Biological Factors in Post-Harvest Quality

- A wide range of biological factors influence stored products

- Any organic product that is not kept in a sterile manner is liable to be degraded by some biological agent, if it is kept for long enough

- **Losses** may be **qualitative** or **quantitative**, or a **combination of both**, and result from the inability of the host to limit biological damage

- In addition, produce may be predisposed to further attack because points of entry for **secondary insect pests** and saprobic **fungi** have been created by the existing damage

- Produce with **surface blemishes**, such as discoloration, blotches or signs of insect activity, may be **rejected** by graders or consumers and hence give rise to **qualitative losses**

- **Qualitative losses** are particularly important in the **international trade** in fruit and vegetables, where emphasis is placed on visual quality, and where even a small cosmetic defect may render the produce **unsaleable** ❶

- ❖ **Quantitative losses** arise when stored produce is directly consumed by **primary insect pests** and **rodents**, or from the rapid and extensive **decay** caused by the action of micro-organisms ❶

- ❖ A stored product **pest** can be defined as 'any organism injurious to stored foodstuffs of all types (especially grains, pulses and fruits), seeds, and diverse types of plant and animal materials'

- ❖ The term '**pest**' includes representatives from **all types of living organism**, but most are insects, fungi and bacteria

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Pests of durable crops – Insects and Arachnids (عنكبوتيان)

- ➢ Nearly all of the important **insect pests** of stored products are either **beetles** or **moths**

- ➢ **Arachnids** (important in stores only as **mites**) are less frequently encountered storage pests but are important when present in **large numbers** ❷

- **Not all insects and mites found in stores are pests:**
  - Some may have just found their way there by accident and are referred to as '**incidentals**'
  - Others may be **predators** or **parasites** of pests and hence are '**beneficials**'

Grain pests

- **Insects** and **mites** that attack stored cereals, grain legumes (pulses) or oilseeds are described as:
  - ✓ **Primary pests**
  - ✓ **Secondary pests**

- ***Primary pests*** are capable of successfully attacking and breeding in previously **undamaged** solid grains, for example, whole cereal and pulse grains and create an **infestation**

- They are rarely successful on **milled or ground commodities**

- They are capable of penetrating an undamaged **seed coat** and sometimes also a <u>pod or sheath</u> in order to feed on the **embryo**, **endosperm** or **cotyledons** of the seed

- **حشراتی که درون دانه‌ها فعالیت می‌کنند و عامل آفت زدگی پنهان دانه‌های ذخیره شده می‌باشند پنج گونه شامل:**

- Granary weevil- شپشه گندم

- Rice weevil- شپشه برنج

- Maize weevil - شپشه ذرت

- Lesser grain borer- سوسک ریز غلات (سوسک مقدس)

-Angoumois grain moths- بید غلات

- *Secondary pests* are not capable of successfully attacking previously undamaged solid grains

- They can only attack and breed in commodities that have been **previously damaged** by:❶

(a) **other pests**, especially primary pests

(b) **bad** threshing, drying, handling, etc.

(c) **intentional** processing of the commodity

❖ **حشراتی که در خارج دانه‌های انبار شده رشد و نمو می‌کنند اغلب از دانه‌های شکسته، گرد و غبار روی دانه‌ها و موارد مشابه تغذیه می‌کنند.**

از گونه‌های مهم این گروه می‌توان موارد زیر را نام برد:

- Confused and red flour beetle- شپشه آرد

- Saw-toothed grain beetle- شپشه دندانه‌دار

- Khapra beetle- لمبه گندم

- Indian-meal moth- شب‌پره هندی

Table 4.1 The main characteristics of primary and secondary pests of cereals and pulses.

	Primary pest	Secondary pest
Diet	Narrow range of foods attacked, whole grain cereals or pulses.	Wide range of hosts including damaged whole grains, flours and other processed foods.
Initial attack	Infestation is frequently pre-harvest in the mature crop in the field. Infestation passes from field into store, sometimes vice versa.	Infestations are normally confined to stores and rarely start before harvest.
Life cycle	Life cycle involves development within single grains so that immature stages are hidden from view and hence difficult to detect. Eggs usually carefully placed in or on a grain.	Larvae move freely in the stored food and so are clearly visible. Eggs laid close to food but generally scattered (placed less precisely than by primary pests).
Damage	Damage to whole grain is often very distinctive in form, so that the pest may be recognised from samples of damaged grain.	Damage caused by surface feeding is indistinct and cannot be used for pest recognition.

Primary pests of cereals

- Beetles of the genus ***Sitophilus*** are important primary pests of whole cereal grains, which are members of the '**weevil**' family

- **Three species are well known as pests of stored grain:**

- **Rice Weevil (***Sitophilus oryzae)***:** This weevil has small round pits on the surface of the thorax, four red to yellow markings on the forewings, and is able to fly. It is approximately 1/8 inch long (3 mm). *Sitophilus oryzae* is particularly associated with small grains, but is often found infesting **maize** and **paddy rice**

- **Maize Weevil (***Sitophilus zeamais)***:** This weevil also has small distinct colored spots on the forewings, and punctures on the thorax, including the midline. Adults can fly. *Sitophilus zeamais* is particularly associated with **maize** and **milled rice**, but is often found on **wheat** and other small grains

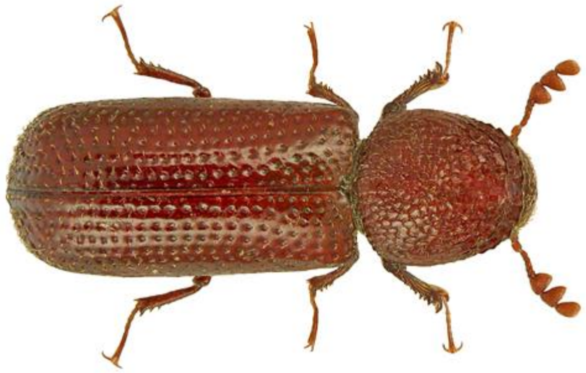
- **Granary Weevil (***Sitophilus granarius*)**:** This weevil is slightly larger (3/16 inch (4.8 mm)) than the other two weevils. It is black-brown in coloring although it can be red-brown shortly after adult emergence. If you examine the thorax closely you can see longitudinal punctures. Adults cannot fly.

Primary pests of cereals

Rice weevil

Maize weevil

Granary weevil



سوسک ریز غلات (سوسک مقدس)

-Lesser grain borer (*Rhyzopertha dominica*)

