Penicillium
(Plectomycetes)

ECOLOGY

A taxonomic account of the genus is given by Raper and Thom (1949) and Pitt (1980). It is one of the most cosmopolitan genera of fungi present in air. Most species are saprophytes. Some species like *P. expansum*; are weak parasites causing rotting and spoilage of fruits (apples, oranges, pear, grapes) in storage. Textiles, paper, pulp and lumber woods are deteriorated by species of *Penicillium*. Some species are of industrial value. *Penicillium roqueforti* and *P. camemberti* are used in hydrolysis of fats and butter and to impart flavour to cheese. Some are source of medicines. *P. notatum* and *P. chrysogenum* are used in the commercial synthesis of the antibiotic, penicillin. *P. citrinum* is possibly "one of the most common eukaryotic life form on earth."

Vegetative Structure

The mycelium is profusely branched with septate hyphae which may penetrate deeper into the substratum or grow superficially as mycelial felt. The cells are thin-walled, one to multinucleate. The colonies appear as floccose, funiculose or velvety. The hyphae are generally coloured due to presence of pigments on the surface of hyphal walls.

Asexual Reproduction

It occurs by the development of conidia on characteristic conidial apparatus-the branched conidiophore bearing successive whorls of branches terminating in a cluster of phialides. The conidiophores arise from aerial as well as submerged hyphae. There are no foot cells. In some species (Section-Monoverticillata) as *P. spinulosum* the phialides are borne directly on the conidiophores (Fig. 7.14A). In most species,

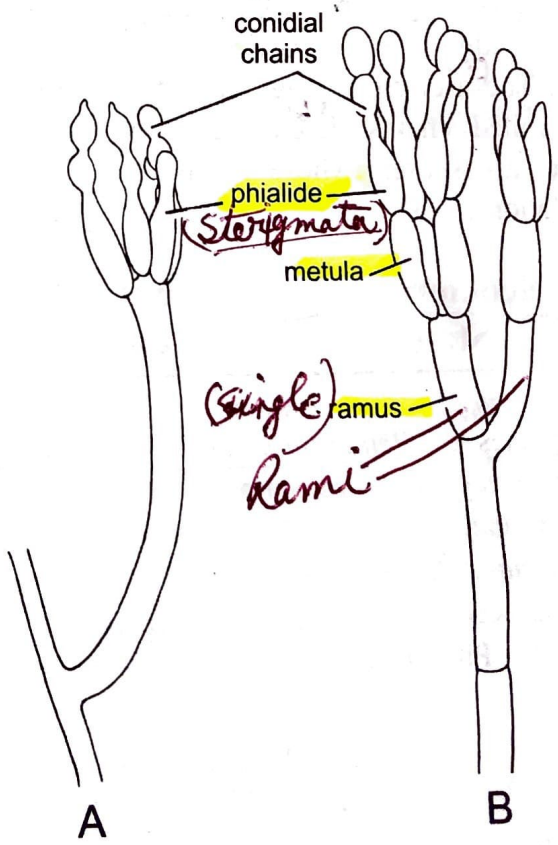


Fig. 7.14. A-B. Conidiophores and conidia of *Penicillium spinulosum* (A) and *P. expansum* (B).

however, the phialides are borne on a further whorl of branches or metulae and these may in turn arise on a further verticil of branches the rami as in *P. expansum* (Fig. 7.14 B). In some species as *P. claviforme* the individual conidiophores may be aggregated together into club-shaped fructifications known as coremia. The detailed method of conidial formation is more or less similar to that described earlier for *Aspergillus*. Phialoconidia are developed within the phialides in besipetalous chains. The conidia are green and dry, and dispersed by air currents.

Sexual Reproduction

Penicillium also presents the taxonomic and nomenclatural problems like *Aspergillus*. Ascocarps are rarely formed. Teleomorphs are known only in 31% of all described species of *Penicillium*. Sexual reproduction, wherever known may be either isogamous or anisogamous. Most species is homothallic except some like *P. luteum* which are heterothallic. In *P. bacillosporum* sexual branches arise as short, identical, multinucleate branches, and become helically coiled around each other. Plasmogamy takes place. Ascogenous hyphae develop within the ascocarp and these give rise to asci. The asci are arranged end to end to form short, coiled chains. Each ascus contains eight globose ascospores whose walls have distinct echinulations.

Teleomorphs (Perfect, Sexual) States of *Penicillium*

Most species of *Penicillium* have no ascocarps. Some species develop ascocarps in their life cycle. Ascocarps can be assigned to different genera : *Eupenicillium*, *Talaromyces* and *Carpenteles*. A taxonomic account of perfect states of *Penicillium* is given by Pitt (1980).

Eupenicillium

The conidiophores (anamorph) are mono–, bi– or triverticillate. This genus includes the species with relatively simple conidiophores which produce either sclerotia or ascocarps with very tough peridia (sclerotic ascocarps). They have pulley wheel-like flanges. This type of ascocarp is found in *Eupenicillium javanicum* and *E. brefeldianum*. The latter species is homothallic.

Talaromyces

The conidiophores in all species are biverticillate with long tapering phialides that are closely appressed to each other rather than divergent. In this way they resemble *Paecilomyces*, some species of which are also associated with *Talaromyces* (Table 7.2). This genus includes the group of Penicillia called the Biverticillata-Symmetrica with long, tapering phialides. In *Talaromyces vemiculatus* (*Penicillium vermiculatum*), the elongated ascogonium and a short antheridium arise from hyphal branches (Fig. 7.15 A, C). The terminal cell of a hyphal branch elongates to become ascogonium which is usually unicellular and uninucleate. As it matures, nuclear divisions occur making it multinucleate. Meanwhile another small slender branch develops close to the ascogonium. This is also uninucleate. This is antheridial branch. It ascends up coiling itself loosely around the ascogonium. The mature male branch cuts off apically the antheridium proper (Fig. 7.15 C) which is uninucleate. It becomes swollen and closely appressed to the ascogonial wall (Fig. 7.15 C, D). The contact wall between the two dissolves. However, nucleus from antheridium has not been seen migrating to ascogonium. The male nucleus perhaps degenerates. Ascogonium divides into a row of large number of cells (Fig. 7.15 E), each containing two nuclei. From some of these binucleate cells, ascogenous hyphae develop and their terminal cells give rise to asci in usual way (Fig. 7.15 F). The asci are held in short chains, and each ascus is eight-spored. An envelope of sterile hyphae grow to form a compact tangled mass around the developing asci. The ascocarps (cleistothecia) are loose, soft, cottony structures (Fig. 7.15 G). The ascospores are variable in shape : spherical, elliptical or lenticular, and

