## CHAPTER 6

# Morphology and Anatomy

**Armando Carrillo-López**[1] **and Elhadi M. Yahia**[2]
[1]Food Science and Technology Postgraduate Program, Faculty of Chemical-Biological Sciences, Autonomous University of Sinaloa, Culiacan, Mexico
[2]Faculty of Natural Sciences, Autonomous University of Queretaro, Queretaro, Mexico

## 6.1 INTRODUCTION

In biology, morphology is the branch that deals with the form of living organisms. For plants, plant morphology or phytomorphology is the study of the physical form and external structure of plants, whereas plant anatomy is the study of the internal plant structure, mostly at the cellular/microscopic level. This chapter deals with vascular plants, also known as higher plants or trichophytes, which are defined as those that have ducts for circulation of fluids, such as xylem and phloem. The main focus will be the morphology and anatomy of fruits and vegetables due to the important role that external and internal plant physical characteristics play during the different stages of the life of a given plant organ. In terms of gas exchange, the extent of interaction between a horticultural produce and its surrounding environment may be determined by the shape of the product (surface area/volume ratio) and by the thickness and nature of its epidermal tissue. An example is how fast a produce loses water by transpiration. The velocity of gas exchange may depend on the size of the intercellular spaces inside the fundamental tissue of the product. Tolerance to bruising during harvesting, packing, or other handling operations is dependent on the nature of the cells that make up the fundamental tissue. Therefore, knowledge on the morphology and anatomy of a certain commodity is essential for establishing the proper postharvest handling requirements of horticultural crops.

## 6.2 STRUCTURAL ORGANIZATION OF PLANTS (ROOT AND SHOOT SYSTEMS)

A whole plant is composed of two main organ systems: the shoot and the root. The shoot system is the aerial part, whereas the root system is the

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underground part. Each organ system is composed of various specialized organs. Stem, leaf, flower, and fruit are organs that make up the shoot system, whereas the roots and their parts make up the root system. Each organ is composed of three types of tissue system: the epidermal, the ground, and the vascular tissue systems. Furthermore, each organ can be composed of various other tissues. These may include parenchyma, collenchyma, or sclerenchyma tissues. These tissues are distinguished by the specific characteristics of their cells. Plant cells are formed at the meristems, which are found in regions of the plant where growth can take place, forming new tissue due to these actively dividing cells, named meristematic cells. These cells give rise to plant organs and keep the plant growing. The stem system supports the aerial part of the plant connecting the leaves and the roots. The leaves are the primary site of photosynthesis (capturing energy from sunlight and using it to make organic materials). Flowers and fruits are reproductive organs. Flowers attract pollinators and fruits attract seed dispersers. Roots anchor the plants into the soil, absorb water and minerals, and may store some nutrients.

## 6.3 FRUIT AND VEGETABLE ANATOMY

Plants tissues are organized into three types of tissue systems: dermal tissue, vascular tissue, and ground tissue.

### 6.3.1 Dermal System

How fast a horticultural commodity loses water by transpiration, how susceptible a produce is to the attack of pathogens, and how resistant the produce is to the penetration of chemicals depend on the characteristics of its dermal system. The dermal tissue system is the outermost covering of the entire plant and may comprise different elements depending on the specific part of the plant. Such elements include the epidermis, cuticular membrane, trichomes, stomata, and lenticels. The dermal tissue protects the internal tissues of the plant or part of the plant, and that is why the dermal tissue is also called the protective tissue. The protection is diverse and since the dermal tissue is in direct contact with the environment it confronts external physical, chemical, and biological threats, in addition of carrying out a dynamic interaction with its surrounding neighborhood. The dermal system protects against pathogen attacks, mechanical injuries, temperature stress, penetration of chemicals, loss of moisture by produce, among others. However, the dermal tissue facilitates gas exchange, allowing the entrance of oxygen to the inner cells, while at the same time allowing carbon dioxide to be released outward.

#### *6.3.1.1 EPIDERMAL CELLS*

The epidermis is usually single layered and is the outermost cellular layer of the plant body, made up of elongated and tightly arranged cells named epidermal cells. These epidermal cells are of the parenchymatous type (described below). Although compactly arranged, these epidermal cells possess points of interruption to facilitate gas and moisture exchange.

### 6.3.1.2 *THE CUTICULAR MEMBRANE*

The cuticular membrane or plant cuticle is an extracellular composite structure made up of cutin and waxes. It is generally described as an extracellular thick waxy layer that covers the outside part of the epidermis. The cutin is a covalently linked macromolecular scaffold composed mostly of C16 and C18 fatty hydroxyacids esterified to each other and to glycerol. On the other hand, the cuticular waxes are a variety of organic solvent-soluble lipids mostly derived from very-long-chain fatty acids (C20–C34), including alkanes, ketones, aldehydes, alcohols, and esters. The cuticular membrane is characterized by its resistance to water loss by transpiration, and its limitation to pathogen invasion and chemical penetration. Based on histochemical staining, the cuticle structure is often divided into two sections: the "cuticular layer" and "cuticular proper." The former is a cutin-rich portion with embedded polysaccharides, whereas the latter is a wax-rich overlying layer. The wax in the "cuticular proper" can be found as intracuticular wax (within the cuticular matrix) or as epicuticular wax forming a film (epicuticular wax film) or in the form of crystals (epicuticular wax crystals). The glossy appearance in many leaves and fruits is due to the epiculicular film, whereas the dull appearance in broccoli leaves is due to epicuticular wax crystals. Cuticle resistance to water loss is mainly attributed to wax rather than to cutin. Furthermore, this resistance appears to be primarily determined by the particular mixture of intracuticular and epicuticular waxes and how they are organized rather than their amount. On the other hand, cutin seems to be more important than waxes as a pathogen barrier, at least in tomato fruit.

