FUNGAL REPRODUCTION

- **Formation of a new progeny**

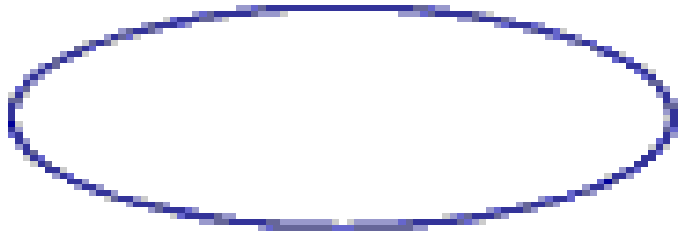
- **Vegetative – Mycelia parts**
- **Asexual – Spore formation**
- **Sexual – Plasmogamy followed by Karyogamy and Meiosis**

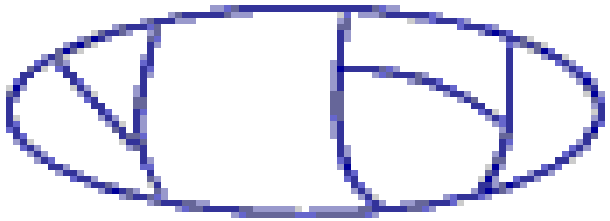
General Characteristics of Fungal Spores

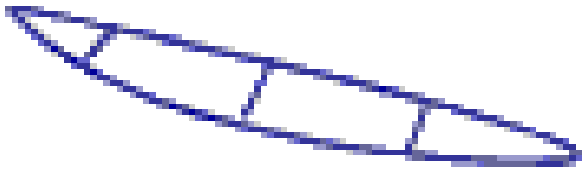
1. Spores represent microscopic dispersal or survival propagules produced by most species of fungi
2. Spores possessing a primarily DISPERSAL role include sporangiospores and conidia
3. Spores whose primary role is DORMANT SURVIVAL include oospores and zygospores
4. Fungal spores vary in size, shape and colour
5. Fungal spores may be unicellular or multicellular. Ex. *Alternaria*

6. Some spores possess a textured or ornamented surface ex. uredospores of *Melampsora* (causal pathogen of willow rust).
7. They possess a relatively low water content
8. While dormant they exhibit a low rate of metabolic activity
9. They vary in the primary functions they serve, which may include: dispersal to a fresh site or host; survival at the same site; increasing genetic variation
10. They also vary in the methods by which they are formed, released and dispersed

General Characteristics of Fungal Spores







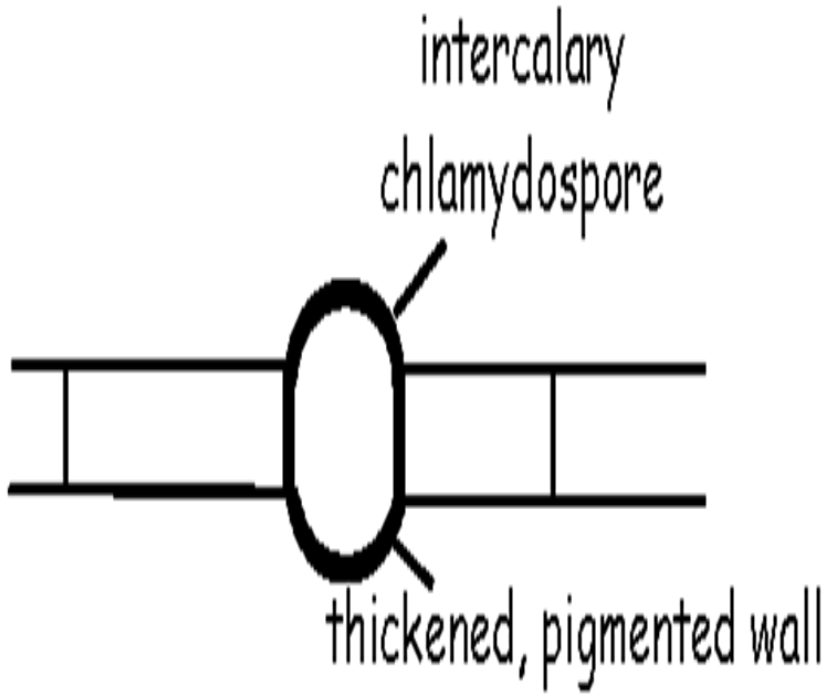
Vegetative Reproduction

- **Fragmentation – Breakage in mycelium**
- **Budding – Terminal out growth**
- **Arthrospore – Wall formation around each cell**
- **Chlamydospore – Resting spore**
- **Sclerotia – Mycelial aggregates**

