LEVEL 3

# PRINCIPLES OF HORTICULTURE

Charles Adams, Mike Early,
Jane Brook & Katherine Bamford

ROUTLEDGE

# Principles of Horticulture: Level 3

This colourful guide will explain the fundamentals of growing plants, whether you are taking a Level 3 RHS, City and Guilds or Edexcel course, are a grower or gardener in the industry, or are just a keen amateur. Written in a clear and accessible style, this book covers the principles that underpin plant production, the use of growing media and crop protection, but with reference also to the same practices in the garden or allotment. With highlighted definitions, key points and illustrated in full colour, this book will be a useful companion as you progress in the study and practice of horticulture.

Complete with a companion website which includes extended horticultural information, questions and exercises to test your knowledge, syllabus cross-referencing and downloadable tutor and student support materials. Available at www.routledge.com/cw/adams

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# Contents

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# Preface

Horticulture is the manipulation and control of plants, their growth and reproduction for production, recreational and social activities. This means that it involves complex interrelating areas of botanical, chemical, physical and environmental sciences and, in professional gardening, the influence of art and art history. In earlier times the importance of the production of plants put its study at the forefront of science. The *Gardeners' Chronicle* (predecessor of *Horticultural Week* was the place to announce new developments and discuss the natural philosophical (science) ideas that were emerging in the mid nineteenth century; indeed, Charles Darwin was a frequent contributor from its first year (1841) and the value of the Wardian Case featured in the first edition. Since then the component sciences have become disciplines of study in their own right whilst Horticultural Science remains as an interdisciplinary study underpinning intensive plant production.

Horticulture includes intensive growing of plants for food or decoration, but also the development, propagation, establishment and maintenance of plants for our enjoyment through the landscape industry, and the provision of sports turf. Professional gardeners tend a variety of gardens, many of which are private, but also others that are open to the public. The horticultural industry provides plants for the public to buy for their gardens through the garden centres. Behind all these activities are the specialists who supply seeds, bulbs, and pot plants and hardy plants for all these different branches of horticulture. A common feature of these 'plant people' is their specialist 'attention to detail' that is necessary when growing to meet particular requirements. These may include the production of pot plants at a low cost for a specific market; a selection of plants for an impressive public display at a particular time of the year; or a grass playing surface suitable for year-round sports use. By studying the **principles of horticulture**, we are able to learn how plants grow and develop. In this way, a better understanding of the plant's responses to various conditions enables us to grow plants more effectively. In the end, the horticulturist wants to be able to manipulate the plant so it is grown more efficiently or so that it fits into the planting scheme or decorative arrangement.

The first chapter reviews the **horticultural industry** in more detail and sets out some of the features of each sector of the industry. This is followed in Chapter 2 by an explanation of how plants are classified, summarizing the major groups of relevance to horticulture and, most importantly, the rules and processes governing plant nomenclature to ensure unambiguous communication with others. Then the nature of the **plant cells and tissues** are described (Chapter 3) and related to their function in the various processes that result in **growth** and **development**. Understanding the principles which underlie physiological processes such as photosynthesis and respiration (Chapter 5), transport and water relations (Chapter 6) and plant growth regulation (Chapter 7) have enabled the industry to employ sophisticated methods to maximize growth, provide consistent quality and manipulate behaviour in plants. Chapter 4 explores **plant reproduction**, examining the structures involved and highlighting how they are designed to achieve their purpose. Such knowledge is used by horticulturists to good effect in the many techniques utilized for **plant propagation.**

In horticulture, a large proportion of plants are grown in soils which vary considerably in their ability to produce suitable plant growth. The **physical properties of soil** and the development of the main **soils of Britain and Ireland** are related to how to cultivate them (Chapter 8). Growing in containers using alternatives to soil as a growing medium is covered in Chapter 9. The management of water including drainage and irrigation is the focus of Chapter 10. **Nutrients** are described in detail because they play such an important part in management of productive soils along with **liming** (Chapter 11) which has a major effect on the availability of nutrients. Chapter 12 provides a comprehensive review of organic matter in the soil, composting, the cycling of nutrients and ending with organic growing.

In growing plants for our own needs, we have created a new type of community which brings along problems – problems of competition for the environmental factors between one plant and another of the same species, between the crop plant and a **weed**, or between the plant and a **pest or disease organism**. These latter two competitive aspects create the need for **plant protection** (the subject of Chapters 12 to 15). It is only by identification of these competitive organisms (weeds, pests and diseases) that the horticulturist may select the correct method of control. With the larger pests there is little problem of recognition, but the smaller insects, mites, nematodes, fungi and bacteria are invisible to the naked eye and, in this situation, the grower must rely on the **symptoms** produced (type of damage). For this reason, the pests are covered under major headings of the organism (most of which are large enough to recognize), while the diseases are described under symptoms. Symptoms of physiological disorders such as frost damage, herbicide damage and mineral deficiencies may be confused with pest or disease damage. These plant **physiological disorders** are described in Chapter 14.

For an understanding of plant (or crop) protection, the structure and life cycle of the organism is emphasized so that specific measures, such as, cultural, biological or chemical control, may be used at the correct time. This will help avoid complications such as spray damage, resistant pests or death of beneficial organisms. For this reason, each weed, pest and disease is described in such a way that control measures follow logically from an understanding of the biology. More detailed explanations of specific types of control, such as biological control, are contained in Chapter 15. The intention in the **plant protection** section of this book is to show the range of these organisms in horticulture rather than it being a reference section for weeds, pests and diseases.

Latin names of species are included in order that confusion about the varied common names may be avoided. Newly occurring weeds, pests and diseases in Britain and Ireland are briefly mentioned in the text.

The indexing and key word cross-referencing is to help the reader integrate the subject areas and to pursue related topics without laborious searching. It is hoped that this will enable readers to start their studies at almost any point, although it is recommended that an overview of horticulture is gained by reading Chapter 1 first. Essential definitions are picked out in red boxes alongside appropriate parts of the text. Further details of some of the science associated with the principles of growing have been included in the grey boxes and specialist areas of the horticulture industry are picked out in green boxes. Each chapter concludes with further reading on the subjects covered. In this edition, a companion website (www.routledge.com/cw/adams) is available with extended horticultural information, questions and exercises to test your knowledge, syllabus cross-referencing, downloadable tutor and student support materials and the colour artwork from the text.

After six editions, the subject matter has been more closely aligned with the accepted levels of study. This book provides the ideal support for those studying horticulture at Level Three. The book is organized to align with the very popular RHS 'Certificate in Principles of Plant Growth, Health and Applied Propagation'. It also covers the plant science, plant/crop protection and soils units in the Level 3 Certificate, Subsidiary Diploma, Diploma and Extended Diploma and Work-based Diplomas in Horticulture. It is also intended to be a comprehensive source of information for the keen gardener.

Charles R. Adams
Jane E. Brook
Michael P. Early

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CHAPTER 1

Level 3

# Horticulture in context

**Figure 1.1** Tomatoes in hydroponics

**This chapter includes the following topics:**

- The horticultural industry
- Organizing, communicating and utilizing plant knowledge
- Climate and microclimates
- Science in horticulture
- Manipulation of the physical environmental of plants
- Managing horticultural units
- Plant propagation

## The horticultural industry

Horticulture may be described as the practice of growing plants in a relatively intensive manner. This contrasts with agriculture, which, in most Western European countries, relies on a high level of machinery use over an extensive area of land, consequently involving few people in the production process. The boundary between the two is far from clear, especially when considering large-scale **outdoor production**. When vegetables, fruit and flowers are grown on a smaller scale, especially in gardens or market gardens, the difference is clearer cut and is characterized by a large labour input and the grower's use of a technical manipulation of plant material. **Protected culture** is the more extreme form of this where the plants are grown under protective materials such as polythene or in greenhouses (clad in glass or modern plastics).