### 6.3.1.3 *THE TRICHOMES*

The trichomes are single-celled or multicellular appendages found on stems and some fruits such as peach and kiwifruit. The multicellular trichomes may be branched or unbranched and help prevent water loss.

### 6.3.1.4 *THE STOMATA*

The stomata are present in stems of herbaceous plants, in low amounts on fruit surface also in the upper epidermis of leaves, and in high amounts in the lower epidermis of leaves. Stomatal densities differ greatly between the different species and plant organs. In leaves of purple passion fruit about 100 stomata/mm$^2$ of the leaf surface can be found, whereas in the fruit surface only about 12 stomata/mm$^2$ were found. Stomata are made up of two specialized guard cells that give form to the stomatal pore, which regulates the exchange of carbon dioxide, oxygen, and water vapor, concretely between the outside atmosphere and the substomatal cavities inside the leaf (Fig. 6.1). The opening and closure of the stomatal pore is promoted by the

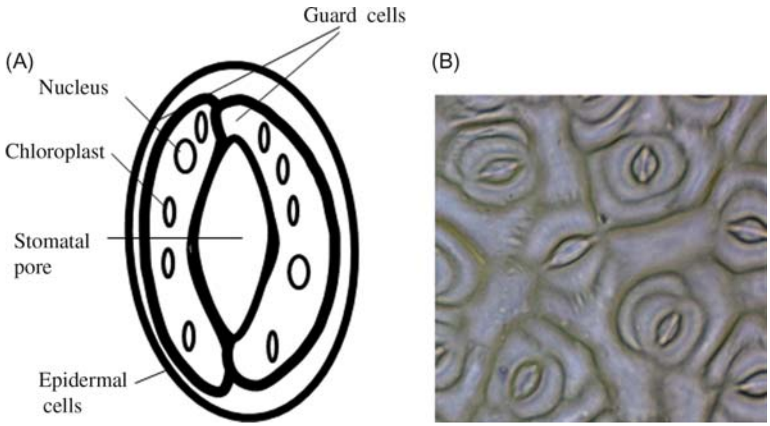

**FIGURE 6.1**
Parts of stomata (A) and stomata in Noni plant leaf (adaxial side) by optical microscopy (40 × ) (B).

inlet and outlet of water in guard cells. The inlet of water causes both guard cells to swell and acquire a kidney-like shape in opposition to each other, thus a pore is established between both guard cells. However, the outlet of water causes guard cells to constrict—the change in shape is reversed, and the stomatal pore is closed.

#### 6.3.1.5 *THE LENTICELS*

The lenticels found on the epidermis of different plant organs (stem, petiole, fruits) made up of parenchymatous cells are pores that always remain open, in contrast to stomata, which regulate their extent of opening. Lenticels are visible on fruit surfaces, such as mango, apple, and avocado. Lenticels permit the exchange of gases between the environment and the internal tissue spaces of the organs (stems and some fruits) (Fig. 6.2). They permit the entrance of oxygen and simultaneously the output of carbon dioxide and water vapor. In apple fruit, lenticels account for up to 21% of the transpiration.

### 6.3.2 Ground System

The ground system accounts for the principal edible portion of fruits and vegetables whose cells carry on the main metabolic processes in order to accumulate diverse substances as nutrients to the plant by itself or to seed dispersers in the case of fruits. Also, this system may provide mechanical support for the organs they conform. This tissue system is made up of three different types of simple tissues: parenchyma, collenchyma, and sclerenchyma tissues, which can be described in terms of their cellular characteristics.

#### 6.3.2.1 *PARENCHYMA TISSUE*

The parenchyma is composed of living cells with primary thin walls forming a tissue that may be compact or have extensive air-filled intercellular spaces.

