Chapter 1, section 3

RESPIRATION

果蔬采后的呼吸作用

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Some Questions 1

- 果蔬采前与采后代谢有何差异？
- 呼吸的本质是什么？
- 呼吸有何意义？
- 呼吸可分哪些类型？各有何特点？
- 如何衡量呼吸的强弱？
- 如何测定果蔬的呼吸强度？
- 测定果蔬的呼吸强度有何意义？

Some Questions 2

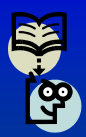
- 呼吸跃变指什么？
- 如何区分跃变型果蔬与非跃变型果蔬？
- 呼吸热指什么，如何计算？
- 呼吸商指什么？有何意义？
- 呼吸的温度系数指什么？
- 呼吸作用的保护作用指什么？
- 影响果蔬呼吸作用的因素有哪些？
- 内因，外因

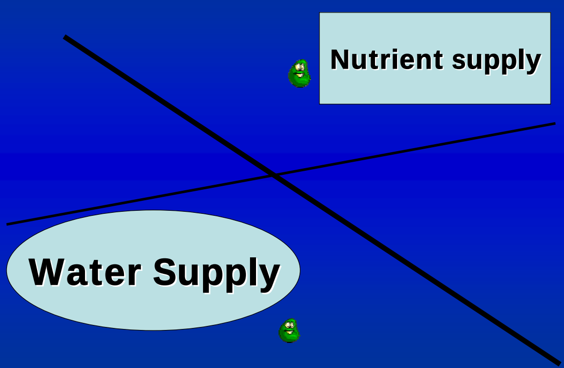
果蔬采后的代谢与采前相比，有何差异？

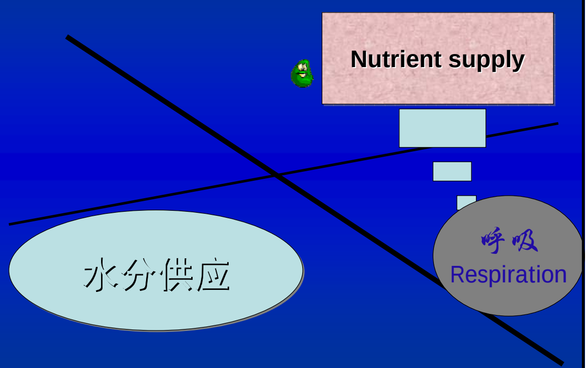
Metabolism difference

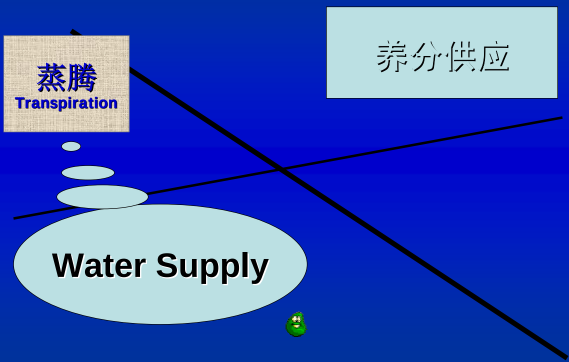
Preharvest ←→Postharvest

What?









- 果蔬采后仍是活的有机体 Still Alive!
- 采后无水分、养分供应 No Water, Nutrient supply
- 呼吸是主要的生理代谢 Respiration
- 呼吸消耗影响果蔬的贮藏寿命与商品价值 Affect Storage life and Commercial value
- 贮藏保鲜的基本任务 essence task of storage

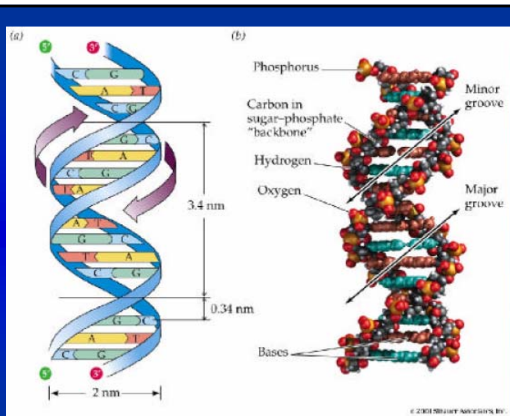
Introduction & Measurement

I. Important Organic Compound

- Four major groups:
  - Nucleic acids
  - Proteins
  - Lipids
  - Carbohydrates
- Another important group are
  - phenolic

Nucleic Acids

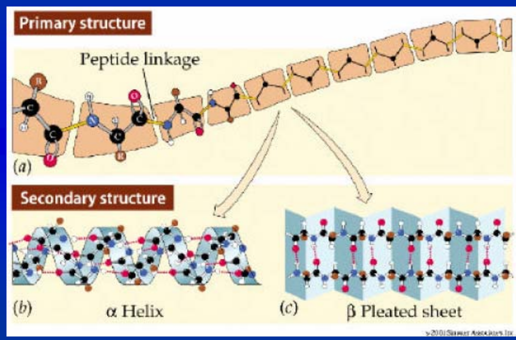
- Genetic information=Polymers of nucleotides.
  - RNA – ribonucleotide polymer.
  - DNA – deoxyribonucleotides.
- Nucleotide=sugar+phosphate+base
  - Sugar=ribose.
  - Base=Adenine, Thymine, Guanine, Cytosine.



