

PLANT REPRODUCTIVE SYSTEM

Reproduction in plants is either asexual or sexual. Asexual reproduction in plants involves a variety of widely disparate methods for producing new plants identical in every respect to the parent. Sexual reproduction, on the other hand, depends on a complex series of basic cellular events, involving chromosomes and their genes, that take place within an elaborate sexual apparatus evolved precisely for the development of new plants in some respects different from the two parents that played a role in their production.

General features of asexual systems

Asexual reproduction involves no union of cells or nuclei of cells and, therefore, no mingling of genetic traits, since the nucleus contains the genetic material (chromosomes) of the cell.

Reproduction by fragments

In many plant groups, fragmentation of the plant body, followed by regeneration and development of the fragments into whole new organisms, serves as a reproductive system. Fragments of the plant bodies of liverworts and mosses regenerate to form new plants. In nature and in laboratory and greenhouse cultures, liverworts fragment as a result of growth; the growing fragments separate by decay at the region of attachment to the parent. During prolonged drought, the mature portions of liverworts often die, but their tips resume growth and produce a series of new plants from the original parent plant.

In mosses, small fragments of the stems and leaves (even single cells of the latter) can, with sufficient moisture and under proper conditions, regenerate and ultimately develop into new plants.

Reproduction by special asexual structures

Throughout the plant kingdom, specially differentiated or modified cells, groups of cells, or organs have, during the course of evolution, come to function as organs of asexual reproduction. These structures are asexual in that the individual reproductive agent develops into a new individual without the union of sex cells (gametes).

Airborne spores characterize most nonflowering land plants, such as mosses, liverworts, and ferns. Although the spores arise as products of meiosis, a cellular event in which the number of chromosomes in the nucleus is halved, such spores are asexual in the sense that they may grow directly into new individuals, without prior sexual union.

The vegetative, or somatic, organs of plants may, in their entirety, be modified to serve as organs of reproduction. In this category belong such flowering-plant structures as stolons, rhizomes, tubers, corms, and bulbs, as well as the tubers of liverworts, ferns, and horsetails, the dormant buds of certain moss stages, and the leaves of many succulents. Stolons are elongated runners, or horizontal stems, such as those of the strawberry, which root and form new plantlets when they make proper contact with a moist soil surface. Rhizomes, as seen in ginger, are fleshy, elongated, horizontal stems that grow within or upon the soil. The branching of rhizomes results in multiplication of the plant. The enlarged fleshy tips of subterranean rhizomes

or stolons are known as tubers, examples of which are potatoes. Tubers are fleshy storage stems, the buds (“eyes”) of which, under proper conditions, can develop into new individuals. Erect, vertical, fleshy, subterranean stems, which are known as corms, are exemplified by sugarcane. These organs tide the plants over periods of dormancy and may develop secondary cormlets, which give rise to new plantlets. Unlike the corm, only a small portion of the bulb, as in the onion, represents stem tissue. The latter is surrounded by the fleshy food-storage bases of earlier-formed leaves. After a period of dormancy, bulbs develop into new individuals. Large bulbs produce secondary bulbs through development of buds, resulting in an increase in number of individuals.

General features of sexual systems

In most plant groups, both sexual and asexual methods of reproduction occur.

The cellular basis

Sexual reproduction at the cellular level generally involves the following phenomena: the union of sex cells and their nuclei, with concomitant association of their chromosomes, which contain the genes, and the nuclear division called meiosis. The sex cells are called gametes, and the product of their union is a zygote. Gametes may be motile, by means of whiplike hairs (flagella) or of flowing cytoplasm (amoeboid motion). In their union, gametes may be morphologically indistinguishable (i.e., isogamous) or they may be distinguishable only on the criterion of size (i.e., heterogamous). The larger gamete, or egg, is nonmotile; the smaller gamete, or sperm, is motile. In oogamous reproduction, the union of sperm and egg is called fertilization.

In bryophytes and vascular plants, sexual reproduction is of the oogamous type, or a modification thereof, in which the sex cells, or gametes, are of two types, a larger nonmotile egg and a smaller motile sperm. These gametes are often produced in special containers called gametangia, which are multicellular. In oogamy, the male gametangia are called antheridia and the female oogonia or archegonia. A female gametangium with a sterile cellular jacket is called an archegonium, and produces eggs. In most plants, the eggs are produced in archegonia and the sperms in antheridia with surface layers of sterile cells.

The plant basis

Individual plants may be either bisexual (hermaphroditic), in which male and female gametes are produced by the same organism, or unisexual, producing either male or female gametes but not both. A bisexual individual, however, is not necessarily capable of fertilizing its own eggs.