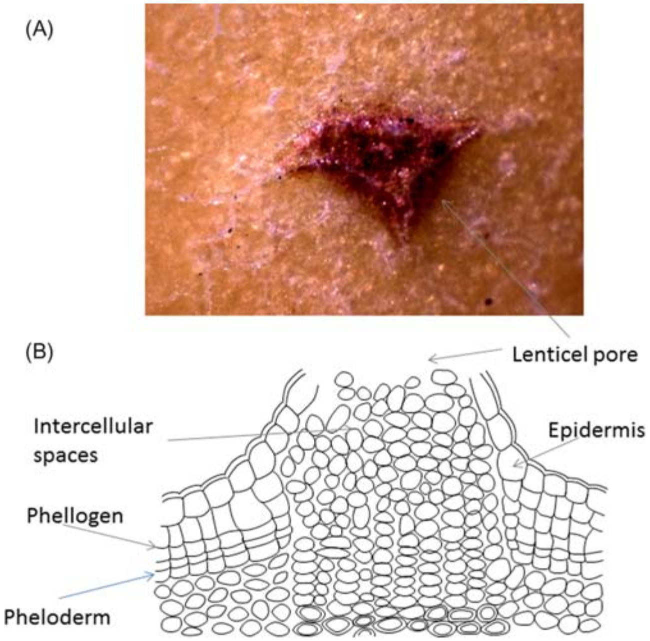

**FIGURE 6.2**
Lenticel pore on apple surface (A) and parts of lenticels (B).

These spaces can be as low as 1%, such as in potato, or vary from 15% to 25% as seen in fruits, for example, apples can reach up to 25%. Parenchyma cells make up the fleshy part of fruits, roots, tubers, and leaves, and form the most common and most abundant plant tissue. Various metabolic processes occur in the parenchyma tissues including the synthesis of hormones, enzymes, pigments, essential oils, toxic substances, etc. One of the most important of these processes to both plants and animals, including humans, is photosynthesis, which produces basic food substances for all living organisms. Another equally important metabolic process is respiration, which provides the energy utilized by the plant to carry out its various activities. Some other important processes include the conversion of glucose to starch, the form in which it is stored in parenchyma tissues, and the reverse process of digestion of starch, which makes glucose available for use by the plant. Parenchyma tissue is found in the leaf mesophylls, which are the tissues located between the upper and lower leaf epidermis, consisting of the palisade layer and the spongy parenchyma. Most leaf mesophyll cells contain chloroplasts (mainly the palisade layer cells), and, as mentioned above, carry on the process of photosynthesis. Parenchyma is also found in the cortex that is the outermost layer of the stem or root in the plant, and in the pith, which is a tissue in the stems of vascular plants, composed of soft, spongy parenchyma cells, and may store nutrients throughout the plant.

#### *6.3.2.2 COLLENCHYMA TISSUE*

Collenchyma tissue is composed by elongated living cells of uneven primary thick walls, which possess hemicellulose, cellulose, and pectic materials. It provides support, structure, mechanical strength, and flexibility to the petiole, leaf veins, and stem of young plants, allowing for easy bending without breakage. The stretchy properties of the strands of celery are due to collenchyma tissue. Collenchyma tissue is found immediately under the epidermis, young stems, petioles, and leaf veins. Also, it has been seen in avocado fruit hypodermis. Collenchyma cells may or may not contain a few chloroplasts, and may perform photosynthesis and store food.

#### *6.3.2.3 SCLERENCHYMA TISSUE*

Sclerenchyma tissue, when mature, is composed of dead cells that have heavily thickened walls containing lignin and a high cellulose content (60%–80%), and serves the function of providing structural support in plants. Sclerenchyma cells possess two types of cell walls: primary and secondary walls. The secondary wall is very thick and highly lignified (15%–35%) and imparts a great rigidity and hardness to the cell and tissue. There are two main types of sclerenchyma cells: fibers and sclereids. Fibers are very elongated cells that can be found in stems, roots, and vascular bundles in leaves. Fibers impart fibrousness as in the case of asparagus. Sclereids are found in different shapes (spherical, oval, or cylindrical) and are present in various plant tissues such as the periderm, cortex, pith, xylem, phloem, leaves, and fruits. The hardness of the shell of nuts, the coat of many seeds, and the stone of drupes (cherries and plums) is due to this type of cell. Sclereids may impart a grainy texture to some fruits when found scattered in their paranchymatous tissue, that is, in pears and quinces.

### 6.3.3 Vascular System

Vascular tissue transports food, water, hormones, and minerals within the plant, and includes the xylem, phloem, parenchyma, and cambium cells. The xylem distributes water and minerals throughout the plant, whereas the phloem conducts the products of photosynthesis from the leaves to all over the plant (Fig. 6.3).

#### *6.3.3.1 XYLEM*

The xylem provides mechanical strength to plant parts, and functions as a conducting tissue for water and minerals from the roots to the stem and leaves. It is composed of four different element types, namely, tracheids, vessels, xylem fibers, and xylem parenchyma. Tracheids are very elongated dead cells with thick and lignified walls and tapering ends. The vessel is a tubular structure composed of many dead lignified cells called vessel members interconnected through perforations in their common walls.

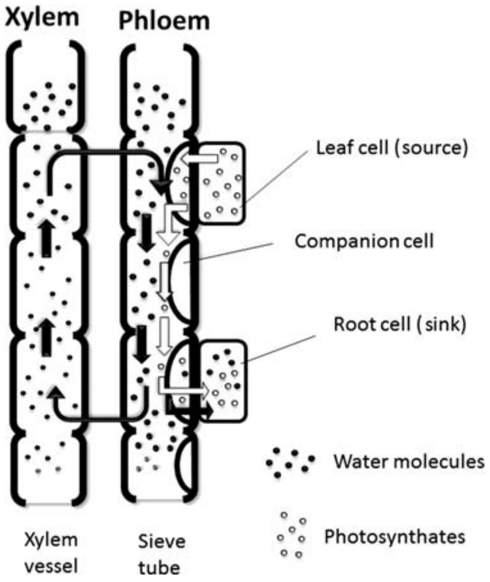

**FIGURE 6.3**
The vascular system.

### 6.3.3.2 *PHLOEM*

The phloem transports food materials derived from photosynthesis, usually from the leaves to other parts of the plant. The sieve tube elements are also long tubular structures, arranged longitudinally and associated with the companion cells. Their end walls are perforated in a sieve-like manner to form sieve plates. Companion cells are specialized cells (parenchyma), which are closely associated with sieve tube elements and help in maintaining the pressure gradient in the sieve tubes. The functions of sieve tubes are controlled by the nucleus of companion cells.