Chlamydospores

A type of resting (survival) spore

- **Found in several groups of fungi (e.g. Zygomycota)**
- **An intercalary or apical hyphal cell or compartment enlarges, rounds up and develops a thickened, often pigmented wall.**
- **Contain dense cytoplasm and nutrient storage compounds**
- **All wall layers are involved in their formation.**
- **Become isolated from adjacent hyphal compartment by the sealing of septal pores (if present).**
- **Usually develop under conditions of stress that are unfavourable for normal somatic growth**



Asexual reproduction

- **Sporangiospore in sporangia**
  - **Zoospores**
  - **Aplanospores**
- **Conidiospore on conidiophore**

Zoospores

- Zoospores are motile sporangiospores - and the sporangia in which they form are called zoosporangia
- The protoplasm of zoospores is not surrounded by a wall - in some respects they resemble flagellate protozoa
- Because zoospores are motile, the fungi that produce them will require water at some stage during their life cycle
- Three different types of zoospore distinguish the Chytridiomycota, Hyphochytridiomycota and Oomycota

Zoospores

single posterior smooth whiplash flagellum

(Chytridiomycota)

single anterior tinsel flagellum

(Hyphochytridiomycota)

tinsel flagellum

(projecting forwards)

whiplash flagellum

(projecting backwards)

biflagellate

(Oomycota)

Aplanospores

A. Thallic Conidia

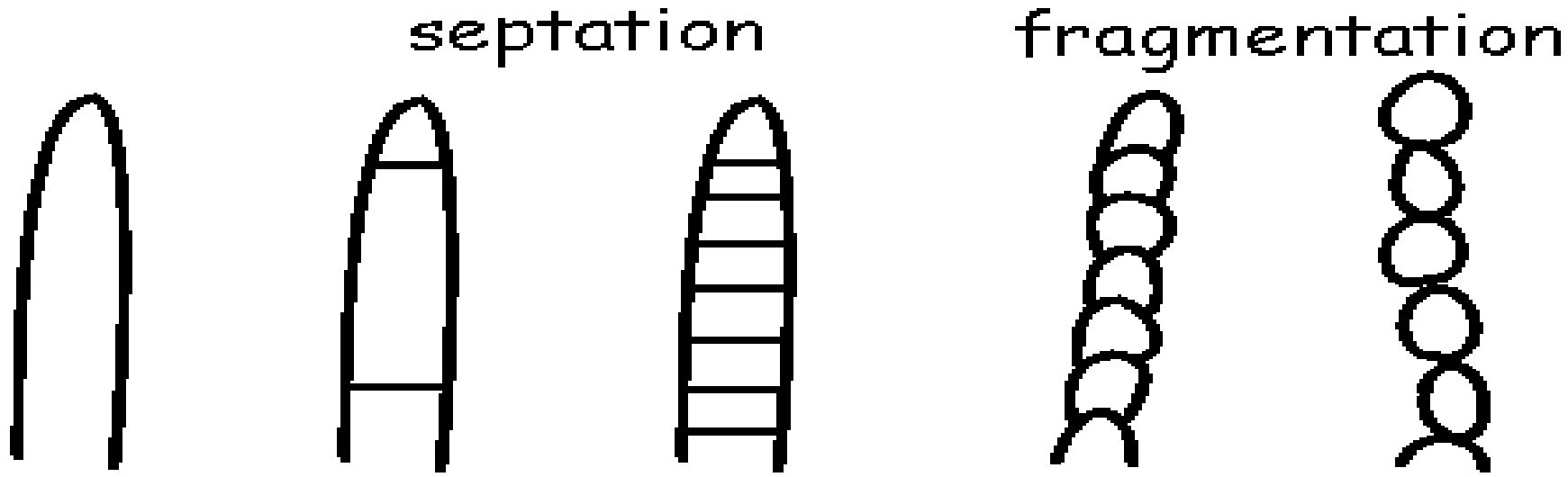
- **Develop by SEPTATION and FRAGMENTATION of a hypha**
- **May develop at the TIP OF A HYPHA or in an INTERCALARY (central) POSITION**
- **In both cases, ALL LAYERS of the hyphal wall are involved in spore formation**

a. **Arthrospore**

b. **Conidiospore (Conidia)**

Arthrospores

- Formed by septation and fragmentation of an existing hypha
- Elements of the hypha (incl. all wall layers) become converted into conidia
- Each fragment is rounded off and liberated in succession
- Separation of the conidia from one another is due to breakdown of the middle region of each septum