Amino Acids & Proteins

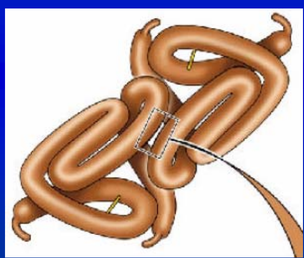
- Comprise up to ~30% of plant DW.
- Some seeds may have as much as 40% DW protein – storage.
- Proteins – comprised of chains of amino acids linked by peptide bonds.
- Proteins – important biological polymers
  - Enzymes
  - Structural components
  - Storage proteins

Protein structure



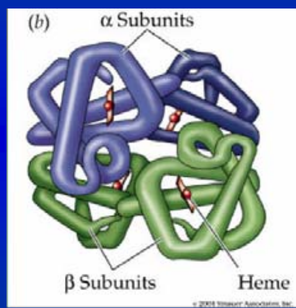
Protein structure

- Tertiary Structure
  - Three dimensional



Protein structure

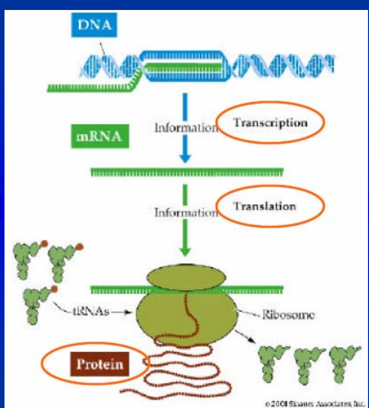
- Quaternary structure
  - Two or more polypeptides that combine to form complexes.



Nucleus

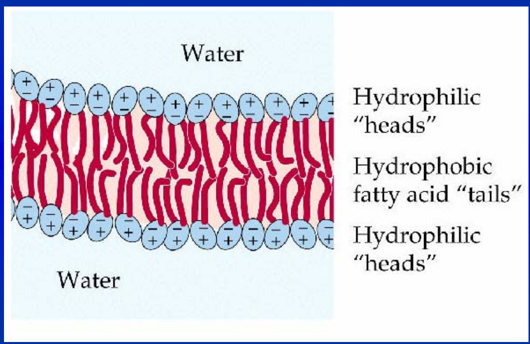
mRNA Processed & Transported

Cytosol

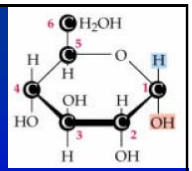


Lipids

- Main membrane constituent.
- Long term energy storage.
  - Can be converted to carbohydrates in plants via the glyoxylate cycles.
- Insoluble in water.
- Structural components – cuticle.

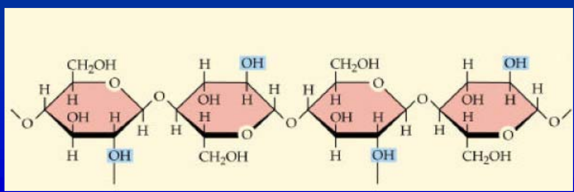


Carbohydrates

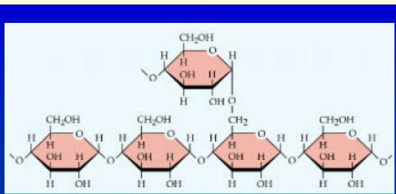


- General formula
  - $(CH_2O)_n$
- Primary energy storage compounds
  - Short term storage – sugars
  - Intermediate term storage - starch
- Also important structural component
  - e.g. cell walls: cellulose, hemicellulose, & pectin.
- Direct products of photosynthesis

Cellulose (β1-4)



Starch (α1-4)



Carbohydrates

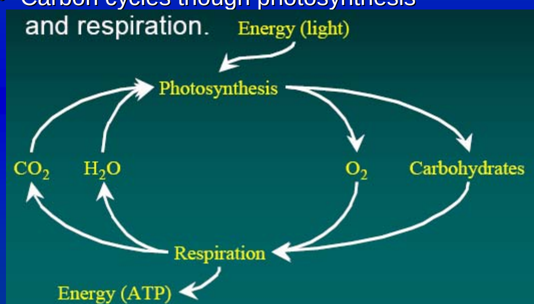
- Monosaccharides:
  - E.g. Glucose & Fructose
- Disaccharides = 2 monosaccharides:
  - E.g. Sucrose (glucose + fructose).
- Polysaccharides:
  - Starch – made of many glucoses (α linked)
  - Cellulose – made only of glucose (β linked)
- Sweetness: Fructose > Sucrose > Glucose.

Phenolic Compounds

- General classes:
  - Lignin, tannins, flavonoids, coumarins, etc.
- Most formed from phenylalanine.
- Important impacts on produce quality:
  - Lignin (texture)
  - Browning reactions (color)
  - Astringency (taste)
  - Phytoalexins (defense)

Carbon Metabolism

- Carbon cycles though photosynthesis and respiration.



Respiration

Sugar + O_2 =>

CO_2 + Water + Energy + Heat

呼吸作用既是本身生存的表现，又是自身消亡的动力

Meaning of Respiration
呼吸的意义

- ① 呼吸作用将光能以物质化学能形式贮存的能量释放出来，形成ATP，供各种生理活动之需。另外，伴随呼吸过程产生的还原型辅酶（NADH和NADPH）可供生物体内其它还原反应所利用。

Meaning of Respiration
呼吸的意义

- ② 有机物分解过程中产生的各种代谢中间产物，可做构成植物体的材料，也为其它合成反应提供原料物质。

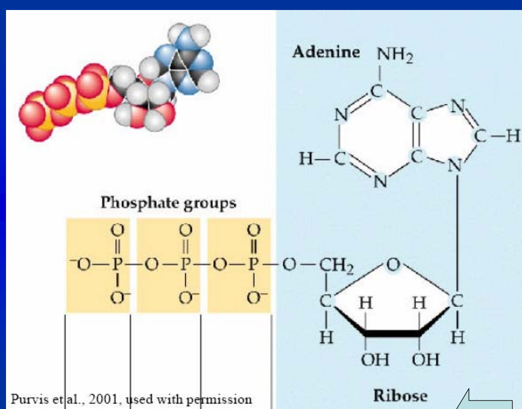
- ③ 呼吸作用具有保护作用。

Use of Energy

- During carbohydrate oxidation (respiration), ATP & heat are produced.
  - ATP molecules are intermediate energy molecules that are easily transported within a cell to sites of action.
  - At sites of action, ATP is coupled to different processes to “power” them.
  - Energy not captured as ATP or not completely used in a process is lost as heat.