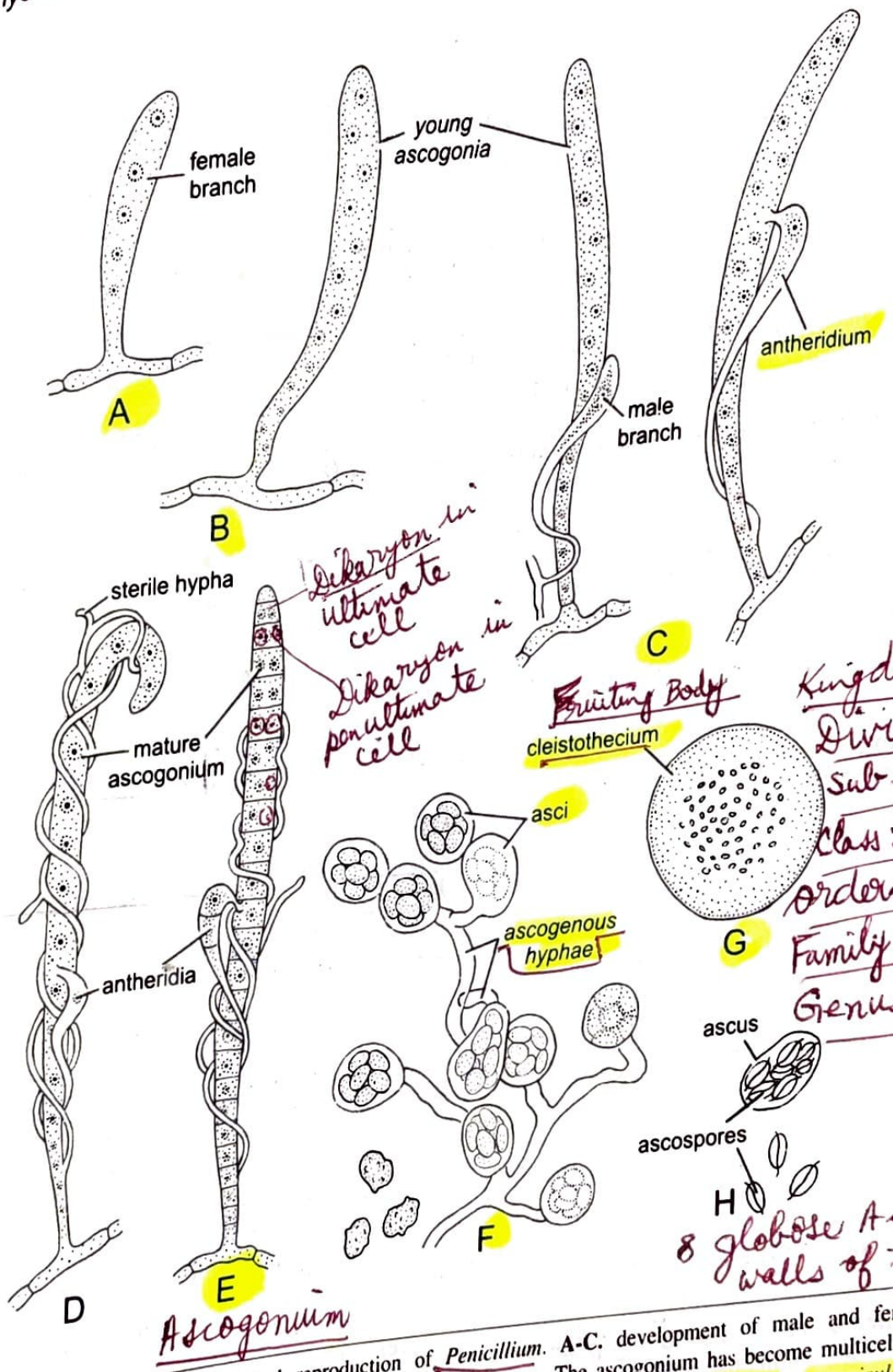


Fig. 7.15. A-H. Stages in sexual reproduction of *Penicillium*. **A-C.** development of male and female branches (antheridia and ascogonia), **D, E.** stages in plasmogamy. The ascogonium has become multicellular with dikaryotic cells **F.** ascogenous hyphae and asci of *Talaromyces vermiculatus*, **G.** an entire ascocarp of *T. vermiculatus*, **H.** ascus and ascospores of *T. stipitatus*.

smooth-walled or echinulate, pitted or distinctly banded giving a pulley-wheel-like appearance (Fig. 7.15 H). Ascospores germinate to form the new mycelium. Another species of *Talaromyces*, *T. stipitatus* (*Penicillium stipitatum*) also produces loose ascocarps.

re thin and
erotia are produced.