There is a fundamental difference between **production horticulture** and **service horticulture** which is the development and upkeep of gardens and landscape for their amenity, cultural and recreational purposes. Increasingly horticulture can be seen to be involved with social well-being and welfare through the impact of plants on human physical and mental health; **horticultural therapy** is a valued means of helping many people through working with plants.

Horticulture encompasses large- and small-scale landscape design and management. Those involved will be engaged in **plant selection, establishment and maintenance**; many will be involved in aspects of garden planning such as surveying and design. Inevitably this may take horticulturists into environmental protection and conservation – for example, motorway verge planting.

There may be some dispute about whether **countryside management** belongs within horticulture, dealing as it does with the upkeep and ecology of large semi-wild habitats. In a different way, the use of alternative materials to turf seen on **all-weather sports surfaces** tests what is meant by the term 'horticulture' in a quite different way; many working 'in horticulture' have responsibilities for much beyond the growing of plants.

This book concerns itself with the principles underlying the growing of plants in the following sectors of horticulture:

- **Outdoor production** of vegetables, fruit and flowers.
- **Protected cropping**, which enables plant material to be supplied outside its normal season and ensures high quality – for example, tomatoes (see Figure 1.1) and strawberries (see Figure 1.2) to a high specification over an extended season, chrysanthemums all the year round (see Figure 1.3 and 7.17), cucumbers from an area where the climate is not otherwise suitable. Plant propagators use a variety of structures to provide seedlings and cuttings for outdoor growing as well as the glasshouse industry. Protected culture using low or walk-in polythene covered tunnels is increasingly important in the production of vegetables, salads, bedding plants and flowers.

**Figure 1.2** Strawberries grown in polytunnels

**Figure 1.3** All year round (AYR) chrysanthemums

- **Interior landscaping** is the provision of semi-permanent plant arrangements inside conservatories, offices and many public buildings and involves the skills of careful plant selection and maintenance. It is considered desirable for the health of workers to maintain indoor landscapes.
- **Landscaping and garden construction** require the skills of construction (**hard landscaping**) together with the ability to develop planted areas (**soft landscaping**). Closely associated with this

sector is **grounds maintenance**, the maintenance of trees and woodlands (**arboriculture** and **tree surgery**), specialist features within the garden such as walls and patios (**hard landscaping**) and the use of water (**aquatic gardening**).

- **Turf culture** includes decorative lawns and sports surfaces for football, cricket, golf etc. Turf management is very much a specialist horticultural profession which is an essential part of the sports industry. On golf courses, for instance, expertise is needed to provide and maintain a range of turf types and, more recently, other areas of golf courses are being managed for biodiversity too (Figure 1.4).

**Figure 1.4** Different areas of turf on a golf course

- **Professional and heritage gardening** covers the growing of plants in both public and private gardens and embraces many aspects of horticulture. It often includes both the decorative and the productive sides of horticulture as seen in many of our stately homes open to the public. Bedding in the Victorian gardens of Waddesdon Manor in Buckinghamshire, for example, is provided on a grand scale and has utilized innovative techniques to provide carpet and three-dimensional bedding (Figure 1.5).
- **Garden centres** provide plants for sale to the public, which involves handling plants, maintaining them and providing horticultural equipment, chemicals, materials and advice. A few have some production on site, but stock is usually bought in (Figure 1.6).
- **Nurseries and the hardy stock industry** is concerned with supplying the other sectors of horticulture including the production of soil-grown or container-grown shrubs and trees (see Figure 1.7) and the young stock of **soft fruit**

**Figure 1.5** Three-dimensional bedding

**Figure 1.6** A range of plants on sale at a garden centre

**Figure 1.7** A hardy nursery stock area

(strawberries etc.), **cane fruit** (raspberries etc.) and **top fruit** (apples, pears etc.).

## Organizing, communicating and utilizing plant knowledge

Common to most of the many and varied sectors of horticulture is the need to be able to identify and describe the various plant groups, so an appreciation of how plants are classified, at least at the level of family and below, is essential. Knowledge of the basic characteristics of plant groups, and the relationships within and between them, helps us to understand their physical and environmental requirements and susceptibilities. It also enables us to predict the requirements of unfamiliar plants. Furthermore everyone who works with plants, be they professional horticulturists, researchers or keen amateurs, need to be able to communicate about the plants involved without ambiguity (see Chapter 2). Recognizing and being able to describe features of plants using botanical terms is also an essential tool for learning about plants and sharing this information with others. For example, the floral features of plants are in large part the basis for plant identification and classification and any description needs to use established terms so it will be accurate and understood by all (see Chapter 4).

As well as being able to describe and name plants effectively, an understanding of how plants operate and their relationships with other organisms can be useful, for example:

- pollinators, e.g. bees that are vital as pollinators in the production of orchard crops
- symbionts, e.g. nitrogen fixing bacteria (see p. 184), mycorrhiza (see p. 184)
- pests and diseases (see Chapters 14 and 15).

Similarly, awareness of the mechanisms involved in pollination and fertilization is necessary to develop plant breeding programmes such as those used to produce F1 hybrids (see Chapter 4). Knowledge of plant tissues and of the process of secondary thickening (see Chapter 3) is useful in propagation from cuttings, grafting and budding (see companion website www.routledge.com/cw/adams) and an understanding of the role of plant growth regulators has led to many applications in horticulture (see Chapter 7).

## Climate and microclimates

Horticulture depends greatly on the prevailing environmental conditions in that it affects plants and the conditions under which the staff work. **Climate** can be thought of as a summary of the

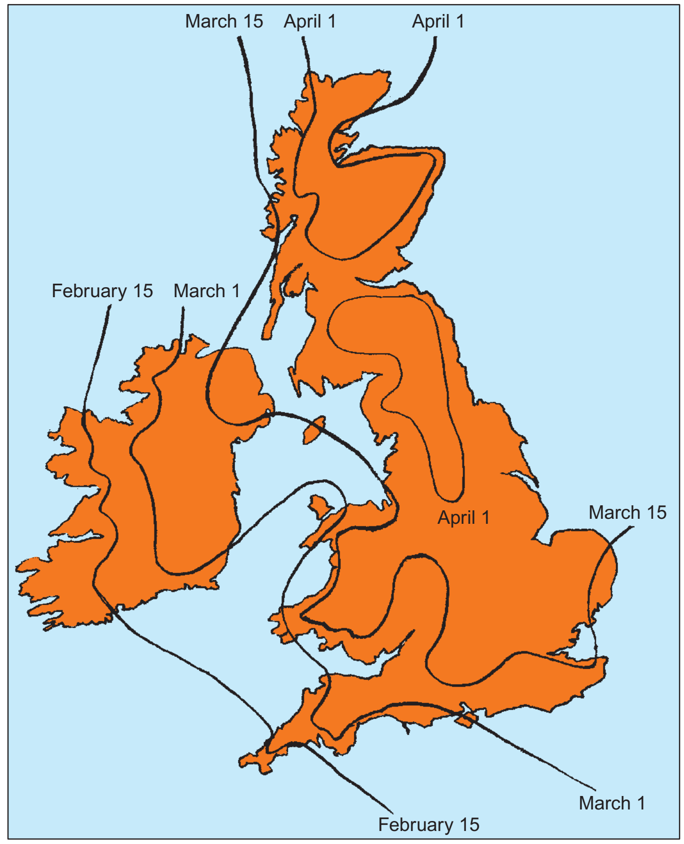


**Figure 1.8** Beginning of spring in Britain and Ireland

weather experienced by an area over a long period of time. More accurately, it is the long-term state of the atmosphere. Usually the descriptions apply to large areas dominated by atmosphere systems (global, countrywide or regional) but **local climate** reflects the influence of the topography (hills and valleys), altitude and large bodies of water (lakes and seas). Growers are aware that even their regional weather forecast does not do justice to the whole of the area because of these factors. The features of the immediate surroundings of the plant can further modify the local climate to create the precise conditions experienced by the plant. This is known as its **microclimate**. Details of these and the following topics are given on the companion website (www.routledge.com/cw/adams):

- weather and climate
- climate of Britain and Ireland (see Figure 1.8)
- world climate
- local climate
- microclimate
- growing seasons
- measurement of rainfall, temperature, humidity, wind, sunlight.