Conidiospore on Conidiophores

1. Simple, unbranched conidiophores:Some species form conidia on single, unbranched hyphae (conidiophores)

E.g. *Geotrichum candidum*

2. Branched conidiophores:Example of a branching pattern of conidiophores bearing clusters of conidia at their tips.

E.g. *Trichoderma viride*

3. Coremium :Conidiophores are aggregated together to form a vertical stalk-like coremium

At the top of the coremium the conidiophores branch and conidia develop at the tips of the branches.

E.g. *Penicillium claviforme*

4.Pycnidium: A flask-shaped structure with conidiophores developing from cells of the pycnidial wall

E.g. *Phoma* species

5. Acervulus: A flat, open pad of short conidiophores growing side-by-side.

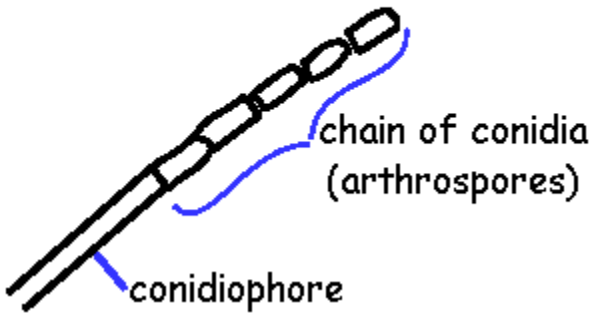
The conidiophores develop from the underlying mass of somatic hyphae

E.g. *Colletotrichum* species

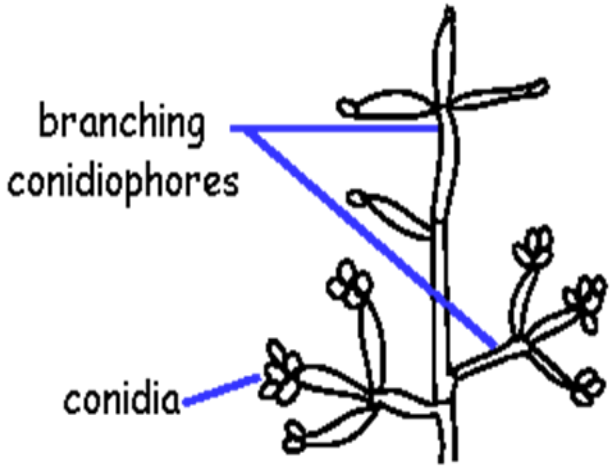
6. Sporodochium: A cushion-shaped mass of short conidiophores