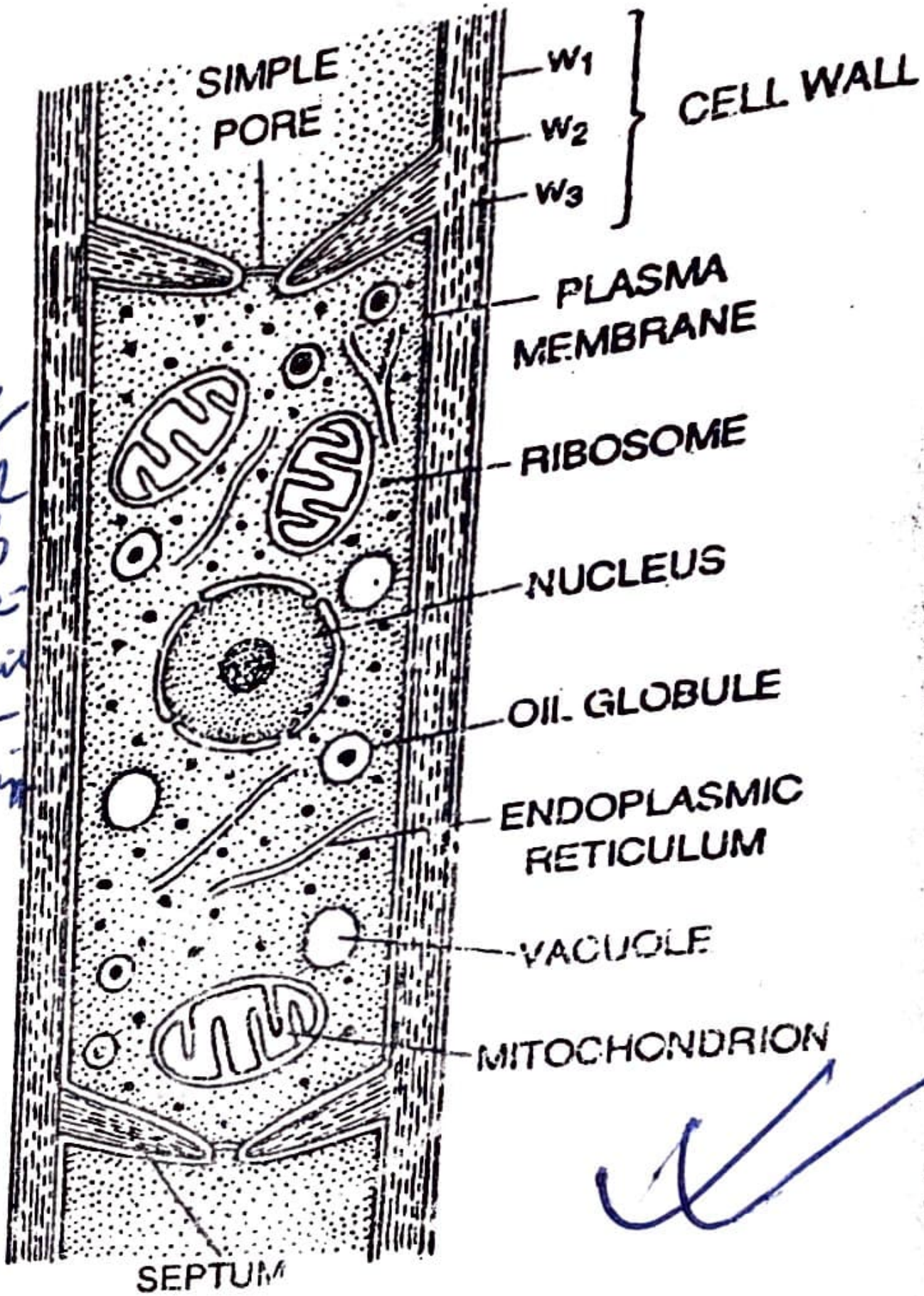


Fig. 12.33. *Penicillium* spp. Ultra

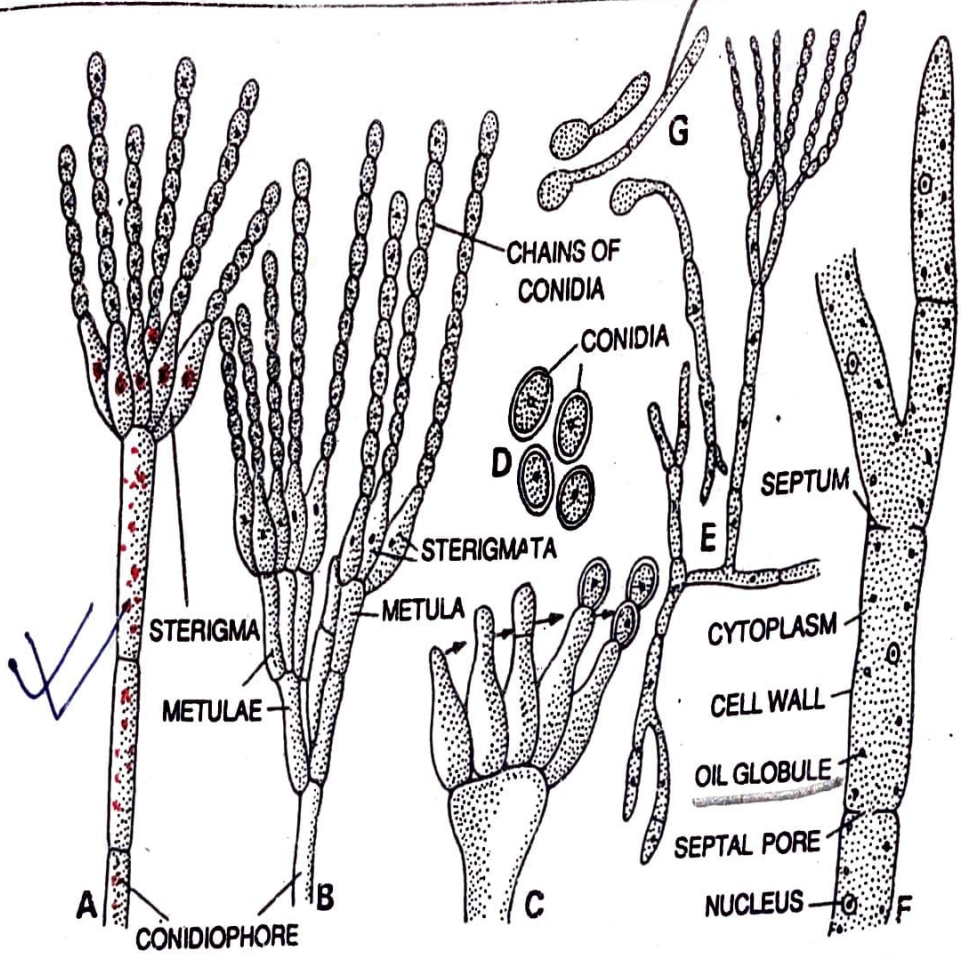


Fig. 12.40. *Penicillium* sp. Asexual reproduction. A, sterigmata and conidial chains arising on unbranched conidiophores; B, sterigmata and conidial chains developing on branched conidiophore; C, formation of conidia on sterigmata; D. conidia; E, conidiophore developed on mycelium; F, part of mycelium; G, germinating conidia.