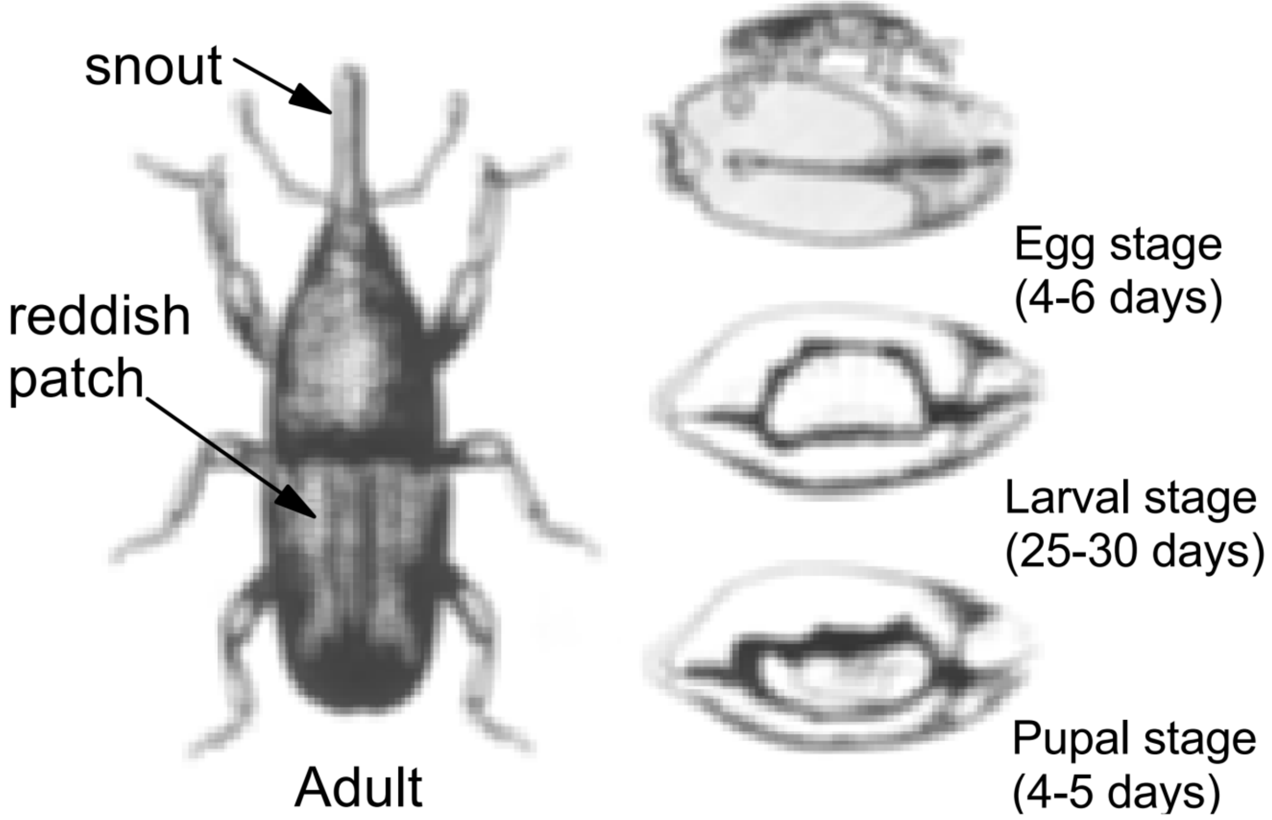


Fig. 4.1 *Sitophilus zeamais* (adult life-size 2.5–4.5 mm) showing its life cycle in a wheat grain; note female laying egg in hole in the grain (courtesy of Central Science

- The adult female weevils lay **eggs** singly in tiny holes that they dig in the seed using the mouthparts that are located at the end of the snout. Each egg is protected by a **gelatinous, mucopolysaccharide 'egg-plug'** that is secreted by the egg-laying female

- The immature stages of *Sitophilus* spp spend all of their pre-adult life hidden inside a cereal grain, so that they are extremely **difficult to detect**

- *Sitophilus granarius* is essentially a **temperate pest** and is not found in tropical countries except occasionally in cooler, upland areas

- *Sitophilus zeamais* and *S. oryzae* are commonly found throughout the world in **tropical and subtropical** regions, especially where ambient humidities are fairly high

- *Sitophilus zeamais* and *S. oryzae* thrive best at warm temperatures (around 27°C) and in grain in which the moisture content is not much less than 13%

- Under favourable conditions, such as 27°C and 70% r.h., development from egg to adult in all three species is completed in about **35 days**

- In *S. zeamais* and *S. oryzae*, development periods are very prolonged at temperatures **below 18°C**, whereas *S. granarius* can develop, albeit slowly, at 15°C when at 70% r.h. - Development can be completed in **about 140 days**

Rhyzopertha dominica **(Lesser grain borer) (سوسک ریز غلات)**

- Adult *R. dominica* are small (about 2–3 mm)

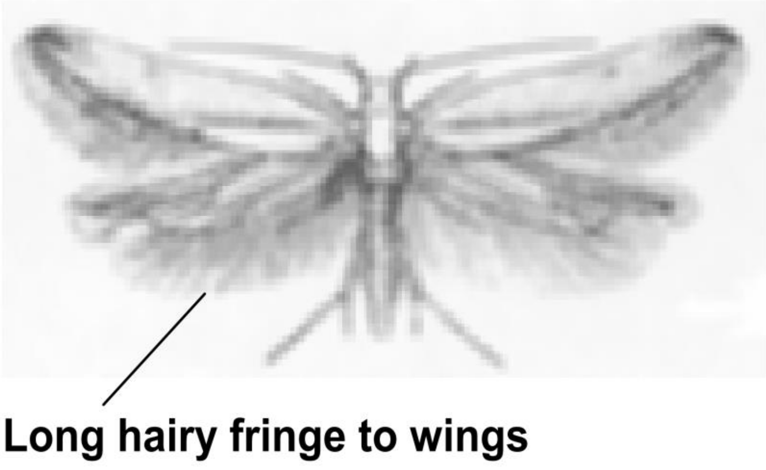
- is widespread throughout the **tropics and subtropics** and is most important as a pest of **wheat** and **paddy rice**

- Unlike *Sitophilus*, larvae may bore out of one grain and into another
- Like *Sitophilus* spp, the pre-adult stages of *R. dominica* and *P. truncatus* develop within cereal grains
- After pupation the newly developed adult escapes from the grain by chewing its way out, then continues to bore through the food
- *Rhyzopertha dominica* is adapted to rather higher temperatures and **lower moisture** contents than ***Sitophilus*** **spp** and they are therefore the **dominant pest in hot, drier areas**

Sitotroga cerealella (بيد غلات)

- is an important primary pest of cereals and can infest grain in the **field before harvest**
- Female *S. cerealella* lays eggs in masses **on the commodity**, and, upon hatching, the **larvae bore** into the grain
- The adult is rather short-lived (typically 7–14 days) and is an active flier.
- Egg to adult development is completed in as little as 25 to 28 days at 30°C and 80% r.h.
- is widespread over tropical and subtropical parts of the world
- The adults are good fliers and cross-infestation occurs easily
- They are delicate and cannot penetrate far into densely packed grain
- Infestations in bulk grain are generally confined to the **outer, most exposed** layers, especially in cereals stored in **bag stacks**
- Infestations of the pest are most frequently encountered in **farm storage**

- Because the larvae compete with those of *Sitophilus* spp, *S. cerealella* is relatively more important in dry conditions that are less favourable to *Sitophilus* spp.



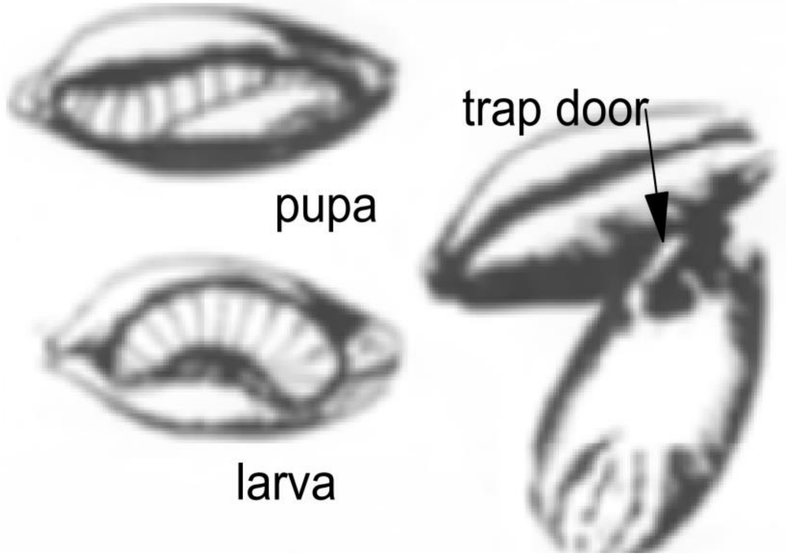


Fig. 4.5 *Sitotroga cerealella* adult (wing span 10–18 mm), pupa, larva and grain with emergence window (courtesy of Central Science

بید غلات

Angoumois grain moths

Secondary pests

- Many are pests of cereal products, but others are associated with oilseeds, spices and other commodities

Trogoderma granarium (لمبه گندم)