## 6.4 THE ROOT

Some examples of edible horticultural roots include carrots, beet, radish, turnip, jicama, and sweet potato. The root is the first organ appearing in sprouting embryos. The seed coat is broken and the root starts to grow downward into the ground, forming tube-like structures. The root lacks buds, leaves, and stomata. Based on the root shape, there are basically two types: taproot and fibrous. Taproots are made up of a large central root with shorter lateral or branching roots, whereas, in comparison, fibrous roots are shorter, smaller and hairy, growing more shallow. Both taproots and fibrous roots are called tuberous when they become swollen due to the accumulation of reserves. Root functions can be divided into primary and secondary. The primary functions of roots include: anchoring the entire plant, supplying the stem with water and minerals absorbed from the soil, and synthesizing plant hormones. Among the secondary functions that can be performed by the roots of certain plants are those of storing food materials mainly sugars, starch, and water as in the case of beetroot, sweet potato, jicama, turnip, radish, and carrot (Fig. 6.4), that swell and become fleshy. The plant stores these substances in the roots with the purpose of utilizing them later for their physiological processes. However, due to these reserves the tuberous roots have been cultivated and used as horticultural edible produce. Furthermore, some of them accumulate pigments, such is the case of beetroot and carrot which are regarded as rich sources of betalains and carotenoids, respectively. Sweet potato may also be used for vegetative reproduction. Roots can be divided into several regions: (1) root cap, (2) meristematic tissue, (3) root elongation, (4) region of root hairs, and (5) region of maturation. Root cap is a thimble-like structure that gives protection to the root tip and is found in the deepest part of the primary root. The meristematic tissue region is immediately above the root cap and is composed of small, thin-walled undifferentiated cells dividing actively. The root elongation region undergoes rapid lengthening due to cell enlargement, allowing the root to get deeper into the soil. The root hairs region, also called the root absorption region, absorbs water and minerals from the soil and is formed by thread-like cells called root hairs. Ultimately, the maturation region, which normally is the major part of the root, is made up of enlarged and differentiated cells that become the different root tissues, for instance, cortex, xylem, and phloem. Lateral roots may also develop from this region. From the outermost to the innermost, the tissues of the root are the epidermis, the cortex, and the vascular cylinder. Morphologically, most root vegetables are products with low surface-to-volume ratio, and generally possess a crispy texture (such as carrot and radish). Root vegetables are sufficiently firm in texture to withstand moderately rough postharvest operations, such as hydrocooling and mechanized sorting.

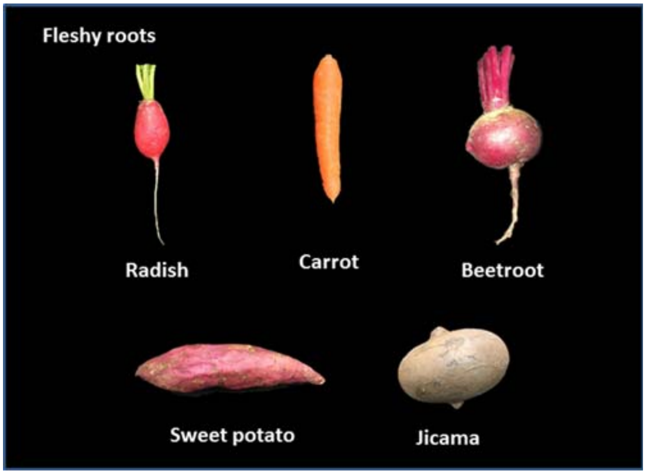

**FIGURE 6.4**
Some fleshy roots.

## 6.5 THE STEM

Some of the commercial edible horticultural stem commodities include potato, onion, ginger, turmeric, kohlrabi, asparagus, cactus stems (nopales), barrel cactus, and sugarcane (Fig. 6.5). The stem develops from the embryo plumule in a germinating seed and is established as a primary axis that grows in the opposite direction to the seed radicle, and although a part of it can be subterranean, becomes the aerial part of the plant. The stem possesses buds, nudes, internodes, and leaves, and lacks absorbent hairs and root cap. Some plants have stems that lack leaves, such as cactus stems. The buds which develop into flowers are called floral buds, whereas the buds which develop into branches are called vegetative buds. The latter can be apical when located at the apex of the stem, axillary when located in the axils of leaves, accessory when located on the sides or above the axillary buds, or adventitious when located at areas other than the nodes. The function of the stem is basically the