## Science in horticulture

There are several science topics that underpin many of the horticultural principles and are incorporated at their most relevant point in the book in grey boxes. These include:

- plant classification systems (see p. 11)
- misleading plant names (see p. 14)
- alternation of generations (see p. 22)
- photosynthetic pigments and light harvesting (see pp. 67–9)
- the 'Z' scheme (see p. 69)
- balancing chemical equations (see p. 66)
- basic chemistry (see p. 173)
- carbon chemistry (see p. 70)
- proteins and enzymes (see p. 74)
- properties of water (see pp. 89–90).

## Plant performance

The performance of individual plants may be judged in many ways depending on which part of the industry is being considered. For much of production horticulture there is a need for maximum yields and optimum quality, although this has to be with an eye on the costs involved. An understanding of how plants are adapted to particular environments and the science behind plant growth (see Chapter 5) and development (see Chapter 7), nutrition and water together is essential to get the best out of a plant for the purpose intended.

## Manipulation of the physical environmental of plants

The physical environment needs to be adjusted in order to grow the chosen plant species successfully. This may involve the selection of the correct light intensity; a rose, for example, whether in the garden, greenhouse or conservatory, will respond best to high light levels whereas a fern will grow better in low light. Another factor may be the artificial alteration of daylength, as in the use of 'black-outs' and cyclic lighting in the commercial production of chrysanthemums to induce flowering all the year round (see pp. 120–1). Correct soil acidity (pH) is a vital aspect of good growing (see p. 178); *Rhododendons*, blueberries and many heathers require low calcium/high acidity (pH below 5.5), whilst many *Saxifrage* spp. grow more successfully in non-acid (basic/alkaline/calcareous) soils. Other examples include control of temperature, carbon dioxide and water to maximize photosynthesis in glasshouse crops, and the use of plant growth regulators in a wide range of horticultural applications, from micropropagation of strawberry to growth control of bedding plants and post-harvest ripening of bananas.

**Figure 1.9** Automatic weather station

It requires the skill of the horticulturist to bring all these together. In modern greenhouses, they need to programme controls to respond appropriately to the aerial and root environment which are monitored on site (see Figure 1.9); heating, ventilation, lighting are adjusted to provide the ideal conditions for growth whilst optimizing energy use. Interesting developments in greenhouse production include the use of waste heat and $CO_2$ from nearby factories and the production of energy from the green waste arising from the crops (see anaerobic digestion p. 184) and combined heat and power (CHP) – with excess being exported to the National Grid.

## Managing horticultural units

The management of horticultural units requires an understanding of the plant in isolation as well as its performance in the appropriate community. The success of the unit depends on other factors besides the principles of plant growth and development.

**Growing media.** The range of substrates used in horticulture is enormous encompassing a wide range of soils types (see Chapter 8), many composts and hydroponics (see Chapter 9). For all these the **pH** and nutrient levels need to be monitored to ensure that it is suitable for the plants intended and adjusted if needs be (see Chapter 11).

**Cultivations** required to grow on soils depend on the plants, the site and the weather. Typically the soil is turned over, by digging or ploughing, to loosen it and to bury weeds and incorporate organic matter. Secondary cultivation (with rakes or harrows) creates a suitable tilth for seeds or to receive transplants. In many situations cultivation is supplemented or replaced by the use of rotary cultivators. If there are layers deep in the soil that restrict water and root growth, they can be broken up with subsoilers (see pp. 138–9). **Bed systems** are used to avoid the problems associated with soil compaction caused by traffic whether feet or machinery. **'No-dig' methods** are particularly associated with organic growing (see p. 188). Mulching with large quantities of bulky organic matter protects the soil surface from the weather and is incorporated by earthworms. This ensures the soil remains open for good gaseous exchange and root growth as well as, usually, adding nutrients.

**Freedom from weeds** is fundamental to preparing land for the establishment of plants of all kinds. Whilst traditional methods involve turning over soil to bury the weeds, there are several methods that use much less energy that have become more common such as 'no-dig', flame throwers (see p. 234), mulches and total weed control. Once planted the crop then has to be kept free of weeds by cultural methods or by using weedkillers (see Chapters 13 and 16).

**Pest and disease control** can be achieved by cultural, physical, biological or chemical methods. The right choice is helped by having knowledge and understanding of the causal organisms or disorders that affect the plants (Chapters 14 and 15). Managing horticultural units requires the ability to make the best choice of control for the combinations of plant species and harmful species with due regard to beneficial organisms whilst staying within the legal constraints. Essentially modern plant protection has moved to a holistic approach, that is, Integrated Pest Management (see Chapter 16). Industry cooperation with government initiatives in legislative control on recently introduced problem species will help in their reduction.

## Plant propagation

Plant propagation is a specialist area undertaken by many in the industry, but it is at the heart of nursery production. It includes the use of seeds, cuttings, grafting and budding. The range of plants being propagated is vast as is the range of techniques used to bring plants forward for use in the industry. There are many skills involved and a mix of experience and science that enables the staff to get good results. Many aspects of the science underpinning the propagation by seed and vegetative means is covered in the relevant parts of the plant science section of the book:

- anatomical features of germinating seeds (see pp. 49–51)
- seed dormancy (see p. 51)
- seed testing (see pp. 54–55)
- seed treatments (see pp. 55–56)
- seed conservation (see p. 56)
- plant anatomy associated with vegetative propagation (see p. 58 and p. 62)
- plant physiology associated with vegetative propagation (see pp. 62–63)
- propagation of plants by micropropagation (see p. 114).

Some practical aspects of nursery production are covered on the companion website (www.routledge.com/cw/adams) including

- propagation facilities
- hedgerow planting
- maintenance of stock plants for the commercial production of stem cuttings
- preparation of a range of propagules (whip and tongue graft, T-budding, chip budding, bulb scaling, scooping and scoring)
- nursery production of a range of plants – roses, grafted tree fruit and chip budded ornamental trees.

Appropriate books to use to find details of the propagation of a full range of plants can be found highlighted (with asterisk*) in the following further reading section.

## Further reading

Adams, C.R., Early, M.P., Brook, J.E. and Bamford, K.M. (2015) *The Principles of Horticulture: Level 2.* Routledge.

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For further information on weblinks, see the companion website (www.routledge.com/cw/adams).

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CHAPTER 2

Level 3

# Plant classification and nomenclature

**Figure 2.1** *Choisya ternata* 'Lich' otherwise known as *C. ternata* **SUNDANCE** (its trade designation or 'selling name')

**This chapter includes the following topics:**

- Plant classification and the taxonomic hierarchy
- Hybrids
- Nomenclature in wild and cultivated plants
- The ICN and the ICNCP
- Plant Registration Authorities and Plant Breeders' Rights
- Plant name changes
- The meanings of plant names
- Some divisions of the Plant Kingdom – mosses and liverworts, ferns and horsetails, gymnosperms and angiosperms

Any classification system involves the grouping of organisms or objects using characteristics common to members within the group. A classification can be as simple as dividing things by colour or size or it can utilize a large array of features. Fundamental to most systems, and making the effort worthwhile, is that the classification meets a purpose and is therefore useful. For example, to help us find books in a library they can be classified in several different ways such as subject or date of publication, author or topic. This chapter describes the classification used for plants, how their botanical and horticultural names are applied and investigates some plant groups of importance to horticulture.