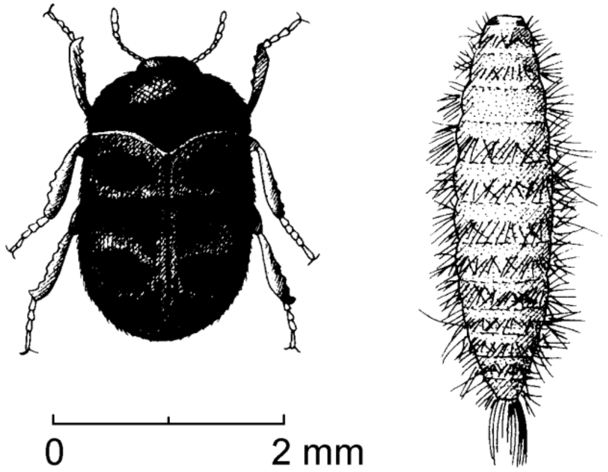
- is a very **serious pest of cereal** grains and oilseeds and many countries have specific **quarantine regulations** against possible importation
- Massive populations may develop and grain stocks can be almost completely destroyed
- The presence of *T. granarium* on grain exported to some countries will result in an order to carry out expensive pest control measures or a rejection of the shipment
- The **larvae** are extremely **hairy** and their cast skins may cover the surface of infested grain. Hairs from the skins are **allergenic**, presenting a health hazard to storage workers and consumers.
- is very **tolerant** of high temperatures (up to 40°C) and **low humidities** (down to 2% r.h.)
- It is therefore a pest in **hot, dry regions** where other storage pests cannot survive

Saw-toothed grain beetle
شپشه دندانه دار

Tribolium castaneum
شپشه آرد

شب پره هندی
Indian-meal moth

لمبه گندم
Khapra beetle



Secondary pests of cereals

- The larvae are able to enter **diapause** (a resting stage) when physical conditions are unfavourable, then move very little, or not at all, and their **metabolic rate** is lowered

- In this state they can survive **several years** of adverse conditions

- In diapause, larvae usually **hide in cracks** in the store, and are thus protected against **contact insecticides**

- Their low metabolic activity also helps to reduce the rate of pesticide uptake. They are therefore very difficult to kill with residual insecticides or fumigants

- *Trogoderma granarium* is widespread in the **Indian subcontinent** and adjacent areas and in many **hot dry regions** around the world

- It is usually not found in **humid regions**

Tribolium castaneum (شپشه آرد)

- Feeds on a range of commodities, especially cereals, but also groundnuts, nuts, spices, coffee, cocoa, dried fruit and occasionally pulses

- Under optimum conditions (33–35°C at about 70% r.h.) adults live for many months

- Throughout their lives females lay eggs loosely among their food and the larvae feed and complete their life cycle without necessarily leaving the food commodity

- Development can be very quick (about 30 days) and population growth is very rapid

- Heavy infestations by *T. castaneum* and other family members can produce **disagreeable odours and flavours** in commodities due to the production of **quinones** from the abdominal and thoracic defence glands of the adults

- Tumours observed in mice that had been fed flour on which an initial population of *T. castaneum* at 20 adults/kg had been allowed to develop for **one year**

- Quinones did not accumulate on milled rice. It was concluded that flour absorbed quinones, probably due to its finely divided nature, while solid semi-crystalline grains did not

Oryzaephilus **spp (شپشه دندانه دار)**

- are distinguished by six large **tooth-like projections** on each side of the prothorax
- *Oryzaephilus surinamensis* develops quickly at high temperatures and humidities (35°C, 90% r.h.)
- Attack cereals, cereal products, oilseeds, copra, spices, nuts and dried fruit

Table 4.5 Selected genera of important field and storage fungi.

Field fungi	Storage fungi
Fusarium	*Eurotium*
Alternaria	*Aspergillus*
Cladosporium	*Penicillium*
Phoma	*Emericella*
Colletotrichum	*Paecilomyces*
Drechslera	*Wallemia*
Curvularia	*Xeromyces*
Aspergillus (some species)	*Rhizopus*
Bipolaris	*Mucor*
Penicillium (some species)	

Postharvest Physiology

Postharvest Technology

- **Post harvest physiology** is the science which deals with quantitative and qualitative study of physiology of agricultural products (especially living plant tissues) after harvesting.

- **Postharvest physiology** deals with the time period from harvest or removal of the plant from its normal growing environment to the time of ultimate utilization, deterioration, or death.

- It has direct applications to **postharvest technology** in establishing the storage and transport conditions that best prolong shelf life.
- Postharvest physiology is about the plant response to technologies and other applications that extend shelf life and quality and delay senescence (plant death).

- An example of the importance of post-harvest handling is the discovery that **ripening** of fruit can be delayed, and thus their storage prolonged, by preventing fruit tissue **respiration**.

- This insight allowed scientists to bring to bear their knowledge of the fundamental principles and mechanisms of **respiration**, leading to post-harvest storage techniques such as cold storage, gaseous storage, and waxy skin coatings

Control of Postharvest loss

- Almost all postharvest technologies manipulate metabolism of the harvested product by inhibiting **respiration rate** of the product

- and **ethylene** action

Respiration and energy

- Ripening requires the synthesis of novel **protein, pigments and flavour** compounds.

- These anabolic processes require both energy and a supply of carbon skeleton.

- These are supplied in fruits, just as in other tissues by respiration.

Respiration and Ripening

– **While all fruits carry out respiration, there are marked differences in both the rate and patterns of change of this respiration between fruits**

– **Fruits can be classified as either climacteric or non-climacteric.**

– **In general fruits such as banana and avocado with highest respiratory rate, tend to ripen most rapidly are most perishable.**

– **For non-climacteric fruit the general correlation exists between high respiratory rate and short shelf life.**

Aerobic Respiration cycles

- Glycolysis
- Kerbs (TCA)
- Pentose Phosphate Pathway (PPP)