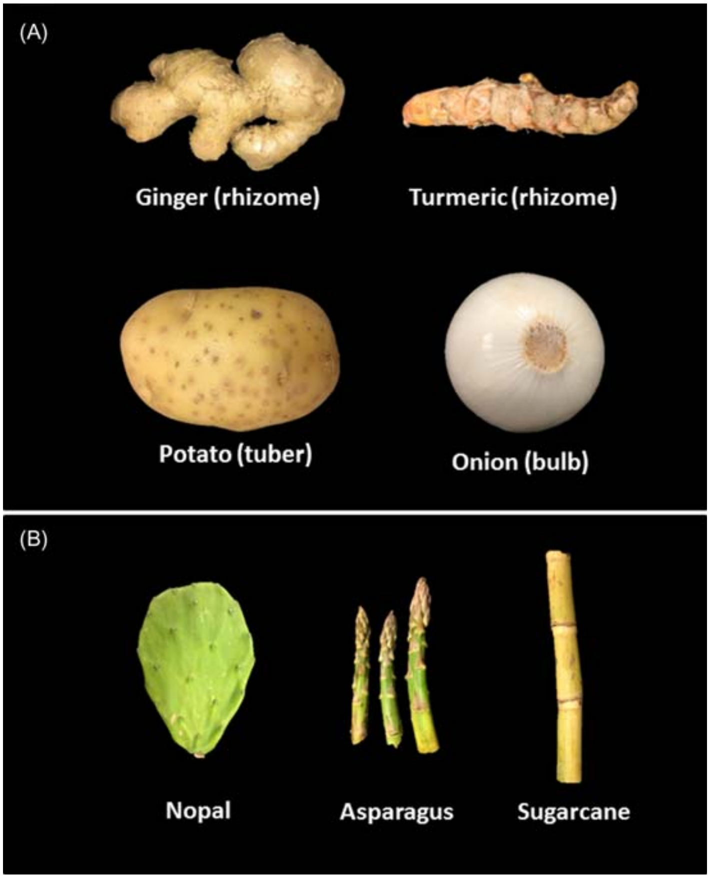

**FIGURE 6.5**

(A) Subterranean stems and (B) aerial stems.

conduction of water, minerals, and photosynthates, in addition to providing support to other parts of the plant. Based on the shape, stems can be classified into cylindrical (such as the case of sugarcane), racket-shaped (such as the case of the prickly pear cactus stem of the *Opuntia* genus, in which the stem is articulated by several green fleshy racket-shaped pads, also called cladodes), spherical (such as the case of the globulous plant of the barrel cactus that is common in arid regions), conical, triangular, quadrangular, polygonal, and acute-angular. Based on consistency, stems can be classified into herbaceous, semiwoody, woody, and fleshy or succulent. This latter class is characterized by its capacity to accumulate a large reserve of nutritive substances and water, and because of that some stems become edible tissue, such as prickly pear cladodes, barrel cactus, and potatoes. The prickly pear cladodes of young plants are tender and juicy. The stem of barrel cactus is eaten as a dessert when combined with sucrose, whereas potato is able to store a great amount of starch. Based on the environment in which the plants live, their stems can be classified as aerial, aquatics, or subterraneous. Among the aerial types are the subclasses named erected, creeping, or climber stems. The aquatics stems belongs to the plants that live in rivers or lakes, whereas the subterraneous stems are those growing underground and are subclassified as rhizomes, tubers, or bulbs. Rhizomes grow and extend horizontally under the soil surface and can be confused with roots, however, rhizomes possess buds from which branches, leaves, and flowers may emerge upward, and also adventitious roots downward. Rhizomes are cylindrical-shaped and are able to store reserve substances. Tubers are subterranean stems that possess evident buds from which may emerge aerial branches. Tubers accumulate nutritive substances, mainly starch, and develop spherical to ovoid shapes, such as potatoes. The bulbs are round-shaped subterranean stems that possess floral and lateral buds established over a basal plate or disc from which adventitious roots grow downward. Onion is an edible example of this type of stems whose fleshy concentric layers store reserve substances (Fig. 6.6).

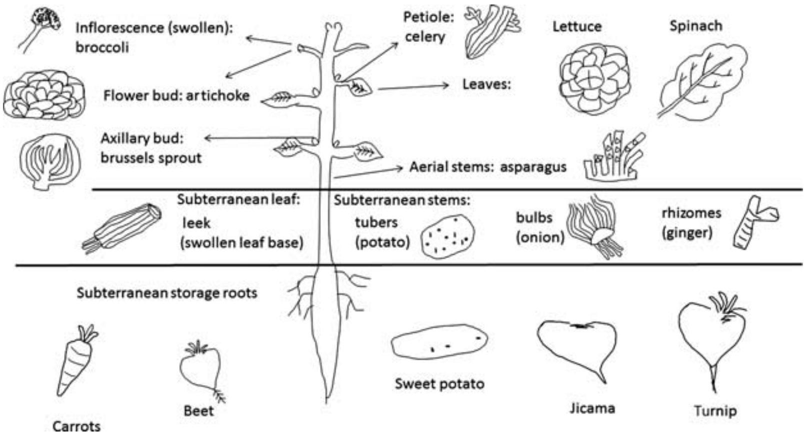

**FIGURE 6.6**
Derivation of vegetables.

## 6.6 THE LEAF

Among the most common horticultural leafy edible crops are lettuce, spinach, leek, celery, endives, and chards (Fig. 6.7). The first leaves originate at seed germination from plumule, and the following leaves to appear come from terminal and axillary buds of stems and branches. Leaves become lateral laminar-shaped structures attached on the stem or its branches at the end of the petiole and may bear two lateral small leaf-like structures called stipules (Fig. 6.8). Leaves bear a bud in their axil named the axillary bud, which later may develop into a branch. The leaf blade or lamina is the green expanded part of the leaf. There is usually a middle prominent vein, called the midrib, and lateral veins connected to the midrib which provide rigidity to the leaf blade and act as a channel for the transport of water, minerals, and food materials. The primary function of leaves is to capture sunlight for the manufacturing of food reserves by photosynthesis. Leaves are also very important in exchanging gases with the environment in order to satisfy the respiration and photosynthesis requirements, in addition to exchange of other gases such as ethylene and water vapor. During gas exchange, the leaf opens its tiny pores, named stomata, located mainly on the lower epidermis. When stomata are