**Taxonomy** is the study of the principles and practices on which classification is based that is, the systems and methods used to classify organisms. **Classification** is the process of assigning organisms to groups. **Nomenclature** is the process of devising names for organisms.

## Classification and nomenclature of plants

The terms 'classification' and 'nomenclature', although often used interchangeably, are in fact quite distinct. Whilst **classification** is the process of assigning organisms to groups, often within a classification hierarchy, **nomenclature** deals with naming of the groups and individuals in them, once they have been classified. The binomial system, for example, is a nomenclatural system (see p. 14) which is used for living organisms. Such systems have rules governing how names are chosen and used.

Various systems of classification for organisms have been devised throughout history, but the seventeenth-century Swedish botanist Linnaeus laid the basis for much subsequent work in the classification of plants, animals and minerals, based on their external characteristics. Later, with the development of ideas about evolution, classification of organisms also came to be based on what was believed to be their place in evolutionary history. For example, in the Plant Kingdom, simple single-celled organisms from aquatic environments are thought to have evolved into more complex descendants, multicellular plants with diverse structures, which were able to survive in a terrestrial habitat, and which developed sophisticated reproduction mechanisms. Nowadays information from many sources including a plant's external and internal structure, its chemistry, its genetic fingerprint and its relationship to other plants, past and present, is used to inform classification systems. It should be remembered that this is still a work in progress, hence there is no one system universally accepted and systems are constantly evolving. Therefore the exact position of some plant groups within a classification system is still a great matter of debate (see Plant classification systems p. 11).

Classification of the Plant Kingdom involves progressive subdivision into ever smaller groups to form a **taxonomic hierarchy**, starting with the largest groupings, **divisions**, and ending with the smallest, the **species**. The hierarchy always has these groups (or ranks) in strict order and higher ranks have specific name endings:

- **division** (ending in –phyta)
- **class** (ending -opsida)
- **order** (ending -ales)
- **family** (ending -aceae)
- **genus**
- **species**.

A **species** is the basic unit of classification, and is defined as a group of individuals with the greatest mutual resemblance, which are able to breed among themselves but not with other species. A number of species with a high degree of similarity constitute a **genus** (plural genera), a number of similar genera make up a **family** and a number of similar families an **order**. Similar orders are grouped together in a **class**, a number of which make up the largest subgroup, a **division**. Within these basic groups there may be a number of other subgroups (see example given in Table 2.1).

**Table 2.1** The lettuce cultivar *Latuca sativa* 'Little Gem' used to illustrate the classification hierarchy up to the level of Kingdom (Cronquist system)

| Kingdom | Plantae | Plants |
|---|---|---|
| Subkingdom | Tracheobionta | Vascular plants |
| Superdivision | Spermatophyta | Seed plants |
| Division | Magnoliophyta | Flowering plants |
| Class | Magnoliopsida | Dicotyledons |
| Subclass | Asteridae | |
| Order | Asterales | |
| Family | Asteraceae | Aster family |
| Genus | *Lactuca* | Lettuce |
| Species | *L. sativa* | Garden lettuce |
| Cultivar | *L. sativa* 'Little Gem' | |

A **species** is a group of individual plants within a **genus** which have the greatest number of characteristics in common and are able to breed among themselves. A **genus** is a group of species within a family which have characteristics in common.

The **taxonomic hierarchy** is the sequential arrangement of plant groups in the Plant Kingdom.

Because all individuals of a species are able to interbreed, there is always some genetic variation between them, much as humans differ from one another although we are all *Homo sapiens.* Within species this variation is 'continuous' – for example, carrots show the whole range of variation in size and colour in their single species. However, between species, variation is 'discontinuous' – for example, there is nothing which is in between a carrot and a potato because they are unable to interbreed with each other. Species can be described therefore as having the greatest number of characteristics in common, being 'reproductively isolated' and showing 'continuous variation'.

Taxonomists will sometimes identify a naturally occurring variant of a species which is distinct from the original species. These can be placed in three categories reflecting the extent to which the plants vary from the original species and their names can be attached to the binomial name following strict rules. **Subspecies** often occur when species evolve in widely different geographical locations such as on different continents. Because evolution has taken place over a long period they have become the most distinct – for example, *Fuchsia encliandra* subsp. *encliandra*, *Origanum scabrum* subsp. *pulchrum*, and *Geranium asphodeloides* subsp. *crenophilum*, of which the latter is characterized by deeper coloured flowers and more overlapping petals. Members of the category **varietas** also evolve through similar but not so severe geographic isolation, perhaps at the top and bottom of a mountain or on the opposite side of a river or even, as has been recently shown, due to man-made obstacles such as the Great Wall of China. An example is *Ceanothus thyrsiflorus* var. *repens,* a prostrate form of the original species. The least variation is found in the subgroup **forma** which usually describes an individual plant growing within a population of plants with a slight variation caused by mutation – for example, in flower colour such as *Arbutus unedo* f. *rubra,* a pink-flowered form of the strawberry tree.

There is much debate among taxonomists as to whether any particular group of individuals merits placement in each category and at what level, but for the horticulturist they represent a useful source of variation in a plant species. *Subspecies*, *varietas* and *forma* all describe variations from the species which have occurred in the wild. Such names are written in italics and added after the species name. The category is abbreviated and unitalicized.

## Plant classification systems

Plant classification has varied over time with our increasing knowledge and this has led to a number of systems being used which vary primarily according to the rank allocated to different plant groups. The flowering plants, for example, have been treated as a division (Magnoliophyta), a subdivision (Magnoliophytina), a class (Magnoliopsida) or a subclass (Magnoliidae) depending on the view of the taxonomist. Similarly the division containing the conifers called Pinophyta was in the past known as Coniferophyta. Different systems have been favoured by different countries. In addition the terms 'Angiospermae' and 'Anthophyta' have been used widely but do not have a position in the taxonomic hierarchy.

Recently members of the Angiosperm Phylogeny Group (APG), a worldwide group of scientists, have produced a new classification for flowering plants based on their evolutionary relationships or phylogeny. Three groups are recognized: basal angiosperms, which include the most primitive flowering plant groups such as the Magnoliales (magnolias) and Nymphales (water lilies) making up about 3 per cent of flowering plants; monocots, making up about 25 per cent and containing typical groups such as Liliales (lilies) and Poales (grasses); and eudicots, the remaining groups and the most recently evolved. This book follows the Cronquist system of classification which is still widely recognized. However, the work of the APG is steadily gaining acceptance so the taxonomy of flowering plants is very much a work in progress.

## Hybrids

When cross-pollination occurs between two genetically different plants, either in the wild or in cultivation, hybridization results, and the offspring usually bear characteristics distinct from either parent. Sexual hybridization can occur between different cultivars within a species, sometimes resulting in a new and distinctive cultivar, or between two different species, resulting in an **interspecific hybrid**, e.g. *Prunus* × *yedoensis* and *Erica* × *darleyensis* (a hybrid between *E. carnea* and *E. erigena*). A much rarer hybridization between species from two different genera results in an **intergeneric hybrid** – for example, × *Cuprocyparis leylandii* and × *Fatshedera lizei* (a hybrid between *Fatsia japonica* and *Hedera helix*). The names of the resulting hybrids include elements from the names of the parents, connected or preceded by a multiplication sign (×) depending on the type of hybrid. A **graft hybrid** or chimaera is not a sexual hybrid but consists of tissue containing genetic material from two distinct parents which were grafted together. It is indicated by a plus sign (+) – for example, + *Laburnocytisus* 'Adamii' which arose from a graft between *Cytisus purpureus* and *Laburnum anagyroides.* This small tree bears both yellow and purple flowers, and also flowers with an intermediate colour.