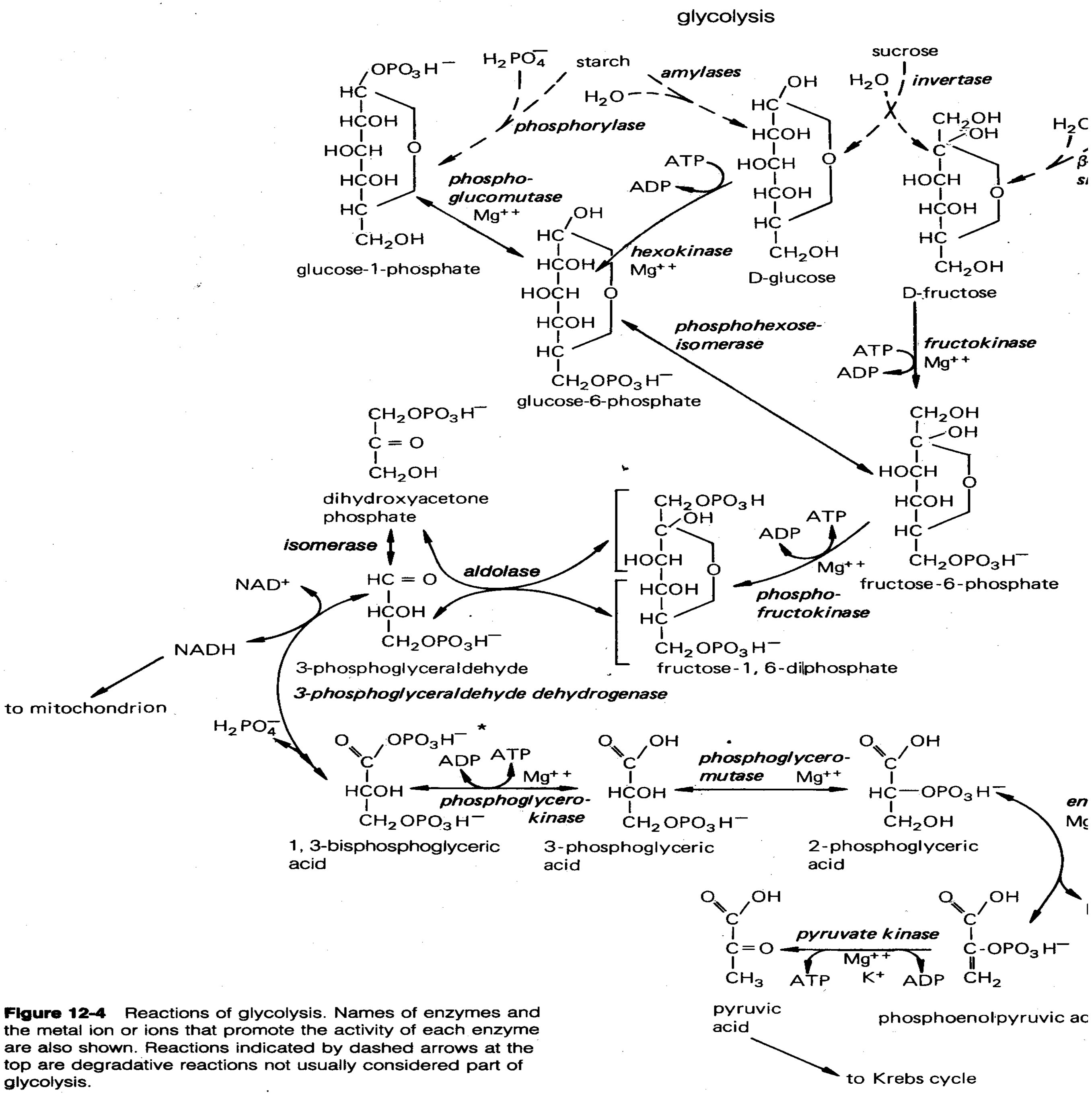
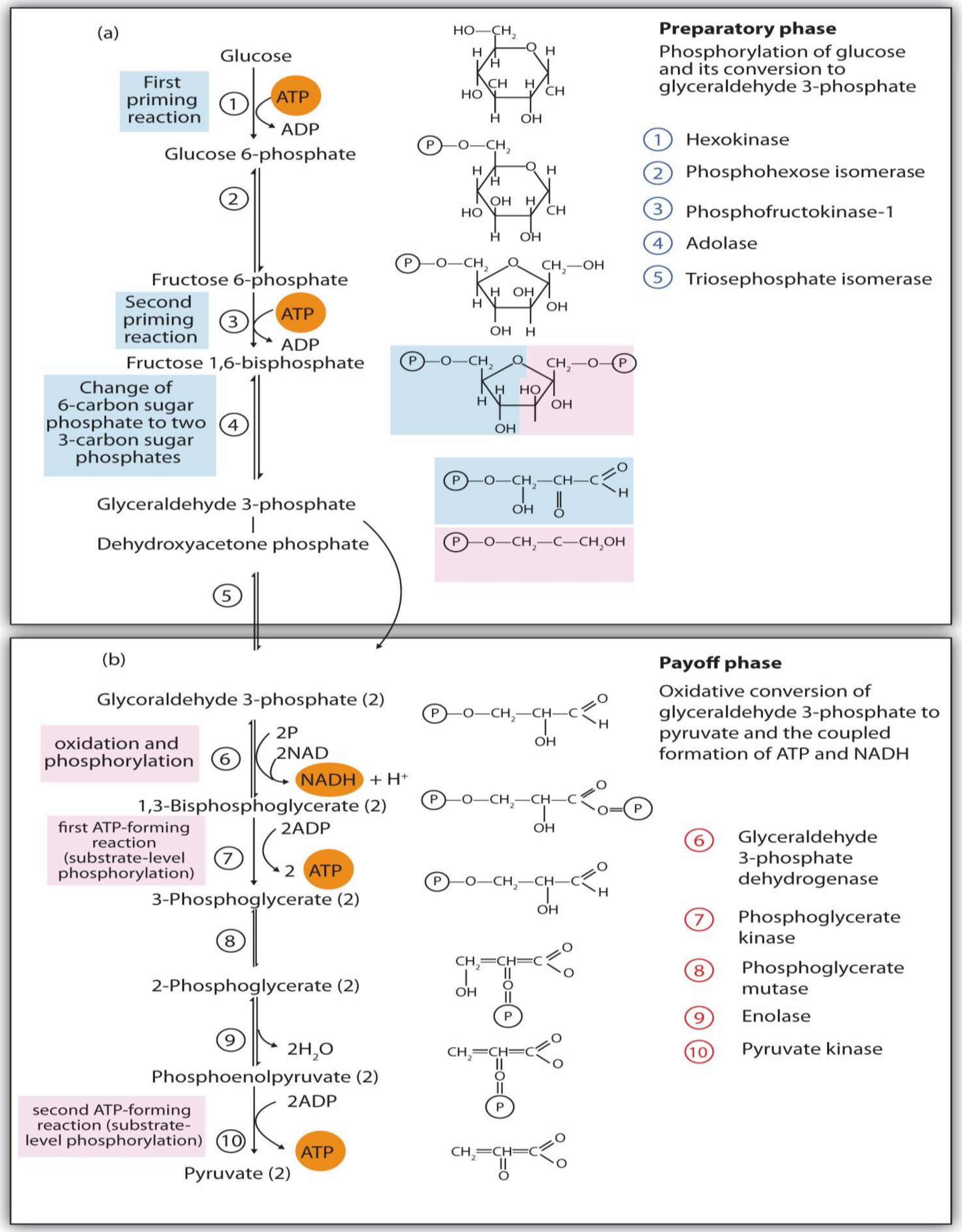


Figure 12-4 Reactions of glycolysis. Names of enzymes and the metal ion or ions that promote the activity of each enzyme are also shown. Reactions indicated by dashed arrows at the top are degradative reactions not usually considered part of glycolysis.


(a)
Preparatory phase
Phosphorylation of glucose and its conversion to glyceraldehyde 3-phosphate
Glucose
First priming reaction
ATP
ADP
Glucose 6-phosphate
Fructose 6-phosphate
Second priming reaction
Fructose 1,6-bisphosphate
Change of 6-carbon sugar phosphate to two 3-carbon sugar phosphates
Glyceraldehyde 3-phosphate
Dehydroxyacetone phosphate
1 Hexokinase
2 Phosphohexose isomerase
3 Phosphofructokinase-1
4 Adolase
5 Triosephosphate isomerase
(b)
Payoff phase
Oxidative conversion of glyceraldehyde 3-phosphate to pyruvate and the coupled formation of ATP and NADH
Glycoraldehyde 3-phosphate (2)
oxidation and phosphorylation
2P
2NAD
NADH + H+
1,3-Bisphosphoglycerate (2)
first ATP-forming reaction (substrate-level phosphorylation)
2ADP
2 ATP
3-Phosphoglycerate (2)
2-Phosphoglycerate (2)
2H2O
Phosphoenolpyruvate (2)
second ATP-forming reaction (substrate-level phosphorylation)
2ADP
ATP
Pyruvate (2)
6 Glyceraldehyde 3-phosphate dehydrogenase
7 Phosphoglycerate kinase
8 Phosphoglycerate mutase
9 Enolase
10 Pyruvate kinase