Adenosine Triphosphate (ATP)

- Adenosine triphosphate (-P-P-P).
  - Energy is stored in each P bond.
- Intermediate energy molecules – analogous to rechargeable batteries.



Respiration & Heat

- First Law of Thermodynamics:
  - Energy can not be created or destroyed.
  - Thus, total energy at the beginning of a reaction must equal energy at the end.

Respiration & Heat

- Respiration creates 38 ATP per glucose molecule, but 674 kcal total energy.
  - 1 ATP= ~7.3 kcal
  - 7.3 kcal * 38 ATP=277 kcal
  - 674kcal – 263 kcal = 397 kcal lost as heat
- If not removed, lost energy will raise the cell /tissue temperature.
  - Heat pumps (refrigeration) move heat from one place to another.

Thermodynamics – 2nd law

- Entropy (disorder) of a system will always increase with time.
- Biological systems are very ordered (low entropy) and maintain their order by making their environment more disordered.
  - Organisms expend energy to counteract the natural tendency to disorganize.
  - Without a constant energy supply, organisms would disorganize and die.
  - Living organisms are never at equilibrium.

Thermodynamics – 2nd law

- When commodities are detached from the plant, they are severed from their food (energy) supply must live on what they have stored.

Types of Respiration

- Aerobic respiration有氧呼吸
- Anaerobic respiration无氧呼吸
- Cyanide resistant pathway抗氰呼吸

Respiration Overview

- Respiration is composed of three parts:
  - Glycolysis 糖酵解– located in the cytoplasm.
  - Krebs cycle 三羧酸循环– located in the mitochondria matrix.
  - Electron Transport System (ETS) 电子传递途径– located on the inner mitochondria membrane.
- Central to overall cell metabolism and synthesis of important compounds.

Respiration Analogy

- Fuel
  - E.g. starch, glucose, fructose, and sometimes amino acids, organic acids or fats.

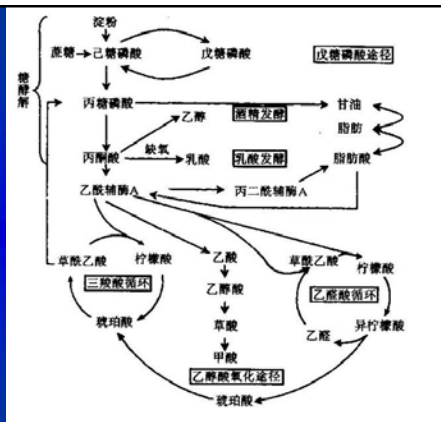
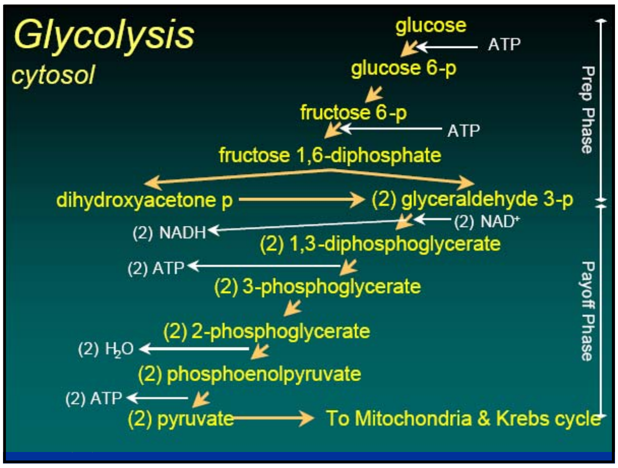


图2-5 植物体内主要呼吸代谢途径相互关系示意图

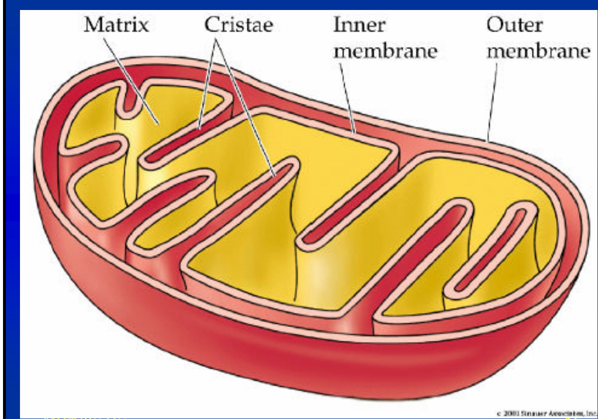
Respiration Analogy

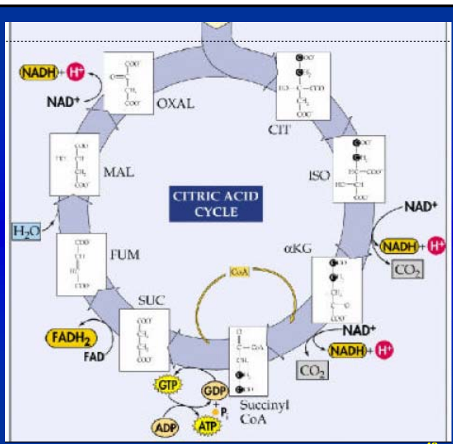
- Processing (Glycolysis)
  - Occurs in the cytoplasm.
  - Turns the fuel into pyruvate.
    - This is transported to the mitochondria and converted into acetyl CoA (a 2-carbon molecule).
  - Also produces a little ATP.