## Nomenclature in cultivated plants

Where variation is due to human intervention, such as through controlled crosses in breeding programmes or by selection of mutants which would otherwise not survive in the wild, the term **cultivar** (short for 'cultivated variety') is used. Cultivar names are always written in the vernacular, enclosed in single quotation marks and are unitalicized. They follow the binomial name (e.g. *Bergenia cordifolia* 'Purpurea') or, for fruits and vegetables, the common name (e.g. potato 'Maris Piper'). In practice, the term 'variety' is widely used to refer to cultivars (which can lead to confusion with the term 'varietas'), so the term 'cultivar' should always be used for clarity. In the classification hierarchy, 'cultivar' is a subgroup of species and is equivalent to subspecies, varietas and forma but the cultivar name always follows these in order – for example, *Hydrangea anomala* subsp. *petiolaris* var. *cordifolia* 'Brookside Littleleaf'.

A collective or **Group** name can be given where a species contains a group of cultivars with similar characteristics. The Group name is included in the full plant name (e.g. *Actaea simplex* Atropurpurea Group) and is placed in brackets when the cultivar name is attached (e.g. *Actaea simplex* (Atropurpurea Group) 'Brunette'; in this case 'Brunette' belongs to a group of cultivars with purple leaves). Group names are always unitalicized and can also be applied to fruits and vegetables (e.g. cauliflower (Australian Group) 'Snowcap'). Group names are also used for all the offspring of a particular cross to indicate that they have the same parentage (e.g. *Rhododendron* Polar Bear Group). For orchids only, the Group name is called a **grex** rather than a Group (e.g. *Pleione* Etna gx 'Bullfinch') and the brackets are not included.

## The ICN (ICBN) and ICNCP

By the mid nineteenth century, confusion in the practice of naming plants led to attempts to bring order to chaos. In order to produce a universally acceptable system of nomenclature, the **International Code for Botanical Nomenclature** (ICBN) was eventually formulated. This is an internationally agreed rule book which governs the naming of plants and aims to introduce stability and uniformity and is regularly updated by the International Botanical Congress. In 2011 it was extended to include algae and fungi and the name was changed to the **International Code of Nomenclature for algae, fungi, and plants (ICN)**. Once a name has been chosen according to the rules set down by the Code, it has to be published along with its position in the taxonomic hierarchy and a description of the plant in a recognized journal. Any previous names which the plant may have been known by (synonyms) are also included. Names must also contain an **authority citation** which refers to the person who published the name – for example, *Fragaria vesca* L. where L. stands for Linnaeus (note this not necessarily the person who collected the plant). Names and descriptions may now be published in English as well as in botanical Latin.

Since 1959, cultivar names must follow the rules set by the **International Code of Nomenclature for Cultivated Plants (ICNCP)** also known as the Cultivated Plant Code. This is a separate Code which specifically governs the nomenclature of cultivated plants, namely cultivars and cultivar Groups. It includes rules which describe whether a particular cultivar name is acceptable or not, for example, Latin cultivar names are permitted if they are in common use, as long as they are not part of the genus to which the cultivar belongs. Cultivar names which are solely made up of single letters, Arabic or Roman numerals, or symbols, are not permitted and names must not be longer than 30 letters or 10 syllables. Acceptable cultivars must be: distinct (different from any previous cultivar), uniform (must not vary from plant to plant) and stable (must not 'break down' during propagation and cultivation). Cultivar names must also be published but it is sufficient to publish the names in trade catalogues which are circulated among the general public rather than scientific journals as long as the catalogue is dated and the cultivar has a description attached.

A **trade designation** is an additional 'selling name' which is considered more acceptable than the cultivar name and replaces it at the point of sale. It is always written without quotation marks and in a different font to distinguish it from cultivar names – for example, *Choisya ternata* **SUNDANCE** is the selling name for the cultivar *Choisya ternata* 'Lich' (Figure 2.1). Trade designations are not covered by the Code and cultivar names should appear on the plant label along with the trade designation but rarely do!

## Plant registration and Plant Breeders' Rights

Plant breeders are encouraged to register new cultivars with the appropriate **International Cultivar Registration Authority** (ICRA) where as much information as possible about all the cultivars in a particular genus is gathered together. The ICRAs check names of new cultivars against previous names, provide information on the correct nomenclature for cultivars and work to prevent confusion among existing cultivars. The Royal Horticultural Society (RHS) is the ICRA for nine groups: orchids, conifers, daffodils, dahlias, delphiniums, dianthus, lilies, rhododendrons and clematis. Registration is voluntary and confers no legal protection.

Plant breeders can also apply for **Plant Breeders' Rights** (PBRs) to give legal protection to their investment in developing a new cultivar and this gives the producer exclusive rights to propagate and trade in that cultivar for 20–30 years, in effect it is like patenting the cultivar. PBRs are governed by the International Union for the Protection of New Varieties of Plants (UPOV). In the UK the Plant Variety Rights Office is the body responsible and operates the scheme for 50 or more horticultural and agricultural crops including: trees, woody shrubs and climbers, herbaceous perennials, bulbs, cut flowers and pot plants, lawn grasses, top and soft fruit and some vegetables. Registration can be very costly because tests must be carried out to check the distinctness, uniformity and stability of the new cultivar and that the chosen name fulfils the requirements of the ICN and ICNCP.

See the companion website (www.routledge.com/cw/adams) for further information on International Cultivar Registration Authorities and Plant Breeders' Rights

## Plant name changes

Most horticulturists yearn for stability in the naming of plants. However, the reasons for change are justifiable. Firstly, new scientific findings may have shown that a genus or species needs reclassifying. Sometimes a group of species within an existing genus may be thought to be sufficiently distinct to be placed in a different genus. Linnaeus described the genus *Datura* in 1753 and included a group of species which, following much debate, were finally transferred to a separate genus *Brugmansia*. So, for example, *Datura arborea* has now become *Brugmansia arborea*. Alternatively, two existing genera may be found to be more similar than was first thought, or more plants may have been discovered which are intermediate between the two genera. For example, species belonging to the genera *Pernettya* and *Gaultheria* are no longer distinct enough to warrant being separated into two groups so all species are now 'sunk' in *Gaultheria,* resulting in *Pernettya mucronata* becoming *Gaultheria mucronata*. Similarly, the genus *Azalea* has now been included in *Rhododendron* with consequent changes to plant species names (although plants are still widely sold as *Azalea*). Evidence from biochemistry, microscopy and DNA analysis is proving increasingly important in adding to the more conventional plant structural evidence for plant classification. There may be differing views over whether a family or genus should be 'split' further into smaller units or 'lumped' together into an existing genus or family, or left unchanged; at the end of the day this is a taxonomic judgement.

As well as changes for taxonomic reasons, plant names may change for nomenclatural purposes. A common problem is that a plant may have been 'discovered' by different plant collectors at different times independent of each other. On each occasion a new name will have been given whereas they are all in fact the same species. For example, 29 synonyms have been found for the common daisy *Bellis perennis.* Where this occurs, ICN rules state that only the earliest published name is legitimate so all subsequent names are invalid. Sometimes this **'Law of Priority'** can be waived and the name 'conserved' if changing the name would have disastrous repercussions. This was the case for the houseplant *Fittonia* (published in 1865) which was allowed to keep its name despite the existence of an older generic name *Adelaster* (published in 1861).