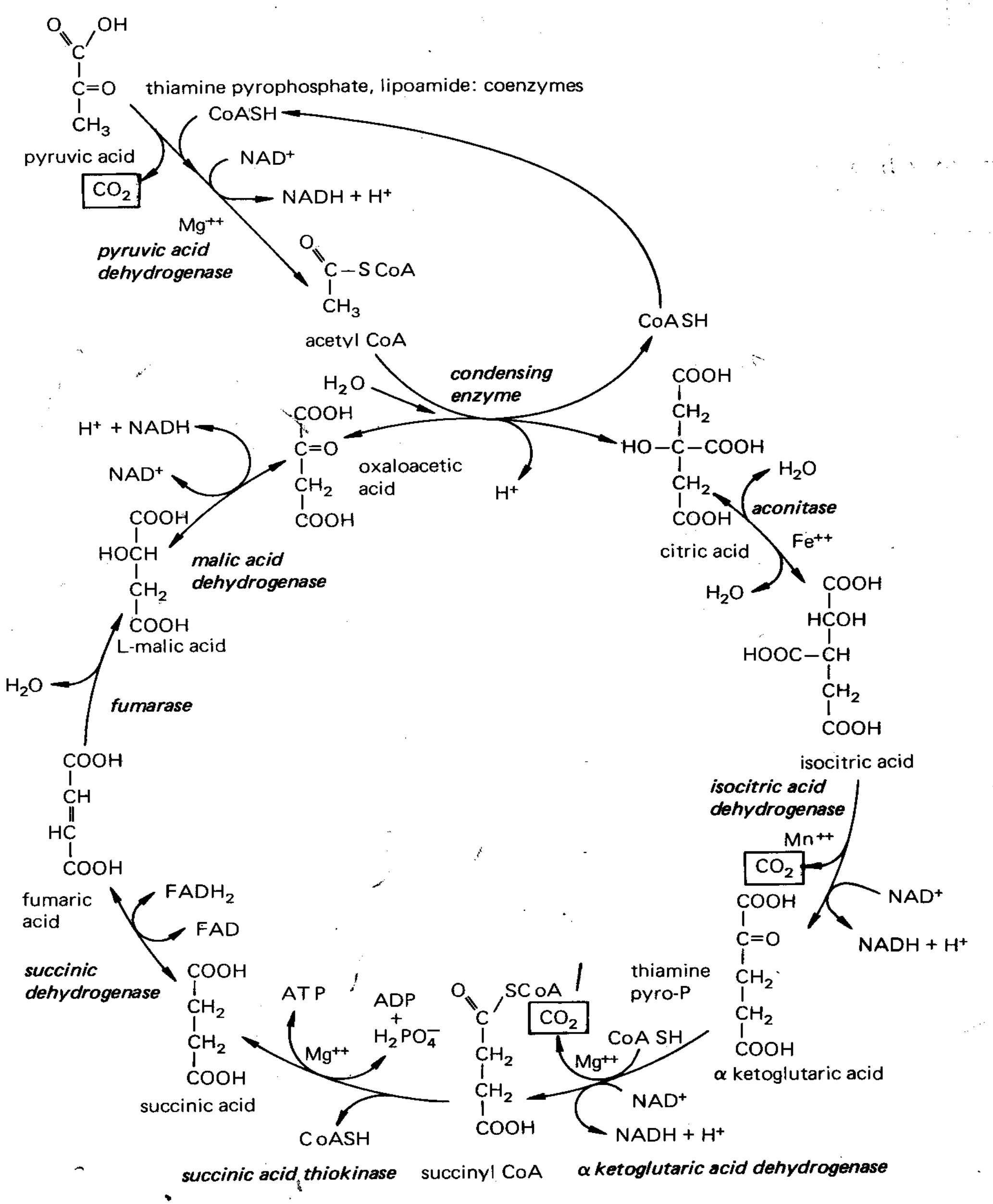


Figure 12-7 Reactions of the Ki cycle, including enzymes and co

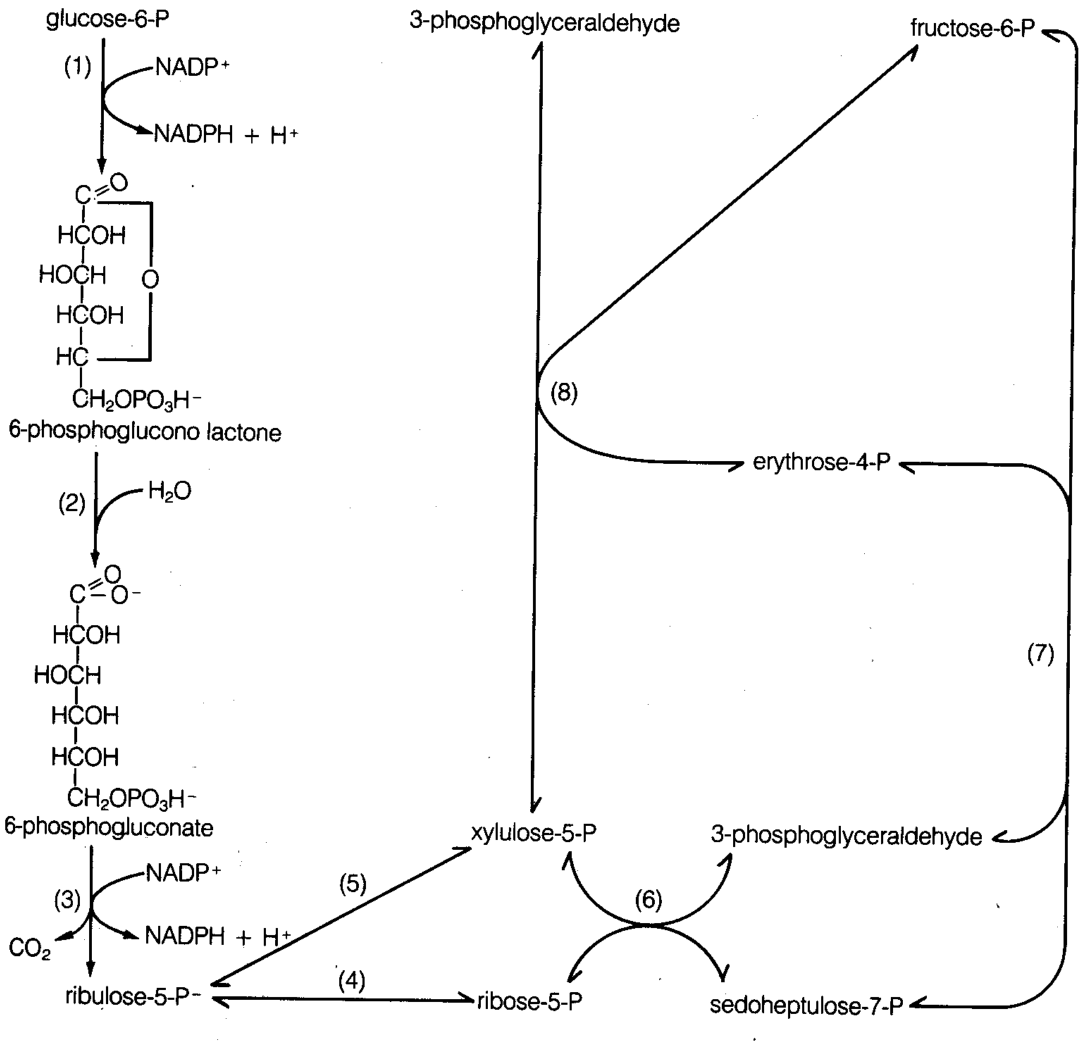


Figure 12-10 Reactions of the pentose phosphate respiratory pathway.

First, a few basic principles:

1. Fresh fruits, vegetables and flowers are living tissues that are subject to continuous changes after harvest!

Some of these changes are desirable, but most are not wanted.

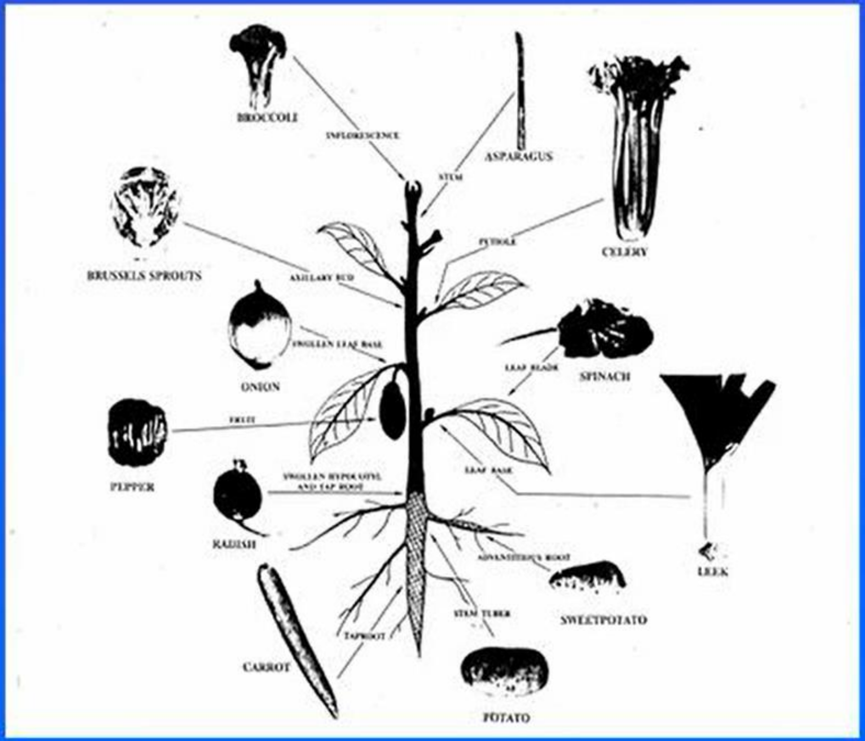
The main goal of postharvest research is to slow these changes as much as necessary.