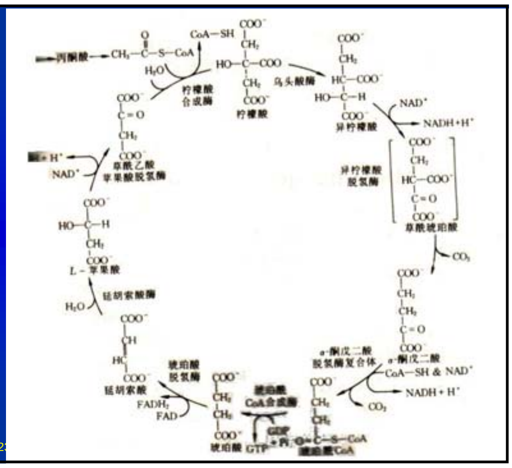
Respiration Analogy

- Furnace & Turbines (Krebs or TCA cycle)
  - Occurs in the mitochondria (powerhouses of the cell).
  - Produces compounds (e.g. NADH) that will be used to make ATP.
  - Produces a little ATP directly.



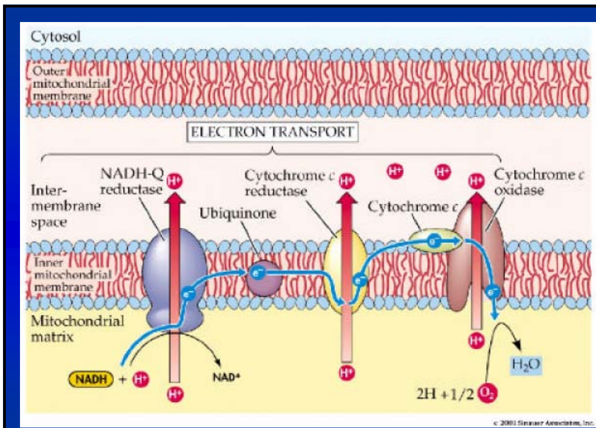


TCA



Respiration Analogy

- Generator (Electron Transport System or ETS)
  - ETS is located on the mitochondrion inner membrane.
  - Products from the Krebs cycle are used to make ATP.



Aerobic Respiration

总反应式:

$$C_6H_{12}O_6+6O_2+36ADP+38H_3PO_3 \rightarrow 6CO_2+36ATP+6H_2O+1.77\times10^6 J(423kcal)$$

Anaerobic Respiration

- Anaerobic respiration = without O_2.
  - Also called fermentation.
- Without O_2, normal ETS cannot function and the pathways backs up (to pyruvate).
- Glycolysis can still function.
  - Pyruvate is shunted off to make Ethanol or Lactic Acid.
- Only 2 ATP formed per glucose.
  - Compared to 36 in aerobic respiration.

Anaerobic Respiration

$CH_3COCOOH$ → $CH_3CHO+CO_2$

丙酮酸脱羧酶

乙醇脱氢酶

$CH_3CHO+2NADH+H^+$ → CH_3CH_2OH+ $2NAD^+$

Energy: 87.9kJ(21kcal)

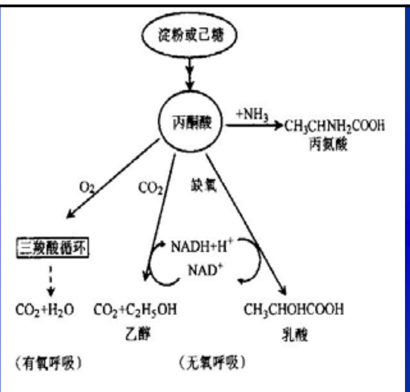
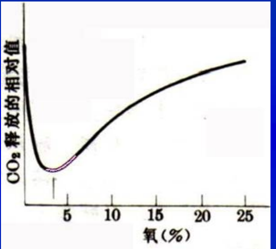


图2-6 丙酮酸在呼吸代谢和物质转化中的作用



植物组织在不同氧水平中释放CO_2的动态模式图

无氧呼吸？

Why?

Cyanide Resistant Pathway

- Many plant tissues have a cyanide resistant pathway (or alternative oxidase pathway).
  - Produces only ~ 1/3 the ATP of the normal pathway (complexes 3 & 4 are bypassed).
  - The loss in efficiency results in much greater heat production.
  - In arum spadices, the cyanide resistant pathway increases tissue temperature up to 10C.

Cyanide Resistant Pathway

- 氰化物阻遏呼吸链电子的传递，阻断有氧呼吸

e^-

NADH → FMN→Fe-S→CoQ→b→G → a→a_3 → O_2

ATP ATP ATP

Respiratory rate
Respiratory intensity

- Units:
  - CO_2 mg/kg.hr
  - O_2 mg/kg.hr
- Concept:

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Respiratory rate
Respiratory intensity

How to Measure?