Finally, plants can sometimes be introduced to the market simply with an incorrect name which then becomes established. An example is *Sutera cordata* (Figure 2.2), a popular trailing plant for hanging baskets and containers, introduced into Britain in mid 1992 and sold as either *Bacopa* 'Snowflake' or *Sutera diffusa*, neither of which is correct.

**Figure 2.2** *Sutera cordata* sold as *Bacopa* 'Snowflake'

It seems likely that changes in plant names will continue to be a fact of horticultural life. There has been a massive increase in communication across the world, especially as a result of the internet. The level of information about plant names has improved and the introduction of the Codes will eventually lead to more stability and uniformity in plant names. An invaluable reference document, 'Index Kewensis', is maintained by Kew Gardens, listing the first published name for plant species not having specific horticultural importance. Within Britain, the RHS has an advisory panel to help resolve problems in this area. Cultivated species are listed in the 'RHS Plant Finder', which also indicates where they can be sourced. It is updated annually and can be viewed online and is an invaluable reference source for checking the accuracy of plant names. Further cooperation across Europe has led to the compilation of The International Plant Names Index, with associated working parties formed from scientific institutions and the horticultural industry. The internet also offers ways of identifying plants as well as many other organisms – for example, a website connected to the Open University, www.ispot.org.uk, connects experts and amateurs who will share their knowledge when prompted by photographs posted on the website.

## The meanings of plant names

Plant names are **binomial**, that is, they have two parts. The first is the generic epithet and the second is the species epithet. Binomial names are written in botanical Latin which is a language universally used for naming plants and has a long history. The words used in generic and species names reflect a range of derivations and many can give us useful information.

Generic names are often commemorative, that is, named after people. These can be associated with Greek or Roman gods or heroes – for example, *Achillea* (a famous Greek warrior) or *Paeonia* (after Paeon, physician and the god of healing). Another set commemorate botanists and their friends or patrons – for example, *Aubretia* (Claude Aubriet, 1665–1743, a French botanical artist) or *Begonia* (Michel Begon, 1638–1710, a French patron of botany). *Tradescantia* is named after John Tradescant (1570s–1638) who was gardener to Charles I. Generic names, or parts of them can also be descriptive and are often Latinized forms of Greek words – for example, Akanthos (a thorn) in *Acanthus* or Rhodo (a rose) in *Rhododendron.*

Specific names can also be commemorative – for example, *Ceratostigma* ***willmottianum*** after the English gardener Ellen Willmott (1860–1934) or *Buddleja* ***davidii*** named after Father Armand David, a Catholic missionary (1826–1900). They may also reflect the plant's geographical origin, either local (e.g. *Geranium* x ***cantabrigiense*** (of Cambridge)), national (e.g. *Prunus* ***lusitanica*** (of Portugal)) or more general (e.g. *Thuja* ***occidentalis*** (of the west)). Many specific names describe the plant's season (e.g. *Stachyurus* ***praecox*** (early)), life cycle (e.g. *Helianthus* ***annuus*** (annual)), use (e.g. *Passiflora* ***edulis*** (edible) and *Betula* ***utilis*** (useful)) or habitat (e.g. *Caltha* ***palustris*** (of marshes) and *Clematis* ***montana*** (of mountains)). The name ***officinalis*** refers to its being sold in shops, such as apothecary shops, and is therefore often applied to medicinal plants. By far the largest group are those that refer to some plant attribute: such as colour – *Cornus* ***alba*** (white) and *Betula* ***nigra*** (black); growth habit – *Ceanothus thyrsiflorus* var. ***repens*** (creeping) and *Hibbertia* ***scandens*** (climbing); leaf characteristics – *Alchemilla* ***mollis*** (soft), *Viburnum* ***plicata*** (pleated), *Bergenia* ***cordata*** (heart shaped) and *Acanthus* ***spinosus*** (thorny), the list is endless. Some examples are shown in Figure 2.3.

### Misleading plant names

Sometimes plant names can lead the horticulturist astray – for example, *Scilla peruviana* did not originated in Peru but was brought to Britain from the Mediterranean where it originates, on the ship HMS Peru. Whilst *indica* can mean a plant originates in India, it can apply to any plant brought back through the trading activities of the East India Company which could be as far afield as China. *Rosa indica,* for example, comes from near Canton. *Weigela florida* is from NE China and Korea, the specific epithet referring to its many flowers rather than the American state.

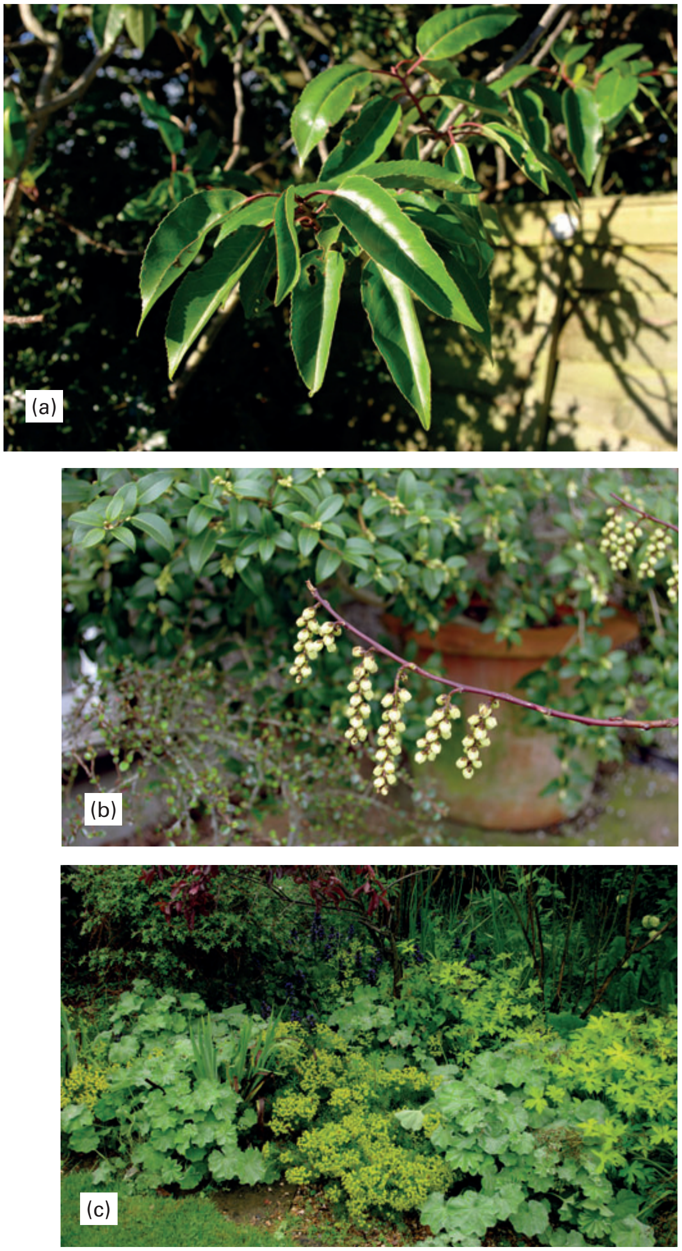



**Figure 2.3** Examples of plant names: (a) *Prunus lusitanica*; (b) *Stachyurus praecox*; (c) *Alchemilla mollis*; (d) *Salvia officinalis*; (e) *Betula utilis var. jacquemontii*; (f) *Acanthus spinosus*

See the companion website (www.routledge.com/cw/adams) for more specific epithets.