2. After harvest – fruits and vegetables are detached from the mother plant and do not ‘enjoy’ anymore from continuous supply of water and nutrients.

Therefore, after harvest, fruit and vegetables depend on their own carbon and water reserves and become perishable – they loose water and dry matter!

3. Fresh horticultural crops are diverse in morphological structure (roots, stems, leaves, flowers, fruit, etc.), in composition, and general physiology.

Therefore, optimal postharvest requirements vary among commodities!



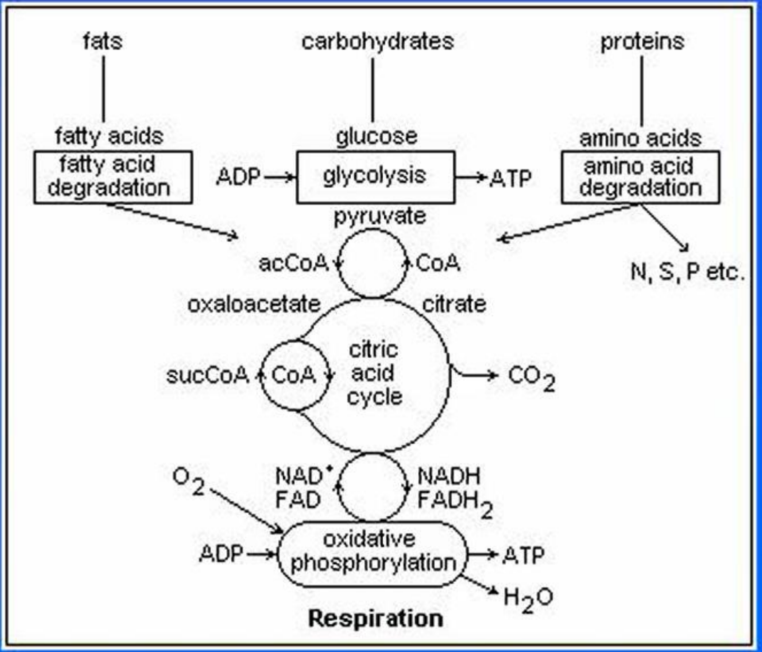
Biological factors involved in deterioration

- Respiration
- Ethylene production
- Compositional changes
- Water loss
- Physical damage
- Physiological breakdown
- Pathological breakdown

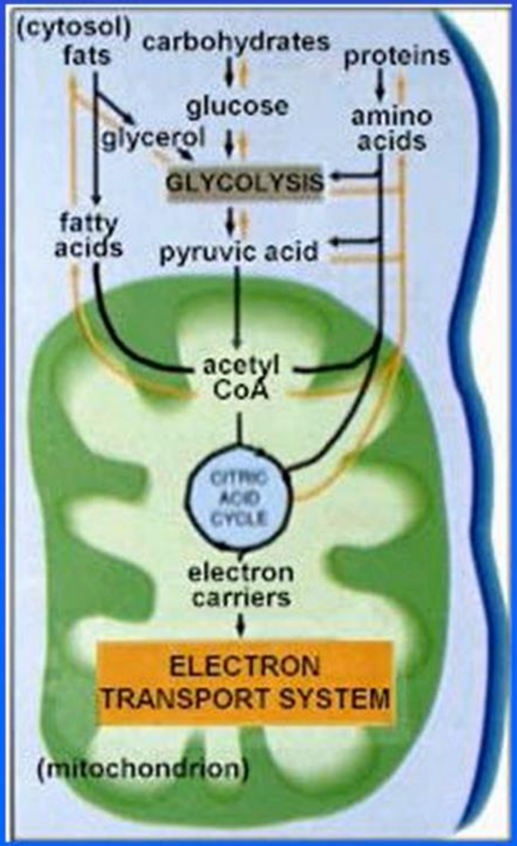
Respiration

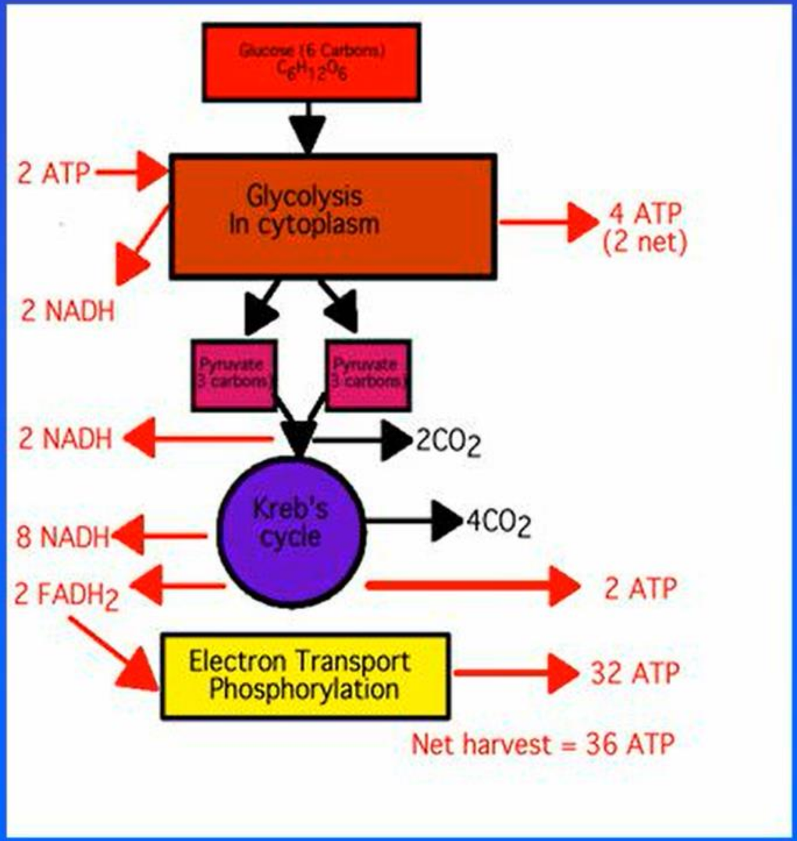
Respiration is the process by which stored organic materials (carbohydrates, proteins, fats) are broken down into simple end products with a release of energy.

During respiration, oxygen (O_2) is used and carbon dioxide (CO_2) is produced.



Respiration involves degradation of food reserves, especially sugars, in order to produce chemical energy (in the form of ATP and NADH) needed to maintain cellular metabolic activity.





When glucose is used as a substrate, the equation for respiration is:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 686\ \text{kcal heat}$$

Respiration results in loss of food reserves, loss of flavor, especially sweetness, loss of salable dry weight, and release of heat that increases the costs of refrigeration, and release of CO_2 thus, requiring extensive ventilation.

In general, the rate of deterioration of harvested commodities is proportional to their respiration rate:

Commodities with high respiration rates will have short potential storage lives.

Commodities with low respiration rates will have long potential storage lives.