如何测定？

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Measuring Respiration

- Measure loss of substrates, or appearance of products.
  - Loss of carbohydrates (dry weight).
  - Measure of gas exchange
    - Loss of oxygen (O_2). Ambient concentration = ~21%
    - Appearance of carbon dioxide (CO_2). Ambient concentration =~0.03% (increasing).
  - Production of heat

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Dry Weight Loss

$$\text{Rate of Dry Wt. Loss (g/kg-hr)} = \frac{\text{Respiration Rate (mg } CO_2\text{/kg-hr)}}{1000 \text{ mg/g}} \times \frac{180}{264}$$

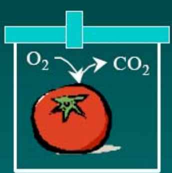
OR

$$\text{\% of Dry Wt. Loss per hr.} = \text{Respiration Rate (mg } CO_2\text{/kg-hr)} \times 68.2 \times 10^{-6}$$

- E.g. Onions held at 30C (respiration = 35 mg CO_2/kg-hr) will loose 1.72% dry wt. per month (30 d).

Measurement of Gas Exchange

- Static System 静置法
  - Tissue is placed in a sealed container and the loss of O_2 or increase of CO_2 are measured.
    - Measure over brief periods so that CO_2 does not accumulate above 0.2% (can inhibit respiration).

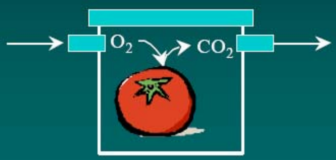


Measurement of Gas Exchange

- Static System 静置法
  - Easy to use and does not depend on a flow rate. However, any leaks (even small ones) will result in large errors.

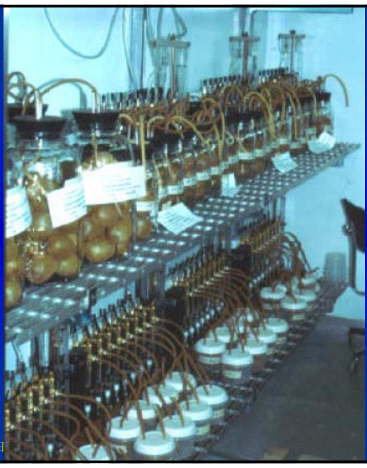
Measurement of Gas Exchange

- Flow-Through System. 气流法
  - Tissue is placed in a container and a flow of known gasses (often air) are passed through.

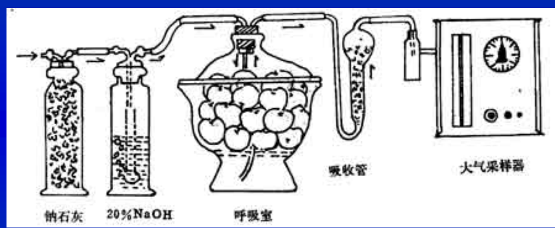


Measurement of Gas Exchange

- Flow-Through System. 气流法
  - O_2 uptake and CO_2 production is calculated by measuring the concentration differences between the inlet and outlet & knowing the gas flow rate.
  - Small leaks are not critical and gas concentrations are not altered far from ambient. However, it is more involved to set up.



气流法



Heat Production

- Newer, more sensitive & precise equipment now allows respiration via this technique.
- Knowledge of respiration rates help refrigeration engineers construct cooling & cold storage facilities.
  - Respiration rate of 1 mg CO_2/kg.hr ➔ 220 BTU per tonne of produce /day.
  - 1 BTU= heat required to raise 1 lb of water 1 F

测定呼吸强度有何意义？

Respiration

- 意义：
  - 衡量果蔬呼吸作用强弱
  - 估计果蔬的成熟度
  - 估计果蔬产品贮藏潜力

几种蔬菜在0℃~2℃时的呼吸强度（CO_2mg/kg.h）

种类	呼吸强度	种类	呼吸强度
石刁柏	44	番茄	18.8
甜玉米	30	甜瓜	5.0
豌豆	14.7*	甘蓝	6.0
菠菜	21	马铃薯	1.7~8.4
生菜	11	胡萝卜	5.4
菜豆	20	洋葱	2.4~4.8

* 为5℃下的呼吸强度

几种蔬菜早、晚熟品种呼吸强度比较(CO_2mg/kg.h)

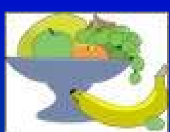
成熟性	种　　类		
	结球甘蓝	洋葱	萝卜
早熟	17.4	16.2	32.7
晚熟	24.8	33.4	57.6

Respiratory Heat
呼吸热

- 概念：
  - 果蔬呼吸作用中，有一部分能量以热能的形式散发出来，这种释放出的热量称呼吸热。
  - $C_6H_{12}O_6+6O_2 \rightarrow 6CO_2+6H_2O+674kcal$（2,821,364J）
  - 其中38ATP→304kcal，被再利用；还有369kcal以热的形式散发到周围环境中，贮存于ATP中的热量经其他途径消耗，最终也是以热量的形式释放出来。所以，674kcal最终都以热量的形式释放出来。

Respiratory Heat
呼吸热

- 呼吸热对贮藏的影响：
  - 呼吸热积累→温度升高→呼吸强度增大→寿命缩短



Respiratory Heat
呼吸热

如何测定或计算呼吸热？

$C_6H_{12}O_6+6O_2 \rightarrow 6CO_2+6H_2O+674kcal$（2,821,364J）

Respiratory Heat
呼吸热

- 呼吸热的计算：

$C_6H_{12}O_6+6O_2 \rightarrow 6CO_2+6H_2O+674kcal$

  - 分解1mol $C_6H_{12}O_6$，产生6mol CO_2和674kcal能量；6molCO_2的重量为：6×44=264g
  - 即产生264g CO_2可放出674kcal热量
  - 产生1gCO_2，则产生674÷264=2.553kcal的能量