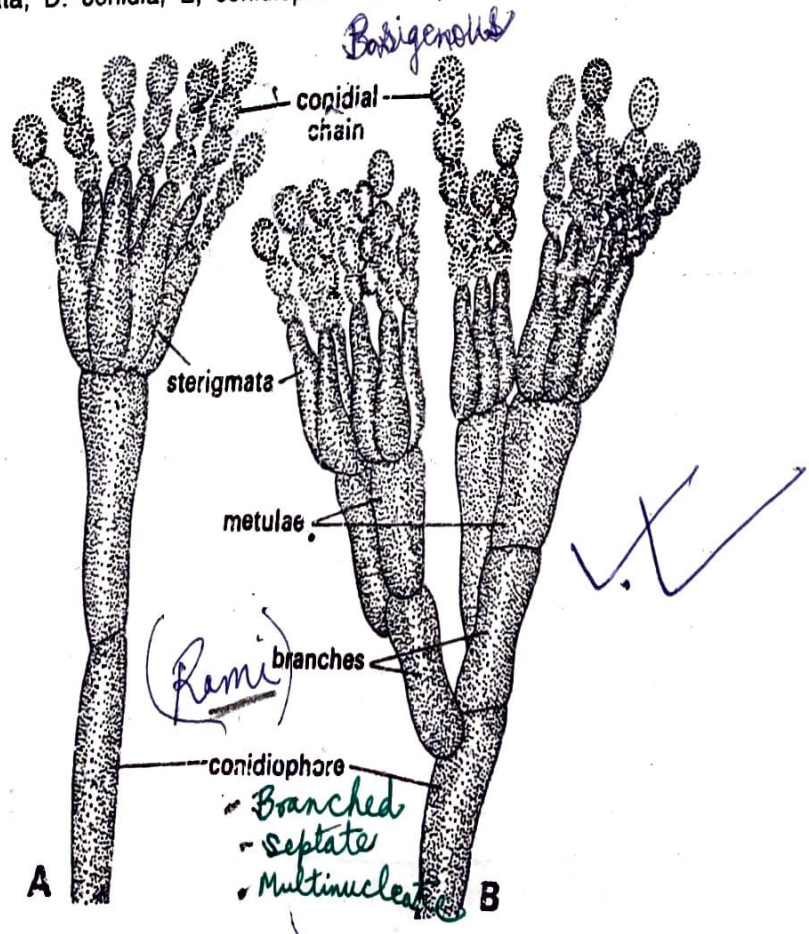


Fig. 12.41. Monoverticillate (A) and biverticillate (B) conidiophores of *Penicillium*.

female nuclei found in the pairs in the ultimate and penultimate cells of the

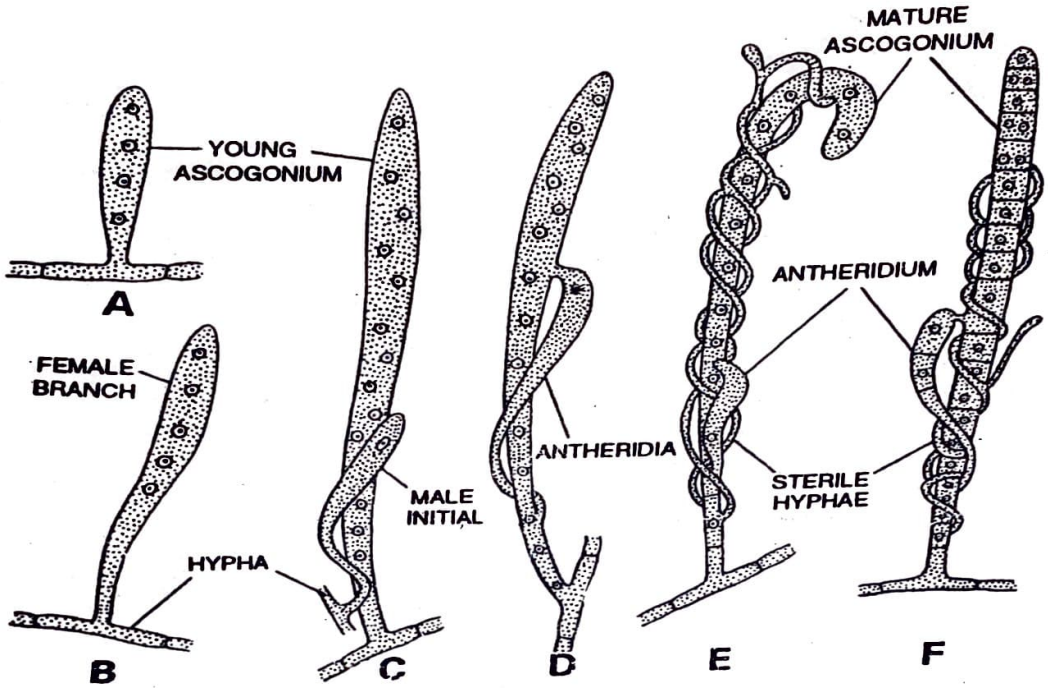


Fig. 12.44 *Penicillium*. Sexual reproduction — early stages.

