Morphology and anatomical structure of the leaf.

Plan

Leaf - lateral organ of shoot.
Leaf mosaic, leaf formations, leaf parts.
The concept of morphological classification of leaves.
Anatomical structure of the leaf.
Classification of leaves depending on the structure of the mesophyll
The structure of the vascular-fibrous bundles of the leaf. Venation of leaves.
Features of the anatomical structure of leaves depending on the type of photosynthesis (C3 and C4).
The structure of the leaf of coniferous plants.

Leaf is a lateral organ of shoot with limited growth, it is growing due to by insertion growth the base (monocotyledons) or the entire surface (dicotyledons). In trees and shrubs, this is a temporary organ.

The main functions of leaf are a photosynthesis, gas exchange, transpiration. In some cases, the leaves can serve for vegetative reproduction. In addition to these functions, the leaf can also perform the functions of storing water and nutrients, attachment to support, absorption of water and nutrients, secretion, protection from eating of animals, attracting pollinating insects, etc.

Being lateral organs, the leaves, as a rule, have a more or less flat shape and a dorsoventral structure. In seed plants, they are always located on the axis of shoot — the stem.

In annual plants, the life span of the leaf is approximately equal to the life span of the stem, in perennial plants it is much shorter. In most plants, the leaf lives no more than 1 -1.5 years, but more often less. In evergreen plants, the leaf functions for 1-5 years, and in some - up to 10-15 years (spruce, araucaria). The exception is a plant of African deserts - Welwitschia mirabilis, in which the leaf is a permanent organ and lives 90-100 years.

Leaf fall is a biological protection of plants from evaporation during physical (summer) or physiological (winter) drought. Together with the leaves, the plant is freed from accumulated excretory substances. In monocotyledonous and herbaceous dicotyledonous plants, the leaf dies and collapses gradually, remaining on the stem. In woody dicotyledonous plants, a separating layer is formed at the base of the petiole, the cells of which undergo natural maceration, and a small mechanical action (wind, rain) is enough for the leaf to fall. The trace left from the leaf on the stem is covered with a cork, it is called a **leaf scar**. In evergreen plants, the leaves fall off at no the same time.

The size of the leaves varies greatly, often even within the same plant. In our flora, some species have very small leaves - up to 1 -1.5 mm long. In plants of tropical and subtropical zones, the leaves can reach 20-22 m in length (palm trees).

The arrangement of leaves on a stem is known as **phyllotaxy**. The number and placement of a plant's leaves will vary depending on the species, with each species exhibiting a characteristic leaf arrangement. Leaves are classified as either alternate, spiral, opposite, or whorled. Plants that have only one leaf per node have leaves that are said to be either alternate or spiral. Alternate leaves alternate on each side of the stem in a flat plane, and spiral leaves are arranged in a spiral along the stem. In an opposite leaf arrangement, two leaves arise at the same point, with the leaves connecting opposite each other along the branch. If there are three or more leaves connected at a node, the leaf arrangement is classified as whorled.

Leaf formations, heterophylly. Usually, leaves are formed on one shoot, which are not the same in size, shape, and color. Leaf formations - it is leaf types of one shoot, differing in shape and location on the shoot. Distinguish basal (lower) - **cataphylls**, median (typical photosynthetic leaves) - **normophylls**, and apical (bracts) - **hypsophylls**. The leaves of the lower formation are usually underdeveloped or modified in connection with the performance of a specialized function (protective, storing) - cotyledon leaves, bud scales, reduced leaves of rhizomes, and sometimes reduced leaves of aboveground shoots. The leaves of the median formation make up the main mass of the leaves of the plant. These are typical leaves for this species and, unlike the previous ones, chlorophyll-bearing. The leaves of the apical formation are located on flowering shoots (in inflorescences). These are bracts, involucre bracts, etc. All of them, as a rule, are underdeveloped, have no petioles, are colored or colorless. When they talk about the leaves of a plant, they mean the median formation of leaves (normophylls). Sometimes the median leaves (normopylls) of one shoot differ markedly in shape, as, for example, underwater, floating and surface leaves of some aquatic plants. This phenomenon is called heterophylly. Heterophylly is exhibited by various land plants including terrestrial and aquatic species. Among angiosperms, heterophylly occurs in diverse taxa. This trait has evolved multiple times during plant evolution among various unrelated taxa. In some cases, heterophylly is perceived to be an adaptive mechanism that allows plants to optimally respond to environmental heterogeneity. That plants capable of exhibiting heterophylly in leaf architecture in response to heterogeneous environment are expected to have better fitness compared to other plants.