Respiratory Heat
呼吸热

- 呼吸热计算公式：
  - 呼吸热(cal/kg.hr)=2.553×呼吸强度(mgCO_2/kg/hr)
  - 呼吸热的单位一般都以千卡/吨/天计算(× 24 hr×1000)
  - 呼吸热（千卡/吨/天）=呼吸强度（CO_2mg/kg/hr）×61.272

Respiratory Heat
呼吸热

- 呼吸热还可用B.t.u.（英国热量单位，British Thermal Unit）表示，1个B.t.u.等于将1磅水提高1° F需要的热量。 (1磅=454克)
  - 呼吸热（B.t.u./吨/天）=呼吸强度(mg CO_2/kg.hr) ×220 (英制)

Respiratory Heat
呼吸热

以B.t.u.为单位的一些果蔬的呼吸热：（B.t.u/天.吨，15-15.6℃）

香蕉（青）	4600~5100
苹果：	3000~6800
橙：	2800~5200
杏：	8300~15100
李：	2600~2800
菠萝：	2900~4000
洋梨：	3300~13200
桃：	7300~9300

Example of Respiratory heat calculation

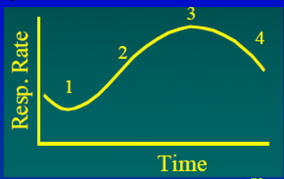
- 根据呼吸反应式可知，每释放1mgCO_2则释放能量10.7J(2.553cal)，那么，当RI=1mg/kg.hr时，每吨产品一昼夜放出的呼吸热=10.7×24×1000＝256.8kJ
- 若已测知某种产品的RI=15mg/kg.hr，则该产品每吨每日产生的呼吸热应为256.8×15＝3852KJ。假若该产品的比热为3.77J/g.℃，并设全部呼吸热无散失，则该产品每吨每天升温3852÷（3.77×1000）=1.02℃。

Climacteric vs. Non-Climacteric

- Climacteric Fruit.
  - Have a "ripening phase" (e.g. soften, become sweeter & less acidic).
  - Have increased respiration & ethylene production during ripening.
- Non-Climacteric Fruit.
  - Do not go through a "ripening phase".

Phases of the Climacteric

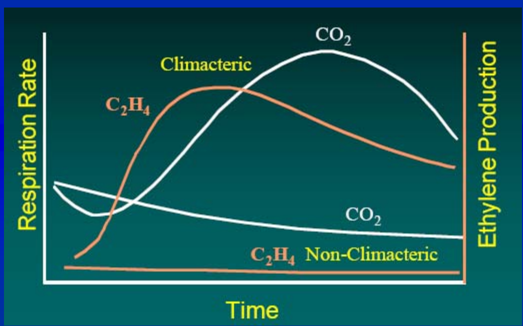
1) The preclimacteric minimum
2) The climacteric rise
3) The climacteric peak
4) The postclimacteric phase

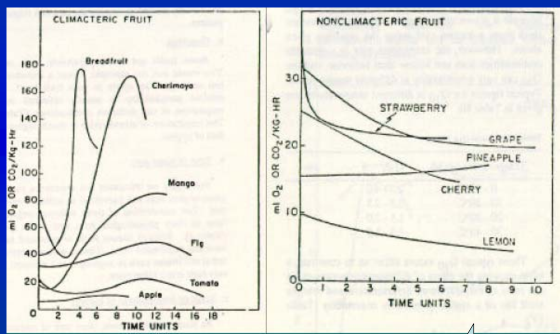


Climacteric Non-Climacteric

Climacteric		Non-Climacteric	
Apple	Nectarine	Blueberry	Orange
Apricot	Papaya	Cacao	Pepper
Avocado	Passion Fruit	Carambola	Pineapple
Banana	Peach	Cherry	Pomegranate
Breadfruit	Pear	Cucumber	Strawberry
Carnation	Persimmon	Grape	Tamarillo
Cherimoya	Plum	Grapefruit	
Feijoa	Quince	Lemon	
Fig	Rambutan	Lime	
Guava	Sapodilla	Longan	
Jackfruit	Sapote	Loquat	
Kiwifruit	Soursop	Lychee	
Mango	Tomato	Olive	
Muskmelon			

Climacteric vs. Non-Climacteric





如何区分跃变型
果实和非跃变型
果实？

Climacteric vs. Non-Climacteric

- 高峰型果蔬与非高峰型果蔬的区别：
  1 成熟时是否出现呼吸跃变；
  2 内源乙烯的产生；
  3 对外源乙烯刺激的反应；
  4 对外源乙烯浓度的反应；
  5 呼吸速率的变化幅度；
  6 内源乙烯的含量。

Temperature Coefficient (Q_{10})

$$Q10 = \left(\frac{R_2}{R_1}\right)^{\left(\frac{10}{T_2 - T_1}\right)}$$

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 =>

$$Q10 = \frac{R_2}{R_1}$$

Typical Q_{10} Values

Temperature Range (°C)	Q_{10}
0-10	2.5-4.0
10-20	2.0-2.5
20-30	1.5-2.0
30-40	1.0-1.5

Temperature effects on shelf-life

Temperature °C (° F)	Q_{10}	Deterioration	Shelf-life
0(32)		1	100
10(41)	3	3	33
20(68)	2.5	7.5	13
30(86)	2	15	7
40(104)	1.5	22.5	4

e.g. grapes at
32 °C for 1 h = 1day at 4 °C =1 week at 0 °C

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 CO_2/kg.hr at 0 °C
  - 10 mg CO_2/kg.hr at 5 °C
  - 15 mg CO_2/kg.hr at 10 °C
  - 30 mg CO_2/kg.hr at 20 °C
  - 45 mg CO_2/kg.hr at 30 °C
  - 55 mg CO_2/kg.hr at 35 °C

Example of Calculating the Q_{10}

- How much additional shelf life would a packinghouse manager expect if they held fruit at 10 °C compared to 30 °C?
- Firest, determine Q_{10} between 10 & 20 °C, and between 20 & 30 °C.