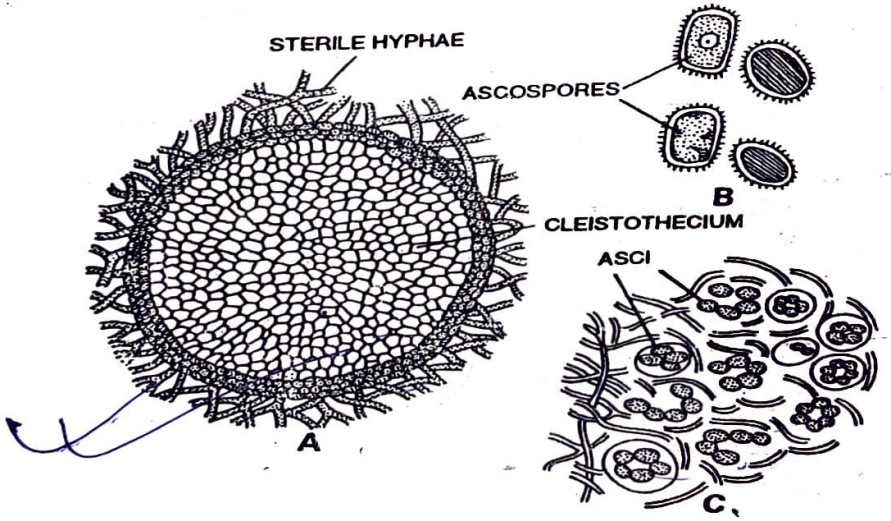


Fig. 12.45. Sexual reproduction is *Penicillium*, later stages. A, cleistothecium; B, ascospores, C, a part of cleistothecium.

Neurospora

(Hymenoascomycetes : Pyrenomycetes)

Ecology

This genus has been widely used in biochemical and genetical studies. Two best-known species are *Neurospora crassa* and *N. sitophila*. From India, the former species is reported on fruits of papaya and from water. These two species colonise burnt ground and charred vegetation, and also found in warm humid places like kilns and bakeries. For this reason, *N. sitophila* is also commonly called the red bread mould.

Vegetative Structure

Mycelium grows rapidly and superficially on the substrate. The hyphae are branched, coarse and septate, with multinucleate cells.

Asexual Reproduction

The mycelium reproduces rapidly by conidia. There are formed two types of conidia : macroconidia and microconidia.

1. **Macroconidia.** They are formed as large conidial masses on upright branches. The aerial upright branches arise from the mycelium. On each branch, there develop branched chains of multinucleate pink conidia. The terminal conidium of a chain may bud further to form more conidia. Conidia of this type belong to the form-genus, *Monilia* (Fig. 7.16 A, B). The individual conidia of a chain break apart, and easily disseminated by wind.
2. **Microconidia.** In contrast to the large, dry, wind-dispersed macroconidia, clumps of smaller, oval, sticky, microconidia also develop laterally on the upright aerial branches (Fig. 7.16 C). The conidiogenous cells are phialides.

Sexual Reproduction

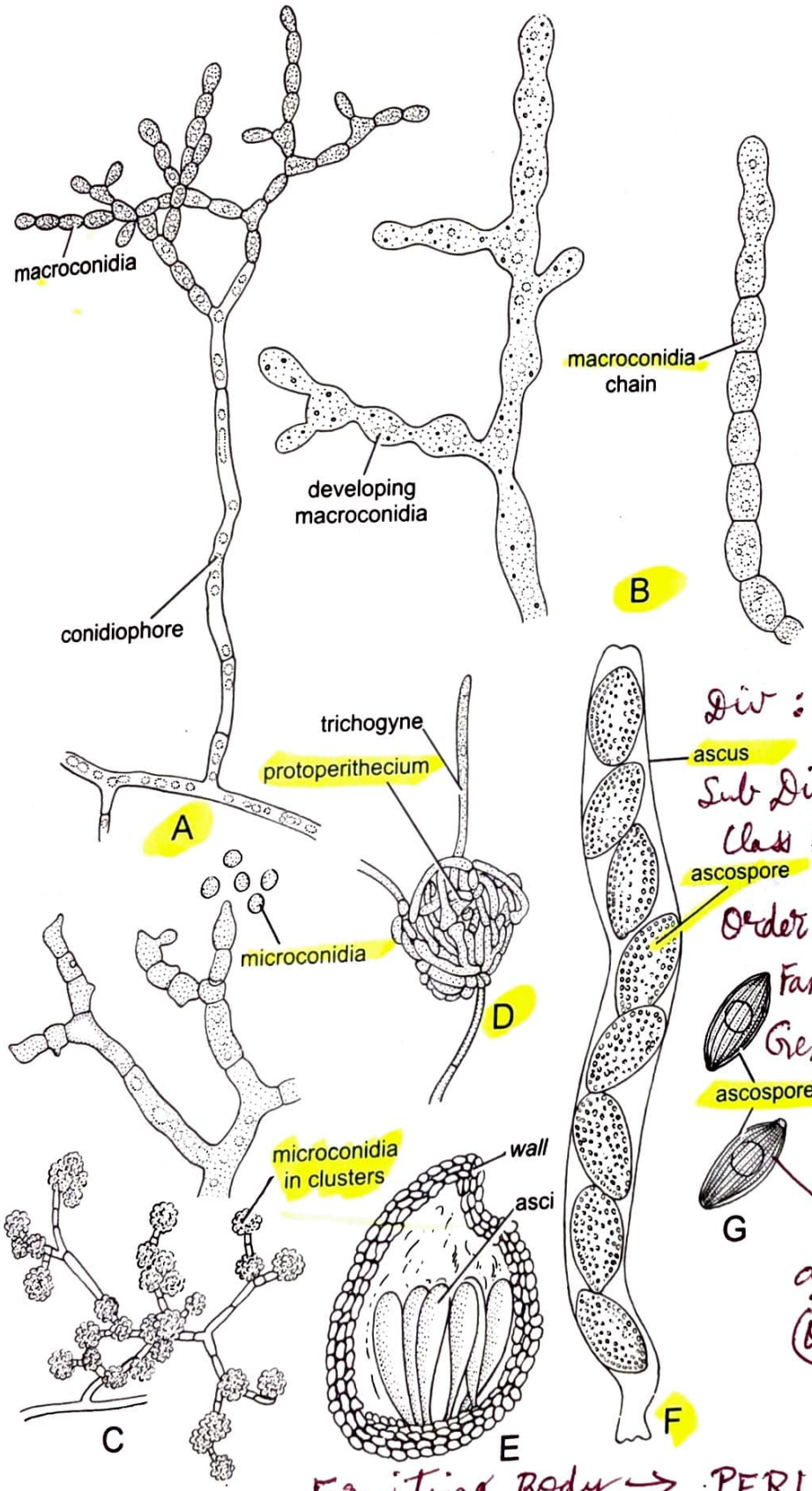
Neurospora terricola and *N. dodgei* are homothallic whereas *N. crassa* and *N. sitophila* heterothallic in which ascocarp development does not take place on mycelium derived from a single conidium. At the time of sexual reproduction, female sex-organs, ascogonia develop on the mycelium. It develops as a coiled, multinucleate, lateral outgrowth of a vegetative hypha. The ascogonium divides later. The neighbouring hyphae surround the developing ascogonium to give rise a pseudoparenchymatous ball-like structure of hyphae. The upper cells of the ascogonium give rise to long tapering trichogyne. The female sex organs of this type are called **protoperithecia** or bulbils (Fig. 7.16 D).