## Divisions of the Plant Kingdom

> The non-vascular plants are often referred to as the bryophytes, the vascular non-seed-bearing plants as pteridophytes and the seed-bearing plants as spermatophytes

### Non-vascular plants

**Mosses and liverworts** Over 25,000 plant species which do not have a vascular system (see p. 26) are included in the divisions Bryophyta (mosses) and Marchantiophyta (liverworts). They do not produce seeds and they spread by means of spores. Both are limited to damp shady habitats because they have no waterproofing cuticle, absorbing water over their entire surface, and also have free-swimming sperm as part of their reproductive cycle. Although they have root-like structures called rhizoids which anchor them in the ground, the absence of true roots, leaves and stems means they remain low growing. Mosses and liverworts have two distinct structures in their life cycle. The plant structure we are familiar with is the gametophyte and is composed of haploid cells. This gives rise to the spore-bearing structure (the sporophyte) which is made up of diploid cells and is entirely attached to, and dependent upon, the gametophyte (Figures. 2.4 and 2.5).

Many mosses and liverworts are 'pioneer plants' that play an important part in the early stages

**Figure 2.4** A liverwort growing on a damp rock. The flat leaf-like structure is called a thallus and is the gametophyte part of the life cycle

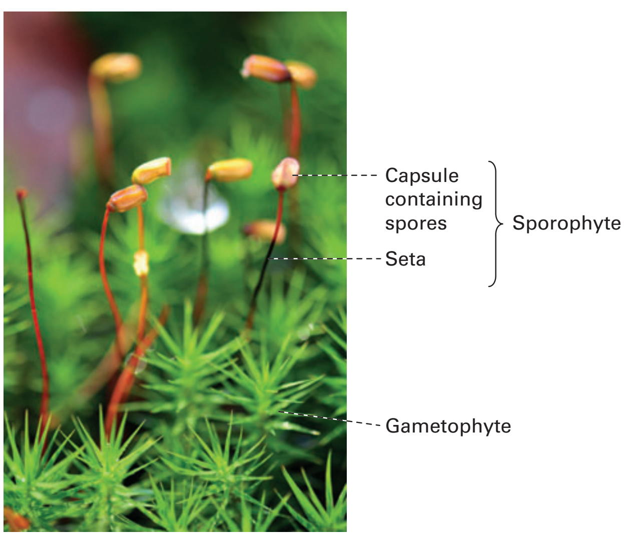


**Figure 2.5** A green moss (the gametophyte) with brown stalks (seta) bearing spore-producing capsules which are the sporophyte part of the life cycle

of soil formation. The low-spreading carpets of vegetation can present a weed problem on the surface of compost in container-grown plants, on capillary benches and around glazing bars on greenhouse roofs. However, moss gardens are an important element in Japanese gardens (Figure 2.6).

## Vascular plants

Vascular plants have identifiable leaf, stem and root organs containing a transport system in the form of xylem and phloem (see p. 26) and a cuticle (see p.25) over their surface to reduce water loss, enabling them to grow taller. They are divided into two groups, those that produce seed and those that do not.

### Non-seed-bearing vascular plants

**Ferns and horsetails** are found in the division Pteridophyta. Like the mosses and liverworts, they spread by spores rather than seeds and they are still limited to damp, shady places as their reproduction involves free-swimming sperm. The major visible structures however are diploid (the sporophyte) with the haploid (gametophyte) part of the life cycle much reduced.

In ferns, the gametophyte is a small leaf-like structure less than a centimetre across called a **prothallus** which bears the reproductive organs. The prothallus resembles a liverwort thallus as it has no roots,

**Figure 2.6** Examples of moss types used in Japanese gardens at the Ginkakuji garden, Kyoto.

Source: Paul Mannix, Creative Commons

stems and leaves and has rhizoids for anchorage. It is only one cell thick which makes it prone to drying out (Figure 2.7a). The prothallus, which grows from a spore, gives rise to the main sporophyte fern body then soon disappears. Fern leaves, or fronds, are generally divided into many pinnae (sing. pinna). On the underside of the pinnae, the spore-producing structures (sporangia) are clustered in sori (sing. sorus) which appear as rusty brown spots (Figure 2.7b).

Many species of fern (e.g. *Adiantum cuniatum* (maidenhair fern)) are often grown as indoor pot plants, and they also provide striking specimens for the garden. *Dicksonia antarctica* (tree fern) is unusual in developing a tall stem from frond bases.

Some tropical horsetails are grown for decorative purposes, but *Equisetum arvense* (common horsetail) and *Pteridium aquilinum* (bracken), which spread by underground rhizomes, are difficult weeds to control (Figures 2.8 and 2.9).

## Seed-bearing vascular plants

Seed-producing plants are the most highly evolved and structurally complex organisms in the Plant Kingdom. There are species adapted to most habitats and extremes of environment. Their well-developed vascular systems enable them to grow much larger and they do not require water for their reproduction. The haploid gametophyte stage of the life cycle is reduced to a few cells, ova (the female sex cells in the ovule) and pollen (see Chapter 4) and the diploid sporophyte structure is the plant we see. Sexual reproduction produces a seed, which is a small, embryo plant carrying its own food store and often contained within a protective fruit.

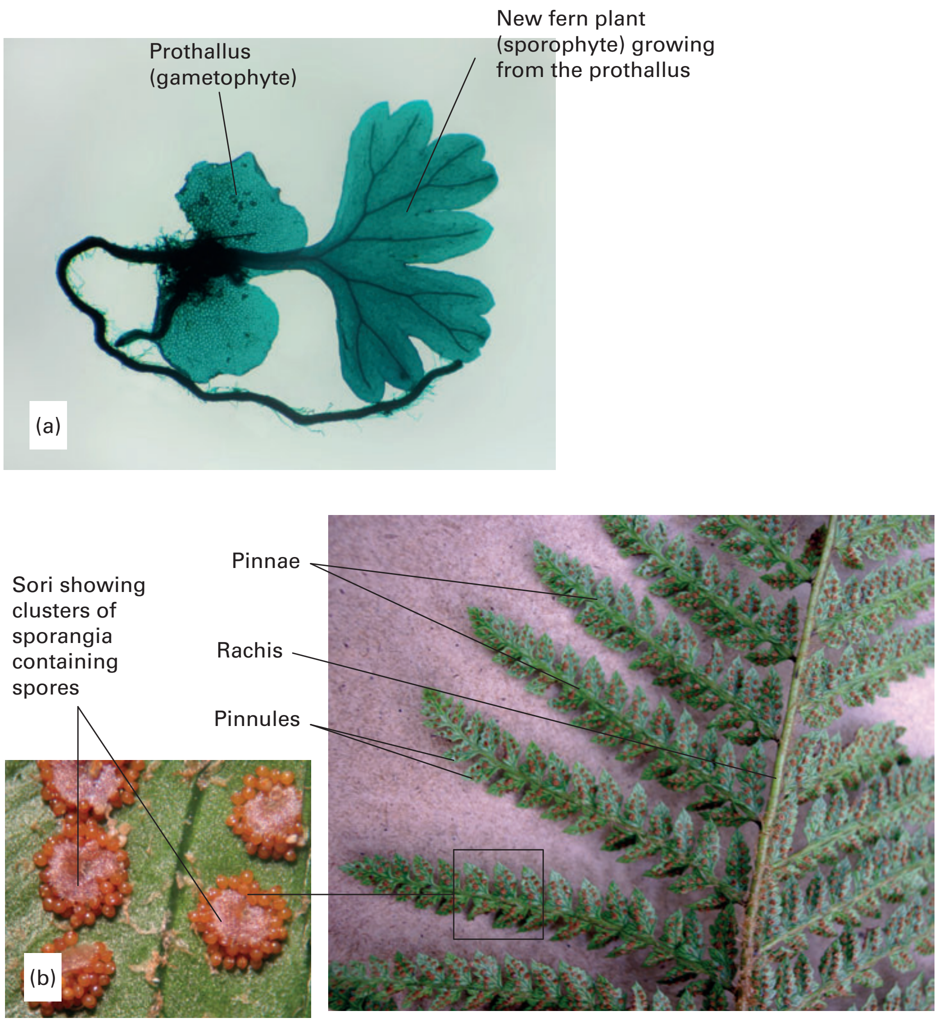


**Figure 2.7** Fern structures: (a) a fern prothallus (gametophyte) showing the new fern plant (sporophyte) just starting to grow; (b) Underside of a fern frond (*Polystichum*)