Horticultural products classified according to their respiration rates

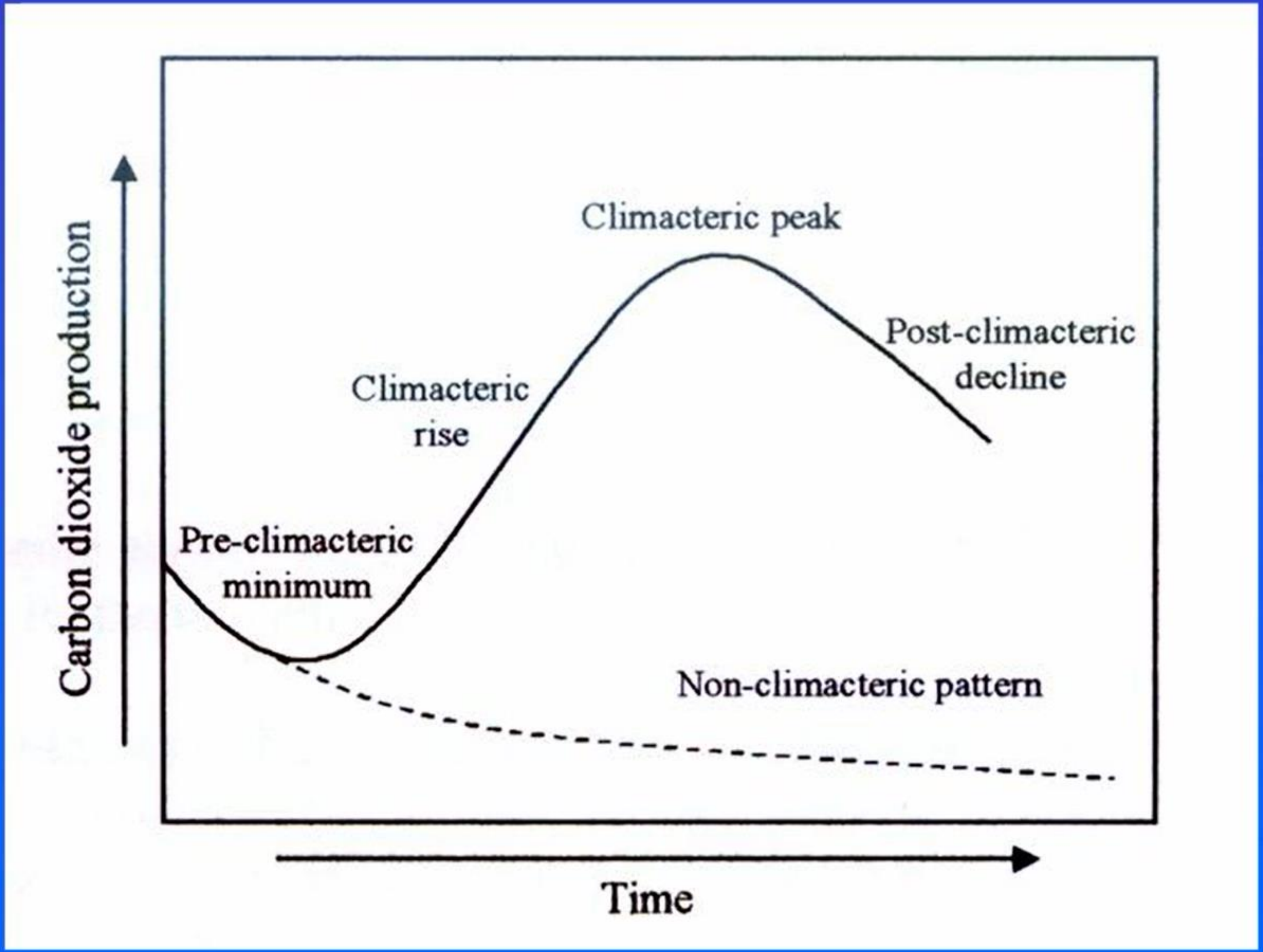
Class	Range at 5°C (41°F) ($mg\ CO_2/kg\text{-}hr$)*	Commodities
Very low	<5	Dates, dried fruits and vegetables, nuts
Low	5–10	Apple, beet, celery, citrus fruits, cranberry, garlic, grape, honeydew melon, kiwifruit, onion, papaya, persimmon, pineapple, pomegranate, potato (mature), pumpkin, sweet potato, watermelon, winter squash
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, leek, lettuce (leaf), lima bean, radish (with tops), raspberry, strawberry
Very high	40–60	Artichoke, bean sprouts, broccoli, Brussels sprouts, cherimoya, cut flowers, endive, green onions, kale, okra, passion fruit, snap bean, watercress
Extremely high	>60	Asparagus, mushroom, parsley, peas, spinach, sweet corn

According to their respiration behavior during maturation and ripening, fruits are classified to either <u>climacteric</u> or <u>non-climacteric</u>.

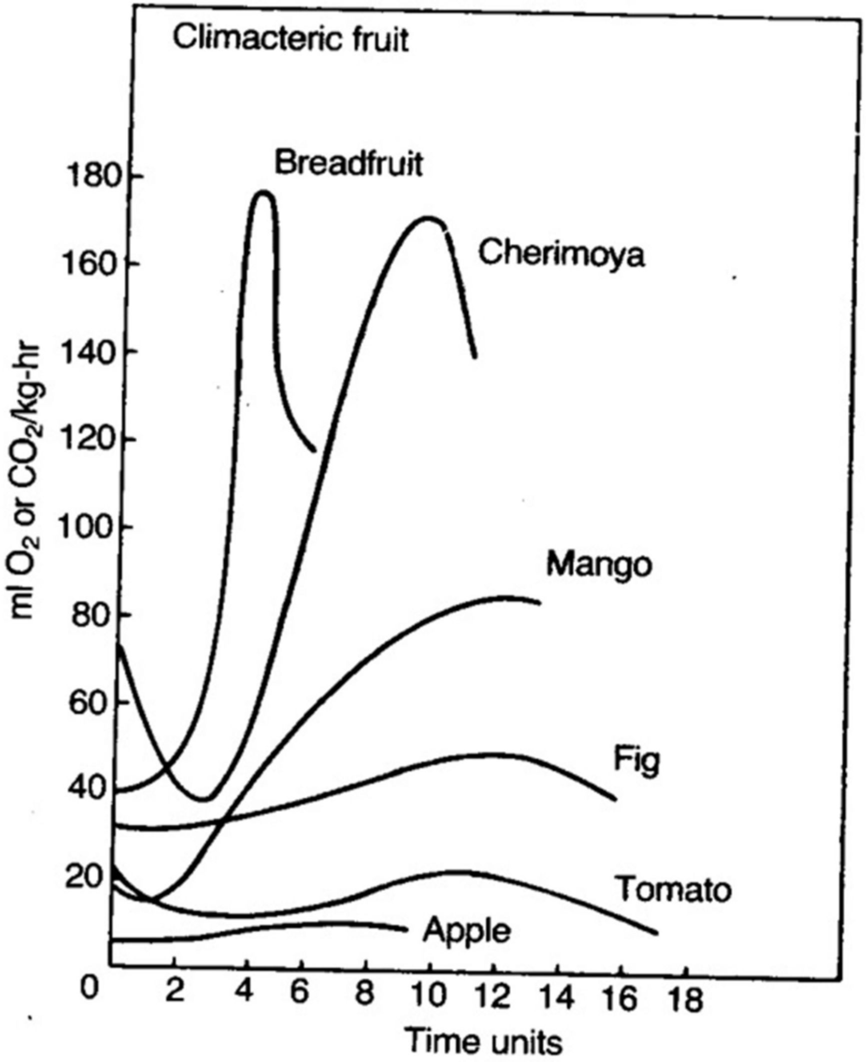
Climacteric fruits – show a large increase in respiration and ethylene production during ripening.