Plasmogamy generally occurs by transfer of macroconidia or microconidia to the trichogyne of the ascogonium of the opposite strain (Fig. 7.16 D). Fusion between the trichogyne and conidium is followed by migration of one or more nuclei from the conidium down the trichogyne into the ascogonium. Perithecia develop within 7-10 days following a general pattern of ascomycetes i.e. by the formation of dikaryotic ascogenous hyphae which develop the croziers. Plasmogamy may also occur by somatogamous copulation between cells of opposite strains. The mature perithecia are dark-coloured, globose, flask-shaped and with a neck (Fig. 7.16 E). The canal of the neck is lined by periphyses. However, paraphyses between asci are absent in mature perithecia. The asci are cylindrical, long and stalked (Fig. 7.16 F). In *N. tetrasperma*, each ascus has four, binucleate ascospores, whereas that of *N. crassa* eight binucleate ascospores (one nucleus in each spore of one mating type). In this species, a single ascospore can give rise to perithecia as it has two nuclei, one of each mating type. Ascospores are arranged in single row, are unicellular, oval, brown with characteristically ribbed wall (Fig. 24 G). In *N. crassa*, ascospores are viable for many years and do not germinate readily unless treated chemically (as furfural) or heat shock (60°C for 20 min). The spores germinate to produce new mycelium.

Peziza

(Hymenoascomycetes–Operculate Discomycetes)

Species of *Peziza* grow as saprophytes on the ground, rotting wood or dung. About 25 species of this genus are known to occur in India, of



Fungi
Div: Ascomycota
Sub Div: Pezizomycotina
Class: Sordariomycetes
Order: Sordariales
Family: Sordariaceae
Genus: Neurospora

Striations on ascospores. (Olive brown in colour).

Fruiting Body → PERITHECIUM

Fig. 7.16 A. A-G. *Neurospora crassa*. **A.** conidiophore with macroconidia, **B.** macroconidial chains enlarged, **C.** microconidia forming sticky clusters, **D.** a protoperithecium with projecting trichogyne, **E.** L. S. perithecium, **F.** an ascus, **G.** ascosporcs.

which the two most common are *P. echinospora* and *P. mutiguttulata*.

Vegetative Structure

The mycelium is frequently perennial and consists of a dense network of branched, septate hyphae. The cells are uninucleate. The hyphae ramify within the substratum and form a complex system which extracts nutrients from the substratum. The apothecia are aerial on the surface of substratum.

Asexual Reproduction

This method is not so common. Some species produce conidia. A conidial state belonging to the form-genus, *Oedocephalum* has been reported in *P. pustulata*. Small conidiophores develop from the mycelium. They swell at their apices into vesicles over which large number of conidia are formed. The conidia are hyaline to lightly coloured and elliptical. Some species also develop thick-walled intercalary chlamydospores either singly or in series on the mycelium.

Sexual Reproduction

No sex-organs are known in *Peziza*. The hyphae grow in all directions to give a pseudoparenchymatous mass. Within this hyphal mass, there may be seen a weft of branching filaments which are fairly more rich in protoplasmic contents. Each cell of the weft contains one or more nuclei. The nuclei have been seen to migrate from one cell of the weft to another. There is somatogamous copulation between vegetative cells of these filaments. Nuclei in such cells then arrange themselves in pairs-dikaryons. In some cases, dikaryotic condition may also be achieved by autogamous pairing i.e. the nuclei of the same cell arrange themselves in pairs.

The cells of these dikaryotic hyphae give rise to ascogenous hyphae, and the asci are formed on them in usual manner. Karyogamy and meiosis occur in the enlarged terminal cells of ascogenous hyphae which behave as ascus mother cells. The croziers have not been observed.

As a result of sexual reproduction, apothecia begin to develop. They develop in hemiangiocarpous manner. Mature apothecia are saucer-shaped, sessile or subsessile, 5 cm or more in diameter (Fig. 7.17 A). Internal structure becomes clear in a longitudinal section of the apothecium (Fig. 7.17 B). There may be seen three main layers. The outermost is hymenium made up of elongated cells at right angles to the surface like a palisade layer. These elongated cells are asci and paraphyses. The middle layer is thin and consists of light-coloured hyphae running parallel to the surface of the hymenium. This layer is known as hypothecium. Then, there is third layer, the excipulum which forms the basal, larger part of the apothecium.

The asci are elongated and eight-spored (Fig. 7.17 C). Ascospores are obliquely placed in a row in the ascus. They are hyaline or faintly coloured, elliptical, surface smooth or coarsely reticulate. They germinate by germ tubes to form new mycelium.

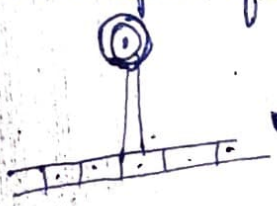
Genus PEZIZA (50 species)

Peziza vesiculosa is one of the larger cup fungi. The cup-shaped, fleshy ascocarp with no hairs are found to be crowded together on mature piles, well fertilized gardens, green houses, etc. *Peziza badia* is commonly found on the ground in deciduous forests and open places. *P. repanda* is found on rotten logs in woods. The apothecia of the fungus are whitish or pale brown and exhibit minute pustules on the surface.