**Figure 2.8** Four plant divisions with horticultural significance: (a) moss – Bryophyta; (b) liverwort – Marchantiophyta; (c) fern – Pteridophyta; (d) horsetail – Pteridophyta

**Figure 2.9** *Pteridium aquilinum* (Bracken) showing underground rhizomes

Seeds and fruits enable the embryo to withstand adverse conditions through dormancy and can be modified for dispersal by various agents, increasing the plants range. The evolution of the seed habit accounts for the dominance of seed-producing plants on earth.

The seed-bearing plants can be divided into two main groups: the gymnosperms and the angiosperms. Together these represent the greatest diversity of plants with adaptations for the majority of habitats. They present the full range of plant types from annuals to perennials and herbaceous to woody species. Structurally, the gymnosperms have a simpler vascular system than angiosperms and they produce unisexual cones with male cones producing pollen and female cones bearing 'naked' seed, that is, the seed is not enclosed in a fruit. The angiosperms have flowers, usually hermaphrodite, which produce complex seeds (see p. 49) inside a protective fruit (see p. 57).

**Gymnosperms** contain the divisions Cycadophyta (the cycads), Ginkgophyta which has a single surviving species *Ginkgo biloba*, Gnetophyta (with three genera *Welwitschia*, *Ephedra* and *Gnetales* which do not fit easily elsewhere) and by far the most significant division, the Pinophyta (the conifers). Conifers are an ancient group of plants, with a history extending back about 300 million years and many examples in the fossil record. Although containing a relatively few number of families including *Podocarpaceae, Sciadopityaceae, Cupressaceae, Cephalotaxaceae, Pinaceae, Araucariaceae* and *Taxaceae,* the conifers are of great economic importance worldwide.

## *Ginkgo biloba* – a living fossil

The maidenhair tree (*Ginkgo biloba*) is a truly unique specimen. It is the only species in its genus, in fact in its whole family Ginkgoaceae. Its characteristics make it hard to place in classification systems. The seeds (which resemble 'fruits') are produced on the plant surface, and are surrounded by a fleshy, foul-smelling seed coat, making them a member of the gymnosperms. Like cycads, their pollen contains sperm-like sex cells which swim down to the egg cells and their leaves have a primitive and distinctive leaf shape and veination, branching in twos. Ginkgo trees are dioecious in common with many other gymnosperms. Living specimens are little changed from fossils dated back to the Permian period some 240 million years ago and disappeared from Europe only 2.5 million years ago. Ginkgos were 'discovered' in China in the eighteenth century where they were revered and protected by Buddhists monks because of their longevity, they can live 1,000 years or more; but they probably no longer exist in the wild. Ginkgos are very useful street trees as they are tolerant of pollution and can survive in difficult conditions of compacted soil, limited root runs and irregular water supply. They provide yellow autumn colour (Figure 2.10) and although the species can reach 30 m or more, smaller clones and male trees which do not bear fruit are usually planted in this situation.

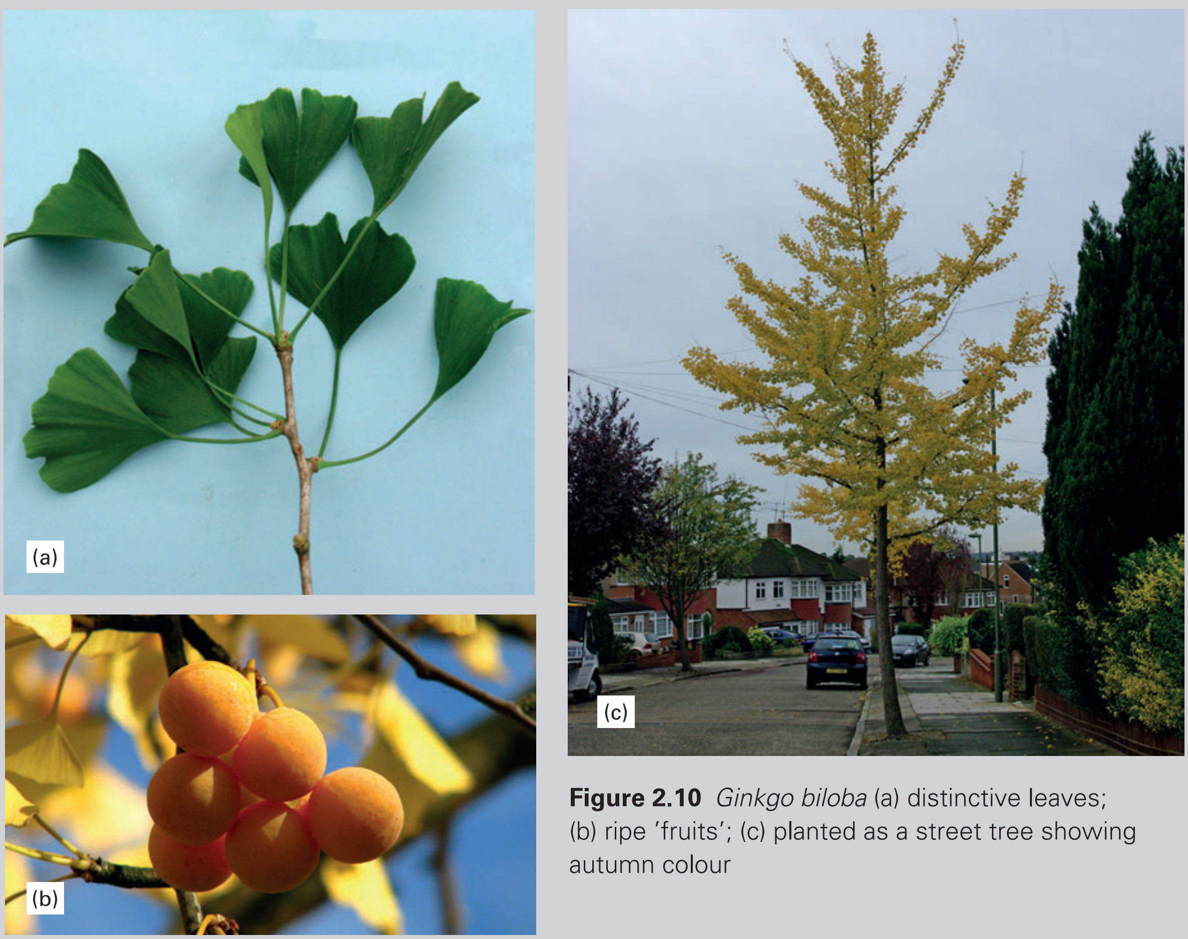


**Figure 2.10** *Ginkgo biloba* (a) distinctive leaves; (b) ripe 'fruits'; (c) planted as a street tree showing autumn colour