Among the liverworts, mosses, and vascular plants, the life cycle involves two different phases, often called generations, although only one plant generation is, in fact, involved in one complete cycle. This type of life cycle is often said to illustrate the “alternation of generations,” in which a haploid individual (i.e., with one set of chromosomes), or tissue, called a gametophyte, at maturity produces gametes that unite in pairs to form diploid (i.e., containing two sets of chromosomes) zygotes. The latter develop directly into individuals, or tissues, called sporophytes, in which the nuclei of certain fertile cells, called spore mother cells, or sporocytes, give rise to haploid spores (sometimes called meiospores). These spores are lightweight and are borne by air currents; they germinate to form the haploid, sexual, gamete-producing phase, usually designated the gametophyte.

Bryophyte reproductive systems - Liverworts and hornworts

The plant bodies of liverworts and hornworts represent the gametophytic (sexual) phase of the life cycle, which is dominant in these plants. In the liverworts, the sporophyte is borne upon or within the gametophyte but is transitory. Liverwort and hornwort plants, depending on the species, may be bisexual or unisexual, and the sex organs may be distributed on the surface (*Riccia*, *Ricciocarpus*, *Sphaerocarpos*, *Pellia*) or localized in groups and borne on special branches (antheridiophores and archegoniophores), as in *Marchantia*; the sperm cells are biflagellate. Release of the mature sperm and the process of fertilization require moisture in the form of heavy dew or raindrops. In all but a few genera (*Riccia*, *Ricciocarpus*), the developing sporophytes are actively photosynthetic—i.e., capable of utilizing light energy to form organic substances.

Mosses

In mosses, as in liverworts and hornworts, the leafy shoots belong to the gametophytic phase and produce sex organs when they mature. The leafy shoots (often called gametophores, because they bear the sex organs) arise from a preliminary phase called the protonema, the direct product of spore germination. Filamentous, straplike, or membranous, it grows along the soil surface. A protonema of a moss may proliferate, apparently indefinitely, under favourable conditions and thus increase the population of leafy shoots that arise as buds. Under adverse conditions, certain buds and branches of the protonema may thicken their walls and thus serve to tide the species over an unfavourable growing period.

The antheridia and archegonia may be borne at the tips (apices) of the main shoots or on special lateral branchlets. Both bisexual and unisexual leafy shoots occur, depending on the species. In a number of mosses (*Mnium*, *Polytrichum*, *Funaria*), the sexually mature shoots become recognizable through the production of special prominent leaves that form an apical cup around the sex organs. If the cup is brightly coloured, it is often flowerlike.

The archegonia and antheridia of mosses are large enough in many species to be just visible to the unaided eye. The jacket cells of the antheridia are often coloured bright orange or rust; their sperm are biflagellate. As in liverworts and hornworts, rains and even heavy dews evoke the liberation of sperm and the opening of the mature archegonia so that fertilization may be accomplished.

The moss sporophyte, which is attached to the gametophyte, photosynthesizes during much of its development and is more or less self-supporting.

After elongation of the moss sporophyte has ceased, the distal portion (farthest away) enlarges to form the capsule (sporangium), or spore-bearing region. The spores (meiospores), which arise by meiosis, are shed from the capsule gradually through a variety of mechanisms. After the operculum (cover) of the capsule has been shed, its mouth is usually partially closed by

the peristome (teeth) and sometimes by associated structures. These teeth absorb moisture, and their resultant swelling and contraction open spaces through which the spores are shed.

TRACHEOPHYTE (VASCULAR CRYPTOGAMS AND SEED PLANTS) REPRODUCTIVE SYSTEMS

Spore plants

In liverworts, hornworts, and mosses, the dominant phase in the life cycle is the sexual gametophyte. In the tracheophytes (vascular cryptogams [which lack true flowers or seeds] and seed plants), on the other hand, the sporophyte is the dominant phase in the life cycle. The gametophytes of the vascular cryptogams mature after the spores that initiated them have been shed from the parent plant, so the gametophytes are free-living. In the seed plants, the gametophytes mature as parasites on the sporophytes.

PSILOPSIDS

The trilobed sporangia of the whisk fern *Psilotum*—not a true fern but a psilopsid—are borne terminally on short lateral branches. During development, some of the potentially spore-bearing tissue is used as nutrient by the sporocytes as they complete the meiotic divisions that result in colourless kidney-shaped spores. The spores, which are shed as the sporangia open along three lines, germinate and slowly develop into cylindrical sparingly branched gametophytes. They presumably derive nourishment from decaying matter and occur in humus-rich soil, in rock fissures, or among roots on the trunks of tree ferns. The cells of the gametophyte contain fungal structures (hyphae) that probably are involved in some type of nutritional relation with the gametophyte.