Parts of the leaf. In most plants, the leaf consists of a more or less wide blade attached to the stem by means of a petiole (petiole leaf). The blade leaf performs the main functions of the leaf. The petiole orients the plate in relation to the light source. If there is no petiole, the leaf is called sessile. If the blade of a sessile leaf grows to the stem for some distance, a low-lying leaf is formed. General characters of leaf include stipules and other structures located near leaf base: sheath (typical for cereals) and ocrea (typical for buckwheat family, Polygonaceae). If paired lateral outgrowths are formed at the base of the petiole green or filmy, they called stipules. They are usually smaller than a blade but in some plants they exceed it in size and function as a blade (legumes). If the stipules fuse, then a ocrea is formed. Sometimes the base of the petiole expands into the sheath, covering the stem (umbellate). In cereals, the leaf consists of a long tubular sheath and a narrow plate. At the base of the plate there is a filmy appendage - a ligula, and sometimes two more outgrowths on the sides - ears.

Thus, The part of the leaf included:

Blade – see lamina.

Lamina – the flat and laterally-expanded portion of a leaf blade.

Leaflet – a separate blade, among others, of a compound leaf

Ligule – a projection from the top of the sheath on the adaxial side of the sheath-blade joint in grasses.

Midrib – the central vein of the leaf blade.

Midvein – the central vein of a leaflet.

Petiole – a leaf stalk supporting a blade and attaching to a stem at a node.

Petiolule - the leaf stalk of a leaflet.

Pulvinus – the swollen base of a petiole or petiolule, usually involved in leaf movements and leaf orientation.

Rachilla – a secondary axis of a multiply compound leaf.

Rachis – main axis of a pinnately compound leaf.

Sheath – the proximal portion of a grass leaf, usually surrounding the stem.

Stipels – paired scales, spines, glands, or blade-like structures at the base of a petiolule.

Stipules – paired scales, spines, glands, or blade-like structures at the base of a petiole.

Stipuloid – resembling stipules.

There are simple and complex leaves. Leaves may be simple, with a single leaf blade, or compound, with several leaflets. In woody plants, they fall off in autumn, and in herbaceous plants they most often die together with the stem. Compound leaves usually consist of several (two or more) leaflets attached to a common petiole (rachis) short petioles forming joints. Thanks to this, the compound leaf falls off in parts - first the leaflets, and then the rachis.

Compound leaves are classified according to the location of the leaflets on the rachis: palmately compound - leaflets are located on the top of the rachis in the same plane and diverge more or less radially; pinnately-compound - leaflets are arranged along the length of the rachis, and one leaflet (imparipinnate) or two leaflets (paripinnate) can be located on top of it; trifoliate - the leaf has only three leaflets. Pinnate leaves are sometimes of a more complex design — bipinnate, biternate and tripinnate leaves.

Simple leaves are characteristic of most all herbaceous plants and the vast majority of trees and shrubs. They are classified according to a number of characteristics.

Being one of the more visible features, leaf shape is commonly used for plant identification. Similar terms are used for other plant parts, such as petals, tepals, and bracts.

The margins of simple leaves may be entire and smooth or they may be lobed in various ways. The coarse teeth of dentate margins project at right angles, while those of serrate margins point toward the leaf apex. Crenulate margins have rounded teeth or scalloped margins. Leaf margins of simple leaves may be lobed in one of two patterns, pinnate or palmate. In pinnately lobed margins the leaf blade (lamina) is indented equally deep along each side of the midrib (as in the white oak, Quercus alba), and in palmately lobed margins the lamina is indented along several major veins (as in the red maple, Acer rubrum). A great variety of base and apex shapes also are found. The leaf may also be reduced to a spine or scale.