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

Temperature Coefficient (Q_{10})

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

If $T_2 - T_1 = 10$
Then

$$Q_{10} = \frac{R_2}{R_1}$$

Example of Calculating the Q_{10}

- First, determin 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

$$Q_{10} = \left(\frac{30}{15}\right)^{\left(\frac{10}{20-10}\right)}$$

$$Q_{10} = \left(2\right)^{\left(\frac{10}{10}\right)} = 2^1 = 2$$

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Example of Calculating the Q_{10}

- Determin 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

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

$$Q_{10} = \left(1.5\right)^{\left(\frac{10}{10}\right)} = 1.5^1 = 1.5$$

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

Temperature Range (°C)	Q_{10}
0-10	3
10-20	2
20-30	1.5

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Temperature effects on shelf-life

Temperature (C)	Q_{10}	Shelf-life
0		90
10	3	30
20	2	15
30	1.5	10

Thus, 1 day at 30C = 3days at 10C = 9 days at 0C

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几种蔬菜呼吸的温度系数同温度范围的关系

种类	0.5~10℃	10~24℃	种类	0.5~10℃	10~24℃
石刁柏	3.5	2.5	胡萝卜	3.3	1.9
豌豆	3.9	2.0	莴苣	1.6	2.0
菜豆	5.1	2.5	番茄	2.0	2.3
菠菜	3.2	2.6	黄瓜	4.2	1.9
辣椒	2.8	3.2	马铃薯	2.1	2.2

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Protective action of respiration
呼吸作用的保护作用

- 概念：
  - 当果蔬在贮运过程中受到损伤或受到病原微生物侵染时，则增强呼吸，以抵抗逆境。这种反应称为呼吸作用的保卫反应。

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呼吸作用的保护作用的表现

- （1）促进防卫层的产生
- （2）合成抗毒物质（过敏反应）
- （3）促进入侵毒素的氧化分解

耐藏性与抗病性

- **耐藏性**指果蔬在一定的贮藏期限内保持其原有质量而不发生明显不良变化的特性。
- **抗病性**指果蔬抵抗病害（包括病理性病害和生理性病害）的特性。
- 不同果蔬的保卫反应不同。其程度的强弱取决于果蔬的种性，即遗传基因。也就是种的耐藏性和抗病性。

Respiration Internal & Environmental Factors

Factors Affecting Respoiration Rate

- 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

Internal Factors

- Genotype of a commodity.
  - Between different commodities and within different cultivars of a single species.
- Type of plant part.
  - E.g. storage organs (potato) have low rates while developing meristems (broccoli) have high rates.

Class	(mg CO_2/kg-hr) at 5 °C (41 °F)	Commodities
Very Low	< 5	Dates, dried fruits and vegetables, nuts
Low	5 - 10	Apple, beet, celery, citrus fruits, cranberry, garlic, grape, honeydew melon, kiwifruit, onion, papaya, persimmon, pineapple, potato (mature), sweet potato, watermelon
Moderate	10 - 20	Apricot, banana, blueberry, cabbage, cantaloupe, carrot (topped), celeriac, cherry, cucumber, fig, gooseberry, lettuce (head), mango, nectarine, olive, peach, pear, plum, potato (immature), radish (topped), summer squash, tomato
High	20 - 40	Avocado, blackberry, carrot (with tops), cauliflower, leeks, lettuce (leaf), lima bean, radish (with tops), raspberry
Very High	40 - 60	Artichoke, bean sprouts, broccoli, Brussels sprouts, cut flowers, endive, green onions, kale, okra, snap bean, watercress
Extremely High	> 60	Asparagus, mushroom, parsley, peas, spinach, sweet corn

Internal Factors

- Stages of development at harvest.
  - Maturing plant organs usually have declining respiration rates.
  - Exception = Climacteric Fruits.
    - These undergo a large, transitory, increase in respiration and ethylene production during the climacteric.
    - This transitory respiratory increase may be higher than more immature tissue.

Internal Factors

- Respiratory Substrate – carbohydrates, lipids and organic acids.

Respiratory quotient (RQ)= $\frac{CO_2 \text{ evolved}}{O_2 \text{ consumed}}$

- RQ range from 0.7 to 1.3 for aerobic (with O_2) respiration.
- RQ is much greater if tissue goes into anaerobic (without O_2) respiration.

Internal Factors

- Respiratory quotient (RQ) when using different substrates.
  - Carbohydrates: RQ=1
  - Lipids: RQ<1
  - Organic Acids: RQ>1

Internal Factors

- Preharvest factors such as:
  - Climate and weather patterns.
    - Temperature
    - Humidity
    - Wind
    - Light intensity, etc.

Internal Factors

- Preharvest factors such as:
  - Plant nutrition (e.g. nitrogen & calcium).
  - Water supply.
  - Pruning, training and thinning.
  - Insect & Pathogen pressures.

Environmental Factors

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

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Respiration and Shelf Life

- Respiration rate is inversely related to shelf life

Higher respiration

==> Shorter Shelf Life

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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 18 F (10 C) increase, respiration increases between 2 and 3 fold (Van't Hoff Rule)

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- Affect of temperature on the quality of broccoli after just 48h of storage at either room temperature (75 F) or in the refrigerator (40 F)

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Low Temperature Injury

- Freezing will kill the tissue.
- Chilling sensitive commodities.
  - Q_{10} 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.

