and Shelf Life

- Respiration rate is inversely related to shelf life
  - Higher respiration =>
    - => Shorter Shelf Life

Environmental Factors

Temperature

- Temperature is the most important factor influencing postharvest life of a given commodity
  - Dictates the speed of chemical reactions (including respiration)
- Typically, for every 10 °C (18 °F) increase, respiration increases between 2 and 4 fold (Q10 or Van’t Hoff Rule)
Affect of temperature on the quality of broccoli after just 48 h of storage at either room temperature (24°C; 75°F) or in the refrigerator (4°C; 40°F)

**Temperature Coefficient (Q₁₀)**

\[ Q_{10} = \left( \frac{R_2}{R_1} \right)^{\frac{10}{T_2-T_1}} \]

- \( R_1 \) = rate of reaction at temperature 1 (\( T_1 \))
- \( R_2 \) = rate of reaction at temperature 2 (\( T_2 \))

Temperatures are in °C.

With a 10 °C change in temperature, \( Q_{10} = \frac{R_2}{R_1} \)

**Typical \( Q_{10} \) Values**

<table>
<thead>
<tr>
<th>Temperature Range (°C)</th>
<th>( Q_{10} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 10</td>
<td>2.5 – 4.0</td>
</tr>
<tr>
<td>10 – 20</td>
<td>2.0 – 2.5</td>
</tr>
<tr>
<td>20 – 30</td>
<td>1.5 – 2.0</td>
</tr>
<tr>
<td>30 – 40</td>
<td>1.0 – 1.5</td>
</tr>
</tbody>
</table>
Temperature effects on shelf-life

<table>
<thead>
<tr>
<th>Temperature °C (°F)</th>
<th>Q_10</th>
<th>Deterioration</th>
<th>Shelf-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (32)</td>
<td>1</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>10 (50)</td>
<td>3</td>
<td>3</td>
<td>33</td>
</tr>
<tr>
<td>20 (68)</td>
<td>2-5</td>
<td>7.5</td>
<td>13</td>
</tr>
<tr>
<td>30 (86)</td>
<td>2</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>40 (104)</td>
<td>1.5</td>
<td>22.5</td>
<td>4</td>
</tr>
</tbody>
</table>

E.g. grapes at 32°C (90°F) for 1 h = 1 day at 4°C (39°F) = 1 week at 0°C (32°F)

Example of Calculating The Q_10

- Say there is a new variety of Grapefruit
- Researchers have determined the following respiration rates at different temperatures:
  - 5 mg CO₂/kg-hr at 0°C (32°F)
  - 10 mg CO₂/kg-hr at 5°C (41°F)
  - 15 mg CO₂/kg-hr at 10°C (50°F)
  - 30 mg CO₂/kg-hr at 20°C (68°F)
  - 45 mg CO₂/kg-hr at 30°C (86°F)
  - 55 mg CO₂/kg-hr at 35°C (95°F)

Example of Calculating The Q_10

- How much additional shelf life would a packinghouse manager expect if they held fruit at 10°C (50°F) compared to 30°C (86°F)?
- First, determine Q_10 between 10 & 20°C, and between 20 & 30°C

\[
Q_{10} = \left( \frac{R_2}{R_1} \right) \left( \frac{T_2 - T_1}{T_1 - T_1} \right)
\]

If \( T_2 - T_1 = 10 \) Then \( Q_{10} = \frac{R_2}{R_1} \)
Example of Calculating The $Q_{10}$