Veins, which support the lamina and transport materials to and from the leaf tissues, radiate through the lamina from the petiole. The types of venation are characteristic of different kinds of plants: for example, dicotyledons such as poplars and lettuce have netlike venation and usually free vein endings; monocotyledons like lilies and bamboo have parallel venation and rarely free vein endings.

Leaf veins are vascular bundles coming to the leaf from stem. Frequently, there is a main vein (midrib) and lateral veins (veins of second order). There are multiple classifications of leaf venation.

Acrodromous – the veins run parallel to the leaf edge and fuse at the leaf tip.

Actinodromous – the main veins of a leaf radiate from the tip of the petiole.

Brochidodromous – the veins turn away from the leaf edge to join the next higher vein.

Campylodromous – secondary veins diverge at the base of the lamina and rejoin at the tip.

Craspedodromous – secondary veins run straight to the leaf edge and end there.

Furcate – forked, dividing into two divergent branches.

Reticulate – veins interconnected to form a network. Net-veined.

Dichotomous venation - vein divides into two similar parts which is known as dichotomous branching. The example of dichotomous venation is the leaf of maidenhair tree, ginkgo (Ginkgo biloba).

Another frequently segregated type of venation is parallellodromous, but in essence, this is acrodromous venation in linear leaves (for example, leaves of grasses) where most of veins are almost parallel.

The leaf blade may be simple or dissected to varying degrees. A leaf is called **entire** if the cuts do not exceed one quarter of the leaf blade.

A leaf is called a **lobed leaf** if the depth of the cuts is more than one-quarter and less than one-half of the leaf. The protrusions between the incisions are called lobes.

A leaf is called **partite leaf** if the cuts exceed half of the blade, but do not reach the middle vein or base of the leaf. The spaces between the incisions are called parts.

A leaf is called a **dissected leaf** if the cuts reach the middle vein or base of the leaf. Their protruding parts are called segments.

Depending on the number and location of the protrusions, there are trifoliate, palmately and pinnately dissected leaves. Leaves are often double or triple dissected if their lobes or segments are dissected

The terms listed here all are supported by technical and professional usage, but they cannot be represented as mandatory or undebatable. Authors often use terms arbitrarily, or coin them to taste, possibly in ignorance of established terms, and it is not always clear whether because of ignorance, or personal preference, or because usages change with time or context, or because of variation between specimens, even specimens from the same plant. For example, whether to call leaves on the same tree "acuminate", "lanceolate", or "linear" could depend on individual judgement, or which part of the tree one collected them from. The same cautions might apply to "caudate", "cuspidate", and "mucronate", or to "crenate", "dentate", and "serrate".

In more detail, we will study the morphology of leaves in practice in botany next semester. You can also get acquainted with the morphology of the leaves by following the link: https://en.wikipedia.org/wiki/Glossary_of_leaf_morphology

https://en.wikipedia.org/wiki/Glossary_of_plant_morphology#Leaves

Anatomical structure of the leaf.

As a rule, the leaf consists of the following tissues:

The epidermis is a layer of cells that protect against the harmful effects of the environment and excessive evaporation of water. Often, on top of the epidermis, the leaf is covered with a protective layer of waxy origin (cuticle).

Mesophyll, or parenchyma— is an internal chlorophyll-bearing tissue that performs the main function — photosynthesis.

A **network of veins** formed by vascular-fibrous bundles (vascular tissue) consisting of vessels and sieve tubes for moving water, dissolved salts, sugars and mechanical elements.

The dermal tissue is the epidermis, covered with trichromes and cuticle. Stomata are located on the lower epidermis, as a rule. In some plants, a layer of hypodermic cells forms under the epidermis, strengthening the strength of the leaf. Often the walls of the hypoderm thicken and perform a mechanical function, in plants of arid habitats they protect from excessive evaporation. The epidermis covers the leaf with a continuous layer, regulates gas exchange and transpiration.

The main mass of the leaf is the **mesophyll**. The mesophyll occupies the entire space between the upper and lower epidermis of the leaf, excluding vascular bundles and supporting tissues. Mesophyll cells are fairly uniform in shape and structure (rounded, slightly elongated). Sometimes the cell walls form folds that protrude inward (infolded mesophyll), which increases the surface and allows you to place a large number of chloroplasts in the wall layer of the cytoplasm. The protoplast consists of a layer of cytoplasm with a nucleus and numerous chloroplasts. There is a large vacuole in the center of the cell.