- Septate
- Uninucleate

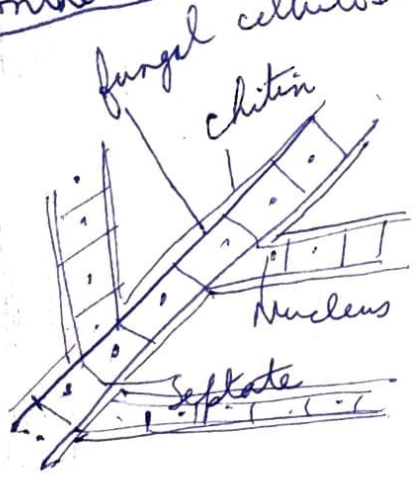
Somatic structure. The mycelium is well developed and consists of network of septate hyphae with uninucleate cells except in the fructification. The hyphae are found within the substratum and therefore, they are not visible from outside. They absorb the nutrition from the substratum.

Asexual reproduction. Most of the Pezizaceae are not known to reproduce asexually. However, conidia have been found in *Peziza repanda* and *Peziza vesiculosa*. In *Peziza pustulata* the conidiophores are found which bear heads of conidia developed from surface hyphae. The conidia are exogenously formed from three to four-celled conidiophores. The apices of them form narrow, clavate, oval or globose heads on which numerous conidia are attached. The conidia are abstricted from the apices of the conidiophores. Each conidium germinates forming a new mycelium.



Certain species produce thick-walled chalmydospores. The chlamydospores are intercalary in position. On the approach of suitable conditions of moisture and temperature they germinate and produce new mycelia.

Sexual reproduction. The sex organs are not found in the species of *Peziza*. The sexual process is extremely simple and consists in the association of two vegetative nuclei in a pair; the compatible nuclei are brought together by means of somatogamy. The vegetative cells are seen to



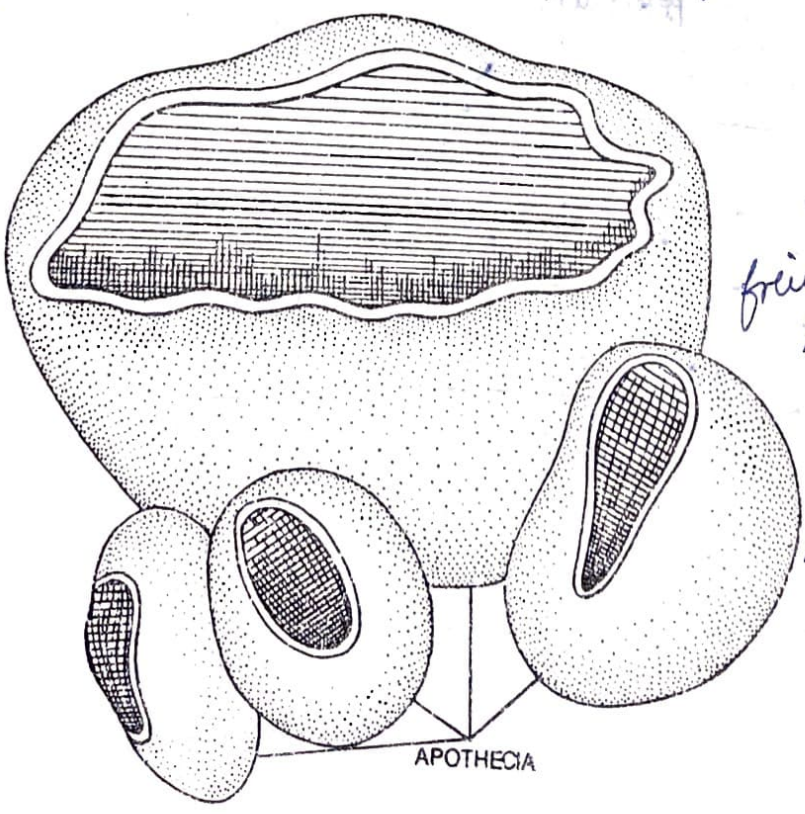


Fig. 12.33. *Peziza*. The apothecia.

Recognized by flattened, purple (violet), cup-like fruit bodies

P.T.O.

Kingdom : Fungi

Div : Ascomycota

Class : Pezizomycetes

Order : Pezizales

Family : Pezizaceae

Genus : Peziza

possess the nuclei associated in pairs. These dikaryotic cells rise to ascogenous hyphae. The ascogenous hyphae become many celled by septa. The cells are binucleate. The terminal or sub-terminal cell of ascogenous hyphae acts as an ascus mother cell which develops into an ascus. The two nuclei of the ascus mother cell fuse together forming a synkaryon. This fusion nucleus divides meiotically and thereafter mitotically, forming eight haploid nuclei which become ascospores. The asci are clavate, erect and lie side by side. They are intermingled with paraphyses.

Apothecium. The apothecial cups of *Peziza vesiculosa* are brown, 2 to 3 inches broad, and are commonly contorted and crimpled. The hymenial surface of *P. venosa* is convoluted. In sectional view the apothecium exhibits three layers. The uppermost layer is the hymenium; middle one the sub-hymenium and the outermost layer, the excipulum. The hymenium consists of erect asci and paraphyses; the sub-hymenium of the weft of hyphae and ascogneous hyphae; and the excipulum consists of pseudoparenchymatous tissue formed of compactly interwoven hyphae.

Asci and ascospores. The asci are clavate and form palisade-like layer lining the cavity of the ascocarp. Each ascus contains 8 ascospores. On maturation, the ascospores are shot off from asci and disseminated by wind. Each ascospore is haploid, smooth and elliptical. On germination it produces the haploid mycelium.