The gametophytes are bisexual and the sperm cells are multiflagellate. The embryonic sporophyte is not easily distinguished from the gametophyte that bears it. At first anchored to the gametophyte by an absorptive foot, the sporophyte ultimately becomes separated from both the foot and the gametophyte.

LYCOPSIDS

In the genus *Lycopodium*, the sporangia are closely associated with the leaves. In some species (*L. lucidulum*), the sporangium-bearing leaves (sporophylls) occur in zones among the vegetative portions of the stems. In most, however, the sporophylls occur in specialized compressed stems called cones or strobili.

In *Selaginella* (Spike mosses), the sporophytes have sporophylls localized in strobili. All species of *Selaginella* are heterosporous i.e. produces spores of two sizes; the larger designated as megaspores which develop into female gametophyte and the smaller known as microspores which

become the male gametophyte. The spores of *Selaginella* begin to develop into gametophytes before they have been shed from their sporangia and attain maturity on a suitable moist substrate.

The microscopic male gametophyte is composed essentially of a single antheridium, which produces biflagellate sperm. The female gametophyte consists of vegetative cells with several archegonia at maturity. Both male and female gametophytes lack chlorophyll (green pigment), which is necessary for photosynthesis, thus they utilize nutrients stored in the spores.

FERNS

As they mature, many fern sporophytes begin to produce spores in clusters of sporangia on the undersurfaces of their fronds (or vegetative “leaves”). Others produce their sporangia on highly modified leaves or portions thereof.

The site of origin of the sporangia is the receptacle, this with its groups of sporangia, is called a sorus. In many ferns, each sorus is covered with a special outgrowth, the indusium; in others the sporangia are covered during development by the margin of the leaf. In a few ferns (e.g., *Polypodium*), the sori remain uncovered.

Seed plants

In the two great groups of seed plants, gymnosperms and angiosperms, the sporophyte is the dominant phase in the life cycle, as it is also in the vascular cryptogams; the gametophytes are microscopic parasites on the sporophytes.

In the gymnosperms, the seeds occur individually, exposed at the ends of stalks, sometimes in whorls on an axis, or on the scales of a cone, or megastrobilus. In angiosperms, or flowering plants, on the other hand, the seeds are enclosed during development in a structure variously termed a pistil or a carpel, which is sometimes considered to represent an enfolded megasporophyll.

A number of parts of the reproductive process are common to both angiosperms and gymnosperms: (1) they produce seeds at maturity; (2) the megasporangium, unlike that of heterosporous seedless plants, is covered by one or two cellular layers called integuments and is termed an ovule; (3) there is a minute passageway, or micropyle, through the integuments; (4) the ovule matures as a seed; (5) only one megasporocyte is present and undergoes meiosis in the megasporangium to produce four megaspores, only one of which usually is functional; (6) the megaspore is never discharged from its megasporangium and ovule; (7) one female gametophyte is produced within each megasporangium and ovule; (8) the microspores begin their development into male gametophytes

while still enclosed in the microsporangia; (9) as they mature, the male gametophytes, which are contained within the microspore wall and are termed pollen grains, develop a tube that conveys sperm to the egg cell; (10) union of sperm and egg and development of an embryonic sporophyte from the zygote occur within the female gametophyte (sometimes called the “embryo sac”), which is covered by the remains of the megasporangium and by integuments; (11) as the embryo develops, the ovule matures as a seed.

Differences, which, in addition to seed position, serve to distinguish angiosperms from gymnosperms. (1) The reproductive cycle in most angiosperms is completed more quickly than that in gymnosperms, and the gametophytes are smaller and simpler and, (2) unlike those of most gymnosperms, lack archegonia. (3) The pollen in angiosperms is transferred to the surface of the megasporophyll, whereas in gymnosperms it is brought to the micropyle of the ovule itself. (4) Two sperm cells are involved in the sexual union in angiosperms: one unites with the egg to form a zygote; the other unites with two nuclei of the female gametophyte to form the primary endosperm nucleus. (5) This divides to form a post fertilization storage tissue, which serves as a food source for the embryo; the embryo of gymnosperms is nourished by the somatic (non-reproductive) tissues of the female gametophyte. (6) The angiosperm ovule increases to mature seed size after fertilization, whereas in gymnosperms, this enlargement occurs prior to fertilization.