In ferns and most flowering plants, the mesophyll is divided into two layers: The upper, palisade layer of densely packed, vertically arranged cells directly under the upper layer of the epidermis; one or two cells thick. The cells of this layer contain much more chloroplasts than in the underlying spongy layer. Long cylindrical cells are usually stacked in one to five layers. They, being close to the border of the leaf, are optimally positioned to receive sunlight. The small spaces between the cells are used to absorb carbon dioxide. The gaps should be small enough to support the capillary action of water transfer. Plants must adapt their structure to optimally receive light under various natural conditions, such as the sun or shade - solar leaves have a multi-layered front garden layer, while shadow and leaves lying close to the ground have only one layer.

The cells of the lower, spongy layer are packed loosely and, as a result, the spongy tissue has a large inner surface due to a developed system of intercellular cells communicating with each other and with stomata. The looseness of the spongy tissue plays an important role in the gas exchange of the leaf with oxygen, carbon dioxide and water vapor.

There are several types of leaves depending on the peculiarities of mesophyll structure:

- Dorsoventral. The palisade parenchyma is single- or multi-row and located on the upper side of the leaf, while the spongy parenchyma is located on the lower side.

- Isolateral-spongy. The entire mesophyll of the leaf is composed of spongy cells.

- Isolateral-palisade. The mesophyll consists of one or more rows of palisade cells on either side of the spongy parenchyma.

- Isopalisade. The mesophyll is formed only by palisade cells. Isolateral-spongy, isolateral-palisadic, Isopalisadic are grouped under the general name Isolateral

- Centric (Radial). Mesophyll with radial symmetry of palisade parenchyma and with central position of main vein, sometimes

Dorsoventral and isolateral leaves are usually flat, while radial leaves are round.

In Dorsoventral leaves, the upper and lower sides of the leaf differ well both in appearance and in internal structure. Example: leaves of a senpolia (Usambara violet), in which the upper side is dark green, the lower side is light, almost white. Under the upper epidermis of such leaves, a layer of columnar (palisade) parenchyma is developed. Then located the spongy parenchyma. The stomata are displaced to the lower side of the leaf.

This is the same leaf that we have already reviewed.

Isolateral leaves have the same structure on the upper and lower side. The leaf mesophyll may be either columnar or spongy, or columnar on the surface and spongy inside.

Radial leaves are usually circular in cross-section. If a radial leaf has one conductive bundle, it is located in the center; if several, they are arranged in a ring around the periphery.

Leaf structure in plants with the C4 pathway of carbon dioxide fixation. This type of photosintesis characterized for xerophytes. Corn is not necessarily a xerophyte, but it is adapted to deal with high temperatures. One of these adaptations, C4 type photosynthesis pathways and results in a cell arrangement called Kranz anatomy (German for crown, crown).

The vascular bundles are surrounded by obviously inflated parenchyma cells that form a structure called a bundle sheath, and these are packed with chloroplasts. This chloroplasts is large (often without granums).

The second layer, leaf mesophyll cells, contains chloroplasts of the normal type. Mesophyll cells encircle the bundle sheath cells. In C4 photosynthesis, carbon dioxide is first gathered by the mesophyll cells and temporarily stored as a four-carbon sugar. This four-carbon sugar is transferred to the bundle sheath cells, where it is broken down to release carbon dioxide. It is in the bundle sheath cells where a process called the Calvin cycle, and glucose is ultimately produced. C4 photosynthesis concentrates carbon dioxide inside the bundle sheath cells, reducing the need to frequently open stomata for gas exchange. This helps conserve water.

The vascular-fiber bundles of the leaf are closed, forming the leaf veins. The vascular-fiber bundle has xylem at the top and phloem at the bottom. The vascular-fiber bundle is surrounded by sclerenchymal cells, protecting the bundle from the pressure of expanding parenchyma cells. According to the location of xylem and phloem, it is possible to determine anatomically the upper (adaxial) side of a leaf and anatomically the lower (abaxial) side of a leaf in flat leaves. If the leaves are centric (radial), the phloem and xylem in the vascular bundles will be arranged in the same way as in the stems.