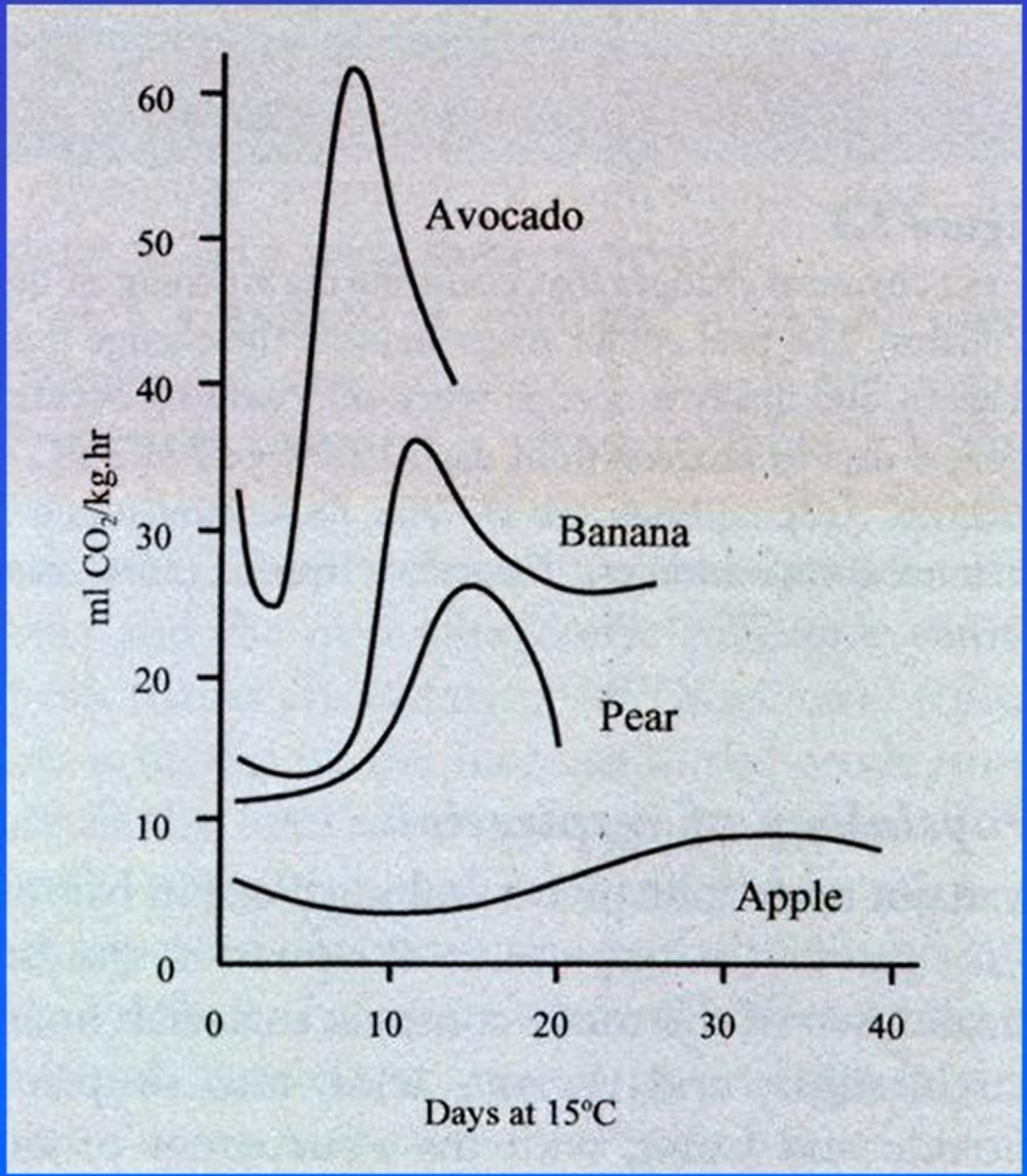
Non-climacteric fruits – show no change in their generally low respiration and ethylene production rates during ripening.

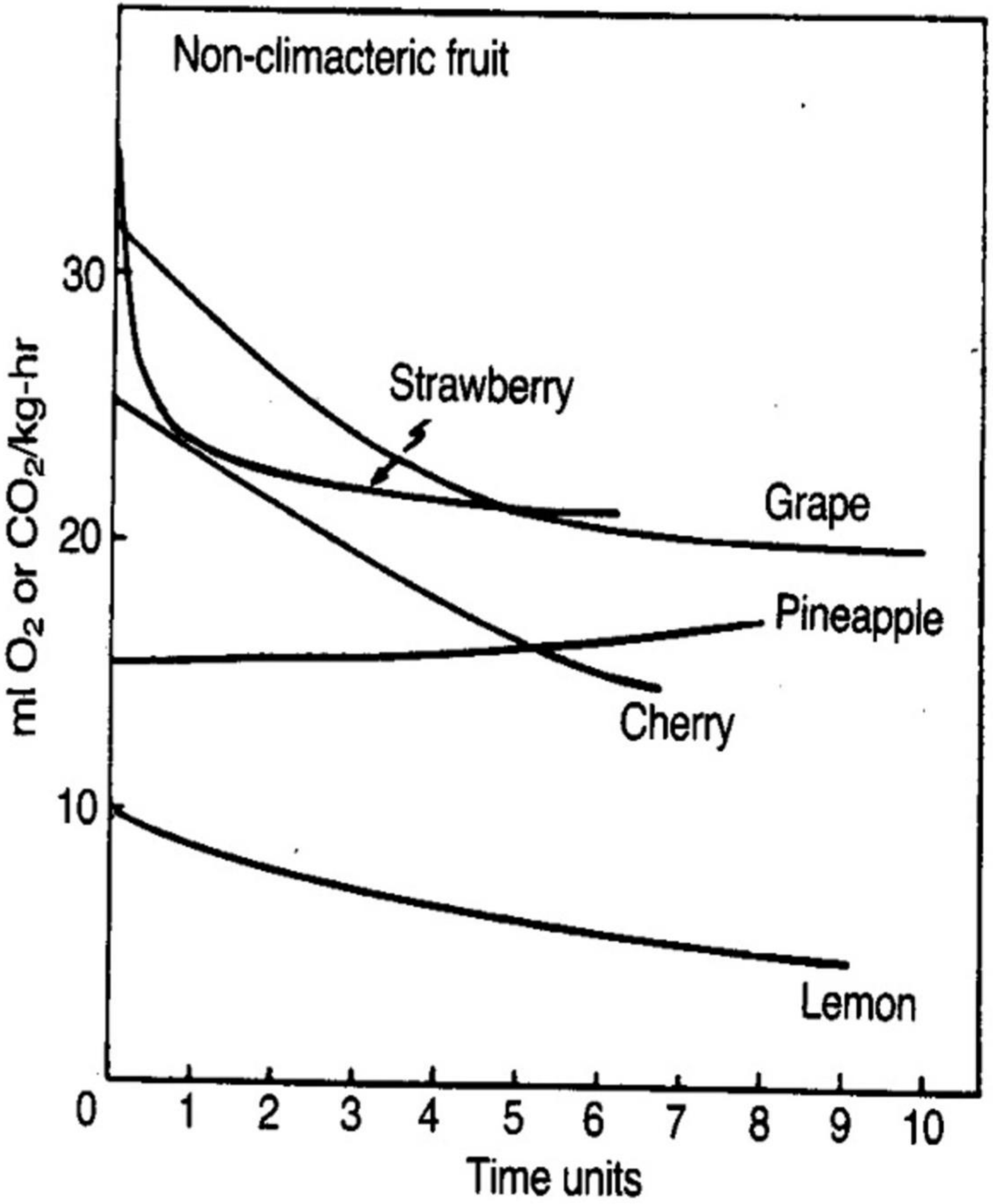
Respiratory phases of climacteric and non-climacteric fruit



Magnitudes of respiration of climacteric fruit







Non-climacteric fruit
Strawberry
Grape
Pineapple
Cherry
Lemon
30
20
10
0
1 2 3 4 5 6 7 8 9 10
Time units
ml O_2 or CO_2/kg-hr

Fruits classified according to respiratory behavior

Climacteric fruits		Nonclimacteric fruits	
Apple	Muskmelon	Blackberry	Lychee
Apricot	Nectarine	Cacao	Okra
Avocado	Papaya	Carambola	Olive
Banana	Passion fruit	Cashew apple	Orange
Biriba	Peach	Cherry	Pea
Blueberry	Pear	Cranberry	Pepper
Breadfruit	Persimmon	Cucumber	Pineapple
Cherimoya	Plantain	Date	Pomegranate
Durian	Plum	Eggplant	Prickly pear
Feijoa	Quince	Grape	Raspberry
Fig	Rambutan	Grapefruit	Strawberry
Guava	Sapodilla	Jujube	Summer squash
Jackfruit	Sapote	Lemon	Tamarillo
Kiwifruit	Soursop	Lime	Tangerine and mandarin
Mango	Sweetsop	Longan	
Mangosteen	Tomato	Loquat	Watermelon

At last, respiration rates (and deterioration) varies among different types of commodities:

Storage organs (nuts, tubers) – **have low respiration rates.**

Meristem tissues (asparagus, broccoli) – **have very high respiration rates.**

Commodities harvested during active growth (spinach, green onions, bean sprouts) – **have high respiration rates.**

Mature fruit (citrus, grape) – **have low respiration rates.**