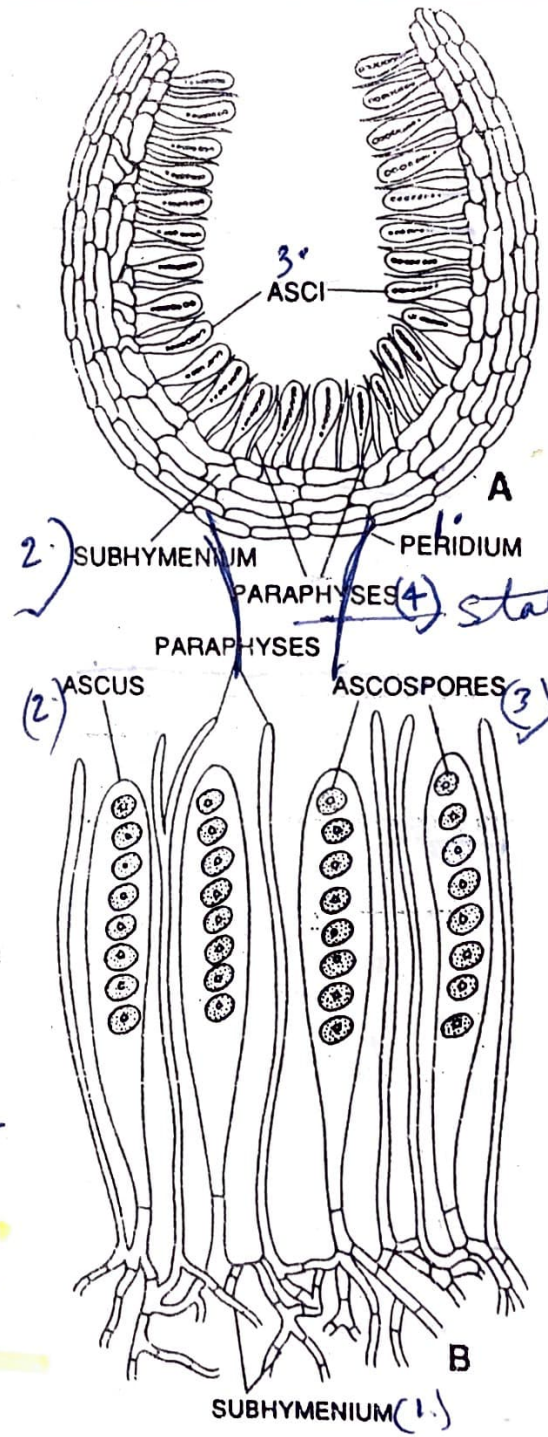


Fig. 12.34. *Peziza*. A, vertical section of mature apothecium; B, a portion of apothecium showing asci, ascospores and subhymenium.

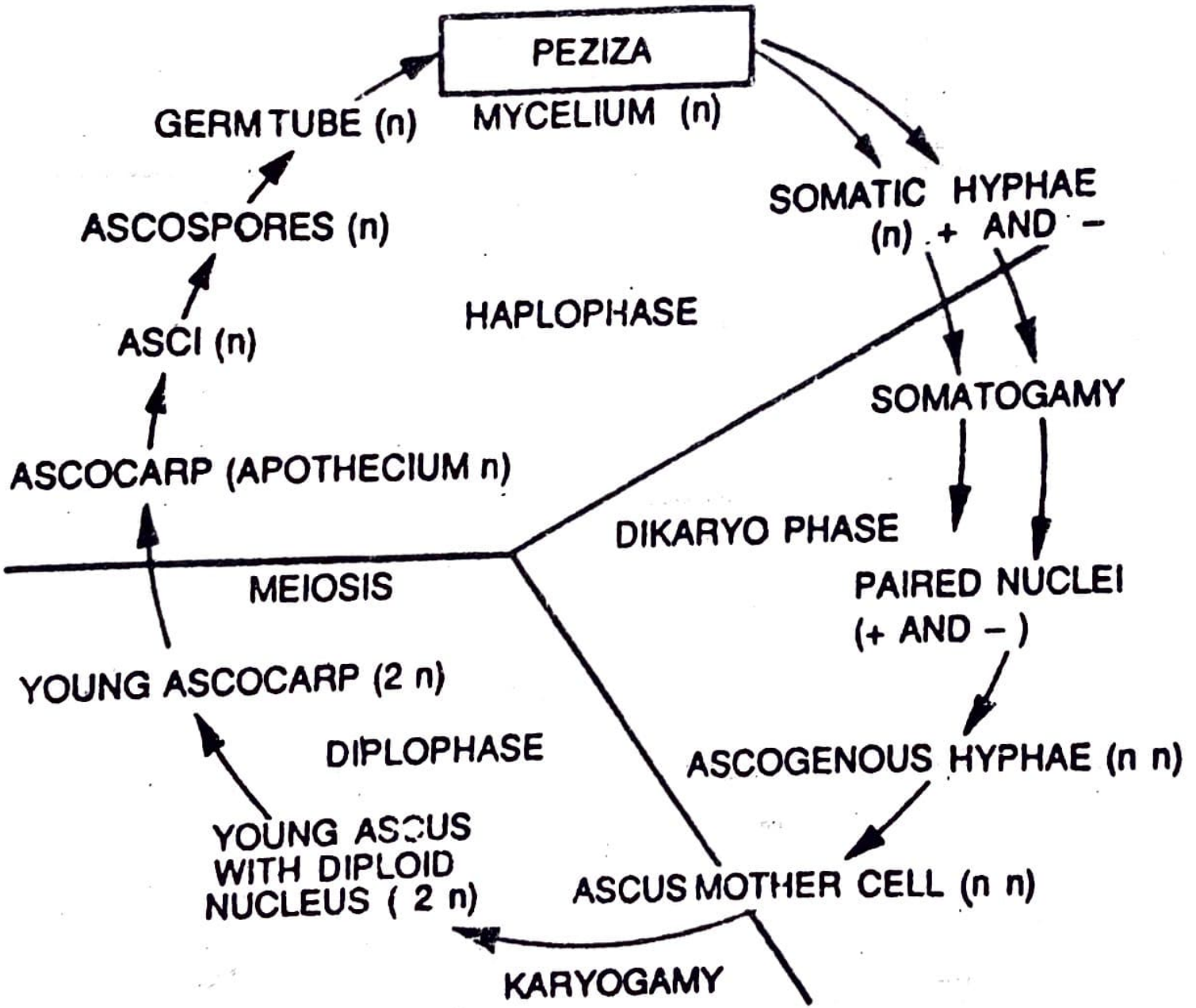


Fig. 12.35. *Peziza.* Graphic life-cycle