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High Temperature Injury

- Respiration increase 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).

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High Temperature Injury

- Heat shock (brief exposure to high, non-lethal temperatures(induce the production of heat-shock proteins that can protect cells from subsequent high or low temperature stress.

Temperature

- What temperature is the proper storage temperature or Optimum storage temperature for fruits and vegetables?

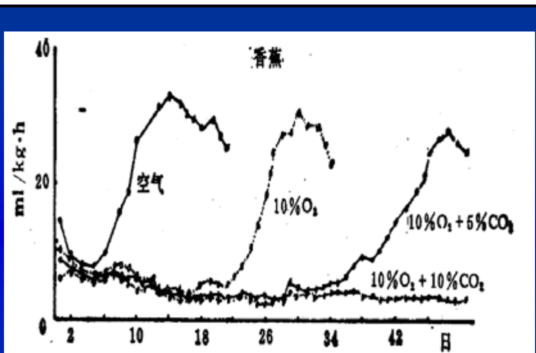
- 如何确定贮藏适温？

Atmospheric Concentration
Oxygen

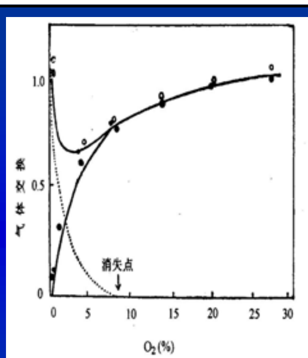
- Low O_2 concentrations reduce respiration.
  - Below ~2-3%O_2, ETS starts to be inhibited.
- If metabolic (ATP) demand is higher than inhibited Krebs cycle and ETS can supply, anaerobic respiration will attempt to satisfy ATP demand.
  - Anaerobic respiration only produces 2 ATP per glucose vs. 38 ATP under aerobic respiration = 19 fold greater ATP production under aerobic conditions.
  - CO_2 production is 6.3 fold faster (2 vs. 6 per glucose molecule)

Atmospheric Concentration
Carbon Dioxide

- High CO_2 also reduced respiration.
  - Probably by inhibiting decarboxylation during aerobic respiration.
- Different commodities vary widely to their ability to tolerate high CO_2 (e.g. lettuce vs. strawberries).
- As with low O_2 inhibition, if metabolic (ATP) demand is higher than inhibited Krebs cycle and ETS can supply, anaerobic respiration will attempt to satisfy ATP demand.



15℃下不同气体组合中香蕉对O_2的吸收量



苹果在不同O_2分压下气体交换

注：实点为耗O_2量，空心点为CO_2释放量，虚线为无氧条件下CO_2的释放，消失点表示无氧呼吸

Atmospheric Concentration
Ethylene

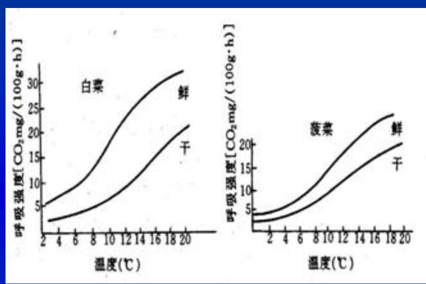
- Climacteric & Non-Climacteric fruits differ in their response to ethylene in the environment.
- Climacteric fruit:
  - Ethylene reduces the time to onset of the climacteric rise (including autocatalytic ethylene production).
  - Concentration of added ethylene has little effect on respiration rate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

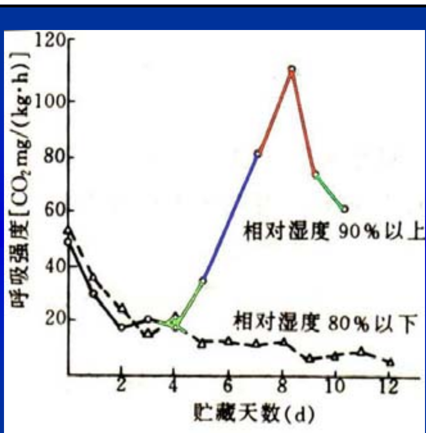
Humidity

- 在稍为干燥的条件下，可以抑制呼吸；而湿度大，则可以促进呼吸
  - 果蔬采后预处理，短期迅速蒸发掉一部分水(发汗)，如大白菜、菠菜和甜橙等，收获后稍经风干，有利于降低呼吸强度
  - 较湿润的贮藏环境对柑桔类果实有促进呼吸的作用
  - 低湿贮藏洋葱不仅有利于洋葱的休眠，还可抑制其呼吸强度。
  - 但甘薯、芋头等要求较高湿度，干燥反而会促进呼吸，产生生理伤害



新鲜和晾晒后的大白菜和菠菜呼吸强度的变化

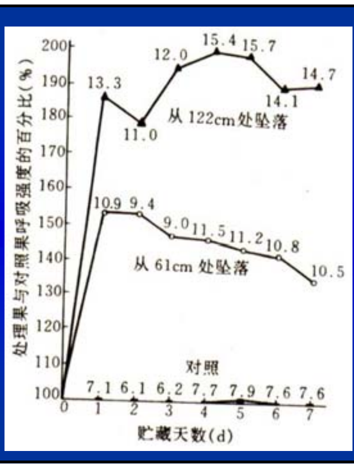
湿度对香蕉后熟中呼吸强度的影响(24℃)(Haard et al, 1969)



Physical Stress

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

伏令夏橙
从61cm和
122cm处坠
落硬地面
后呼吸强
度的变化



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Environmental Factors

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

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