- First, determine $Q_{10}$ between 10 & 20°C
  $-15$ mg CO$_2$/kg-hr = $R_1$
  $-10$°C = $T_1$
  $-30$ mg CO$_2$/kg-hr = $R_2$
  $-20$°C = $T_2$

$$Q_{10} = \left(\frac{10}{15}\right)^\frac{30-15}{18-10} = 2$$

Example of Calculating The $Q_{10}$

- Determine $Q_{10}$ between 20 & 30°C
  $-30$ mg CO$_2$/kg-hr = $R_1$
  $-20$°C = $T_1$
  $-45$ mg CO$_2$/kg-hr = $R_2$
  $-30$°C = $T_2$

$$Q_{10} = \left(\frac{45}{30}\right)^\frac{30-20}{10-8} = 1.5$$

Calculated $Q_{10}$ Values for the new grapefruit variety

<table>
<thead>
<tr>
<th>Temperature Range (°C)</th>
<th>$Q_{10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 10</td>
<td>(you calculate)</td>
</tr>
<tr>
<td>10 – 20</td>
<td>2</td>
</tr>
<tr>
<td>20 – 30</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Temperature effects on shelf-life

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Q₁₀</th>
<th>Shelf-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>30</td>
<td>1.5</td>
<td>10</td>
</tr>
</tbody>
</table>

Thus, 10 days at 30°C = 15 days at 20°C = 30 days at 10°C

Low Temperature Injury

- **Freezing** will kill the tissue
- **Chilling** sensitive commodities
  - Q₁₀ is usually much higher at chilling temperatures. In some commodities, respiration may increase at the lowest chilling temperatures
  - Upon return to non-chilling temperatures, respiration becomes abnormally high and may remain high

High Temperature Injury

- Respiration increases as temperature increases to a point
  - Above that point (tissue & commodity specific) protein denatures and respiration declines rapidly
- Time x Temperature component to thermal cell death
  - Cells can survive short periods at high temperatures (used for some quarantine treatments)
High Temperature Injury

- Heat shock (brief exposure to high, non-lethal temperatures) can protect cells from subsequent high or low temperature stress
  - Induce the production of heat-shock proteins
  - Turns on the antioxidant defense system that counters reactive oxygen species (ROS) that can damage cellular components

Atmospheric Concentration

Oxygen

- Low O₂ concentrations reduce respiration.
  - Below ~2–3% O₂, ETS starts to be inhibited
- If metabolic (ATP) demand is higher than inhibited Krebs cycle and ETS can supply, anaerobic respiration will attempt to satisfy ATP demand
  - Anaerobic respiration only produces 2 ATP per glucose vs. 30 ATP under aerobic respiration = 15 fold greater ATP production under aerobic conditions
  - CO₂ production is faster under anaerobic respiration (at least 15-fold higher!)

Carbon Dioxide

- High CO₂ also reduced respiration
  - Probably by inhibiting decarboxylation during aerobic respiration
- Different commodities vary widely to their ability to tolerate high CO₂ (e.g. lettuce very sensitive vs. strawberries very tolerant)
- As with low O₂ inhibition, if metabolic (ATP) demand is higher than inhibited Krebs cycle and ETS can supply, anaerobic respiration will attempt to satisfy ATP demand
Relationship Between O2 and CO2 Concentrations and Respiratory Metabolism

Atmospheric Concentration Ethylene

- Climacteric & Non-Climacteric plant organs differ in their response to ethylene in the environment
- Climacteric fruit:
  - Ethylene reduces the time to onset of the climacteric rise (including autocatalytic ethylene production)
  - Concentration of added ethylene has little effect on respiration rate before or during the climacteric

Atmospheric Concentration Ethylene

- Non-Climacteric fruit:
  - Added ethylene induces a rise in respiration
  - Exposure to greater ethylene concentrations do not change how fast maximum respiration rates are obtained
  - Exposure to greater ethylene concentrations elicit greater rates of respiration
  - Does not induce autocatalytic ethylene production
  - Respiration rates return to normal after ethylene is removed
Physical Stress

- Any type of physical stress can cause respiration and ethylene production to rise quickly in both climacteric and non-climacteric commodities

Environmental Factors

- Temperature
- Atmospheric composition
  - Oxygen concentration
  - Carbon dioxide concentration
  - Ethylene
- Physical stresses
- Pathogen attack
- Other plant growth regulators
  - Light
  - Radiation
  - Chemical stress
  - Water stress