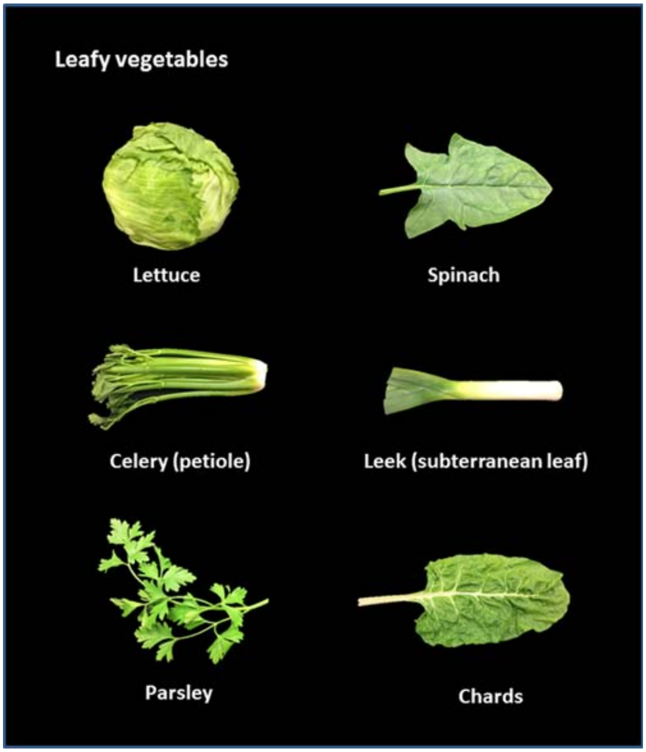

**FIGURE 6.7**
Some leafy vegetables.

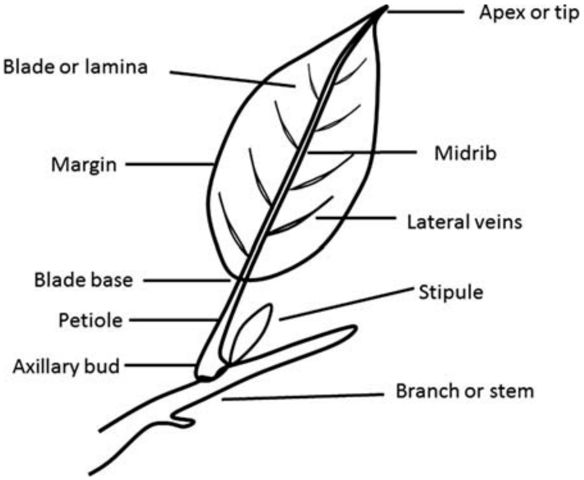

**FIGURE 6.8**
Parts of the leaf.

open, carbon dioxide enters into the leaf, and simultaneously oxygen and water vapor escape into the atmosphere. The phenomenon of water vapor exchange carried out by plants is called transpiration. The water that is lost by the plant due to transpiration should be rapidly recovered by the roots in order to avoid wilting.

The high surface-to-volume ratio of leaves due to their laminar morphology allows them to be very efficient organs for sunlight capture, plant temperature regulation, and gas exchange. Leaves easily lose water due to their laminar shape and the high stomata density (number of stomata/$mm^2$). However, once the leaves have been detached from the plant, they continue transpiring and no more water can be recovered from the soil. Hence, the loss of water from the leaves after harvest must be reduced in order to avoid rapid wilting of the produce. Accordingly, postharvest handling techniques acquire great relevance, and both the temperature and the relative humidity of storage must be optimal for the optimum preservation of leafy vegetables. Likewise, the high surface area-to-volume ratio of leaves, such as in lettuce and cabbage, permits an efficient precooling of the produce by using the method of vaccum-cooling.

## 6.7 THE FRUIT

Botanically speaking the fruit of a flowering plant (angiosperm) is a reproductive organ that can be edible or inedible. However, for the purpose of this textbook fruit has been described in terms of being an edible organ. The fruit is a mature ovary or mature ovaries of one or several flowers, developed after fertilization of flowering plants. After fertilization, all floral organs naturally detach, except the ovary that persists, develops, and undergoes transformations

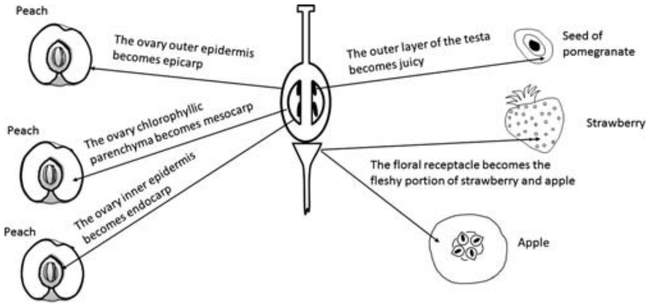

**FIGURE 6.9**
Derivation of fruits.

to becoming a fruit. In some cases, floral structures united with the ovary also develop, in which case it is referred to as accessory fruit. Strawberry is a fruit that has most of its edible part as a product of the development of the floral receptacle (Fig. 6.9). Furthermore, a fruit may be formed without fertilization of the ovary and if this is the case then it is called parthenocarpic fruit.