In the leaf, the vascular bundles usually branch and anastomose in various ways. In most cases, the conductive system of a leaf appears in the form of the so-called veining, usually particularly well expressed on its lower side. Leaf veining is very diverse and in different groups of flowering plants has its own characteristic features. Often, finding a single leaf of a plant on the ground, you can tell by the nature of the veining which genus, and sometimes even species it belongs to.

The conductive system of leaves of flowering plants is usually a rather complex structure in which the veins of different branching orders are more or less clearly distinguished. The first order veins are the thickest, basic leaf veins. In leaves with pinnate veining, it is the middle vein, which is a direct extension of the petiole. In leaves with another type of veining, several veins branch from the apex of the petiole.

Primary veins are followed by thinner secondary veins. Even thinner veins, usually branched off from secondary veins but also directly from primary ones, are called tertiary. Then there may be veins of the fourth, fifth, or even subsequent orders. Branches of veins of different orders usually anastomose to one another and often form a complex network densely covering the entire leaf blade. Examining this network under high magnification, we notice that it consists of more or less distinct cages, or areoles (from the Latin areola, plate). In many cases, the loose ends of individual thin veins, which often branch, are visible in these cages.

The vascular bundles of different sizes show quantitative and qualitative differences in their histological composition. The largest bundles contain xylem and phloem in quantities comparable to those in petiole or leaf trace bundles. In collateral bundles, xylem is located on the adaxial (upper) side and phloem on the abaxial (lower) side of the leaf. If leaf traces are bicollateral, the adaxial (upper) phloem is also found in the leaf, but may be absent in small veins. In the largest leaf veins of dicot leaves, conductive tissue forms either one or several bundles.

The arrangement of conductive bundles in the stem indicates a close connection in structure and development between it and its lateral organs, i.e., the leaves. The general term "shoot" serves not only as a convenient designation for the complex of above-ground vegetative organs, but also reflects this relationship.

In each node, one or more vascular bundles go from the central cylinder of the stem through the bark to the leaf (or leaves) of the given node. In the stem, the bundle going from the longitudinal stem bundle to the leaf base, where it connects with the latter's conductive system, is called a leaf trace, and the wide gap, that is, the section of the main tissue located in the central cylinder above the place where the leaf trace departed, is called a leaf burst. A single leaf may include one or more leaf traces from the stem. The number of internodes that they cross varies, i.e., the length of leaf traces varies.

If we trace the course of the vascular bundle up and down the stem, we find that it is connected with several leaf traces, forming what is called a sympody. In some stems, some or all of the sympodia are interconnected, while in others each is an independent conductive complex. In either case, the structure of the stem's conductive system reflects the arrangement of the leaves on the stem.

The structure of the leaf of conifers.

From the surface, the needles are covered with thick-walled epidermal cells. Epidermal cell walls are strongly cutinized. Under the epidermis of the needles, there is a layer of hypodermis, which consists of one layer of small cells with weakly thickened, woody walls, which performs a mechanical function and protects the plant from harsh environmental influences. Stomata are located throughout the epidermis both on the upper and lower sides in depressions of the epidermis, at the level of hypodermic cells. Above the stomatal cleft hangs the cuticle influx.

Mesophyll is parenchyma cells. Chloroplasts are located along the folds, thereby greatly increasing the surface of light absorption. The mesophyll of the needles, consisting of such cells, is called the folded parenchyma. Resin duct can be seen in the needle mesophyll. Each resin duct is lined by a layer of living epithelial cells that secrete resin into it. The epithelial cells are surrounded by a layer of sclerenchymal fibers.

The central axial cylinder is separated from the folded mesophyll by endoderm with Caspari spots. The conducting system, represented by two bundles, is framed from below by sclerenchyma bands, which adjoin tightly to the conducting bundles and connect them into a single whole. This creates a good mechanical support in the center of the bundle, which gives strength to the needle. The rest of the space is occupied by the transfusion tissue, which links the bundles with the mesophyll. Transfusion tissue consists of dead and living cells. The rows of living cells carry assimilates into the phloem. Dead cells transfer water from xylem to chlorenchyma.