## 6.7.1 Parts of the Fruit

Generally, the fruit consists of two main parts: pericarp and seed. The pericarp tissue is often the edible part of the fruit and generally develops from the ovary wall (Fig. 6.9).

### *6.7.1.1 THE PERICARP*

The pericarp may be dry or fleshy and is composed of three layers not easily distinguishable in dry fruits, but if the pericarp is thick and fleshy these layers may be easily differentiated into epicarp (outermost layer), mesocarp (middle layer), and endocarp (inner layer surrounding the seeds) (Fig. 6.10).

#### The Epicarp

The epicarp, also called the exocarp, forms the generally tough outer skin of the fruit. The epicarp is also called flavedo in the case of citrus fruits.

#### The Mesocarp

The mesocarp, which is found between the epicarp and the endocarp, is the fleshy middle layer of the pericarp. It is usually the edible part of the fruit, and is eaten along with the epicarp when the latter is rather soft, for example, peach, plum, guava. The mesocarp is known as albedo in the case of citrus fruits, where the epicarp or flavedo along with the mesocarp or albedo constitute the peel that is generally the nonedible part of the citrus fruit.

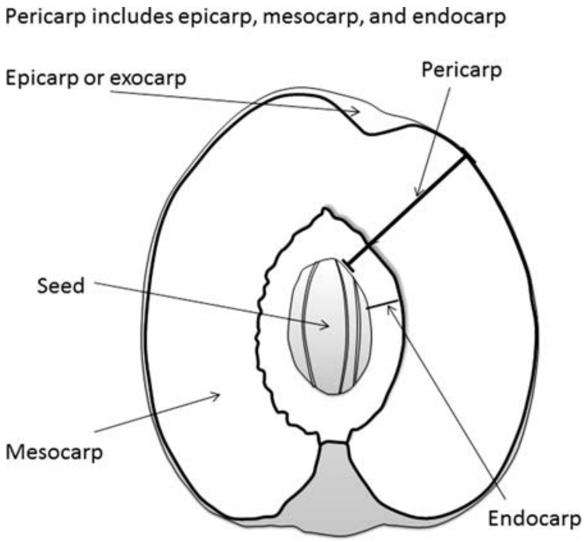

**FIGURE 6.10**
Parts of fruits.

### The Endocarp

The endocarp is the innermost layer of the pericarp, which directly surrounds the seeds. This may be very hard and nonedible as in drupes (also called stone fruits) such as peaches, plums, and cherries, or may be membranous and edible as in the case of citrus fruit where the endocarp is separated into segments filled with juicy vesicles. In some cases, such as lychee, longan, and pomegranate, the edible portion of the fruit is not derived from the pericarp but the aril, which is the fleshy cover of some seeds, usually arising from the funiculus.

### *6.7.1.2 THE SEED*

Examples of edible horticultural seeds are nuts whose stony endocarp must be broken to release the inner edible content, whereas the rest of the pericarp is inedible. Once fertilized the ovule develops into seeds whose general structure is made up of a seed coat and an embryo. The seed coat has two layers, the outer testa and the inner tegmen, whereas the embryo is made up of radicle and plumule. The ovules from the ovary become seeds, whereas the ovule wall becomes the seed coat.

## 6.7.2 Classification of Fruits

Botanically, fruits are classified in accordance with the number of ovaries and flowers involved in their development into three major categories: simple, aggregate, and multiple or composite (Table 6.1). Simple fruits are derived from one flower of a simple or compound ovary. A simple ovary is made up of a simple carpel, whereas a compound ovary is made up of two or more

**Table 6.1** **Classification of Edible Fruits**

| | | |
|---|---|---|
| Simple fruits | | |
| ***Simple monocarpus*** *(it develops from a simple ovary)* | | |
| **Dry** | **Legume** | Dry- and pod-shaped fruit that possesses multiple seeds. Its immature pericarp is edible but withers and turns inedible and exhibits ventral and dorsal dehiscence at maturity, e.g., pea, green beans (Fig. 6.11) |
| | **Caryopsis** | Monospermy dry fruit whose very thin and small pericarp is fused with the seed, e.g., sweet corn (Fig. 6.11) |
| **Fleshy** | **Drupes** | Mesocarp is fleshy . The endocarp is a hard and woody layer that covers the seed, e.g., peaches, plums, walnuts, apricots, almonds |
| Simple syncarpous **(it develops from a compound ovary)** | | |
| **Dry** | **Balausta** | Dry-coriaceous pericarp wrapping a cavity divided by false membranous walls with inserted seeds and juicy testa, e. g., pomegranate |
| **Fleshy** | **Berries** | Fleshy fruit of tiny fleshy endocarp whose frequently numerous seeds are found centered or dispersed all over the mesocarp, e.g., tomatoes, grapes, guavas |
| | **Pepos** | Fruit of hard epicarp, fleshy, and well-developed mesocarp. The fleshy and juicy endocarp is usually confused with the mesocarp, e.g., cucumbers, cantaloupes, watermelons, squash. |
| | **Pomes** | Fruits whose seeds are enclosed by a membranous endocarp. The central portion of the fruit, named the core, develops from the carpel and is clearly differentiated from the surrounding fleshy portion that develops from the floral receptacle, e.g., apple, pear, quince |
| | **Hesperidium** | Thick and soft epicarp that possesses essence excretory glands. Mesocarp is thin, soft, and white that can be spongy or compacted. Edible and juicy endocarp is divided into segments, e.g., all citrus |
| Aggregate fruits **(it develops from numerous separated ovaries of a single flower)** | | |
| **Poly-aquene** | Fruit formed by several single-seeded fruitlets named aquenes is characterized by possessing a dry pericarp that is easily loosen from seed, e.g. strawberry | |
| **Poly-drupe** | Fruit formed by several fruitlets that are drupes attached to a dry receptacle, e. g., raspberries, blackberries | |
| Multiple fruits (also named composite fruits or infructescences. **It develops from clusters of many separate flowers of individual ovaries).** | | |
| **Sicono** | Fruit composed by the fusion of numerous small aquenes surrounded by a fleshy-developed receptacle. It possesses a small pore at bottom end, e.g. figs | |
| **Sorosis** | Infructescence formed by a moderately fleshy axis surrounded by the numerous and compacted fruitlets that come from the inflorescence. Bracts and calyces may be notorious, e.g., pineapples, cherimoyas | |

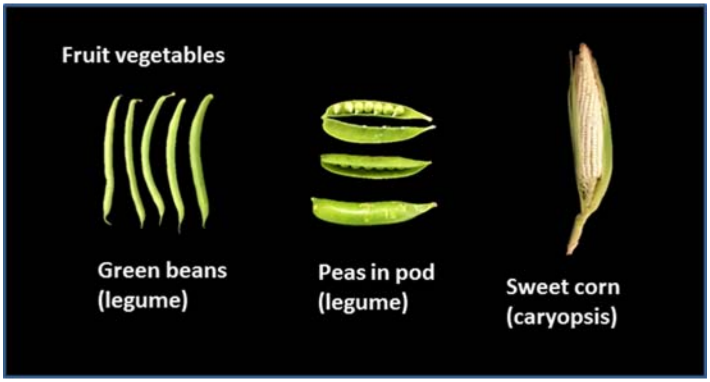

**FIGURE 6.11**
Some fruit vegetables.

fused carpels. Simple fruits of a compound ovary are also called syncarpous or fused fruits. Simple fruits can be either dry or fleshy. Dry fruits may be either dehiscent or indehiscent. Dehiscent fruits are those fruits whose structure is split in order to release their mature seeds, a phenomenon named dehiscence, which is not observed in indehiscent fruits. Simple fleshy fruits include the berries (such as grapes and tomatoes), drupes (such as peaches, cherries, apricots, olives, and plums), pomes (such as apples and pears), pepos (such as cucumbers and pumpkins), and hesperidium (such as oranges and lemons). Simple dry dehiscent fruits include the legumes (such as peas and peanuts). Simple dry indehiscent fruits include the achenes (such as caraway and sunflower) and balausta (such as pomegranates). Aggregate fruits develop from a single flower of numerous ovaries. Aggregate fruits include poly-achenes (such as strawberries) and poly-drupes (such as raspberries). Multiple fruits or infructescences develop from inflorescences which are clusters of many separate flowers of individual ovaries, for example, sicono (such as fig) and sorosis (such as pineapple and cherimoya). Berries develop from compound ovaries, and possess a fleshy endocarp, and usually contain many seeds.

## 6.8 SUMMARY AND CONCLUSIONS

This chapter describes the structural organization of flowering plants based on morphological and anatomical aspects focusing on horticultural crops marketed for edible purposes. Since the relationship between produce and environment is dynamic and depends on many factors, the specific characteristics for the dermal, ground, and vascular systems are addressed. Anatomical characteristics of produce, such as the number of stomata on epidermis, type of surface, thickness and chemical composition of wax and cuticle, tissue underlying the skin and the structure, each play an important role in determining the extent of the produce–environment interaction, and these features vary greatly among fruits. The different parts of a plant, such as the roots, stems, leaves, and fruits are presented separately and commercial examples of products are given. This chapter includes a classification of fruits based upon fruit ontogenesis for which the flower characteristics are of main concern. The great diversity in morphology and anatomy of horticultural commodities complicates their classification in order to integrate groups in a convenient manner to facilitate their postharvest handling. However, same plant parts or organs from different species may present similar anatomical and physiological characteristics and therefore similar postharvest handling conditions, that is, many leafy vegetables such as lettuce, cabbage, and spinach can be subjected to similar postharvest handling techniques such as precooling and storage conditions (i.e., low temperature and high relative humidity). Similarly, for root vegetables (such as carrot, radish, and beetroot) or stem vegetables (asparagus). The group of fruits and fruit vegetables show more diversity in postharvest requirements than vegetables, due to differences beyond the morphological and anatomical characteristics. Aspects such as physiological behavior, climate/region of origin, and stage of development at harvest are more determinants to grouping fruits in groups of similar storage conditions.

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