E.g. *Epicoccum* species

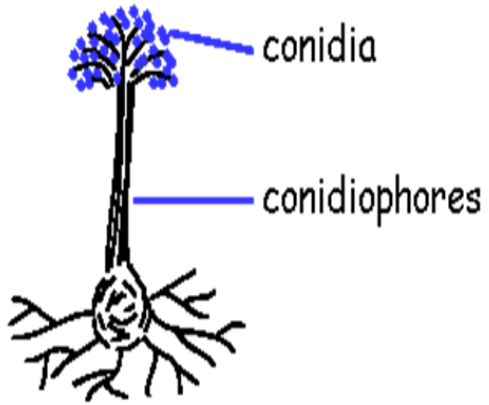
Simple, unbranched conidiophore



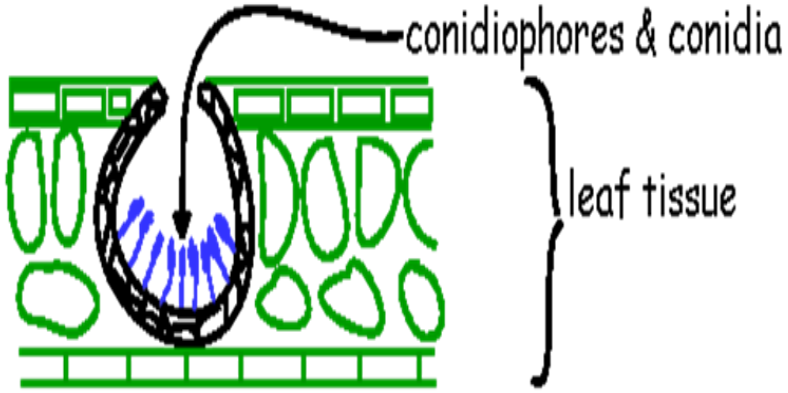
Branched conidiophore



Coremium

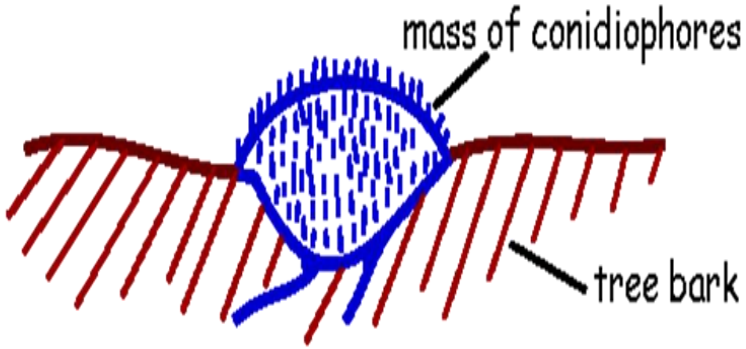


Pycnidium



Acervulus

Sporodochium



Asexual Sporulation

B. Blastic Conidia

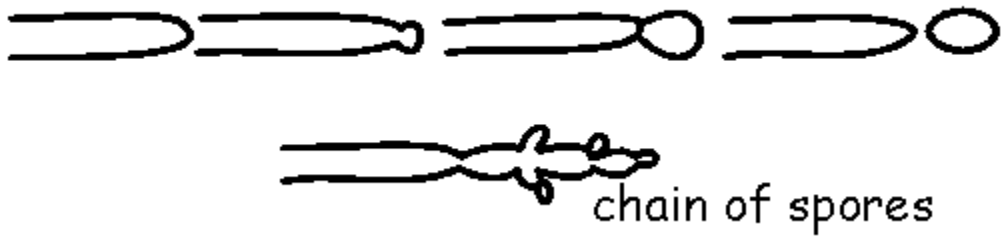
- Develop by a BUDDING or SWELLING PROCESS
- May develop as SINGLE SPORES or in succession to form a CHAIN OF SPORES

Blastospores

Formed by budding of a hypha or yeast cell

- Both the wall layers are involved
- The spore may remain attached and bud further blastospores - giving rise to a branched chain of spores

Blastospores



Porospores

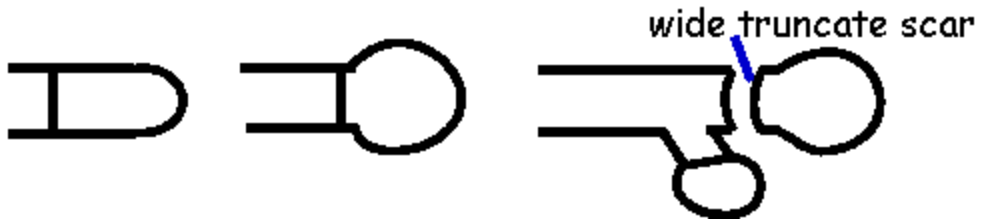
- The developing spore emerges through a distinct 'pore' in the hyphal wall
- Only the inner layer of the hyphal wall is involved in spore development
- The new spore then develops its own new inner wall layer.
- The outer spore wall is often thickened and pigmented
- A scar is usually obvious at the point of detachment from the hypha (conidiophore)

Porospores

Aleuriospores

- Develop as single, terminal spores
- Conidiophore apex inflates and becomes separated by a septum at an early stage in spore development
- Both wall layers are involved in spore formation
- The spore possesses a wide, truncate scar
- Normally no further development of spores occurs at the point of detachment
- So the next spore usually has to develop by production of a branch below the scar on the conidiophore

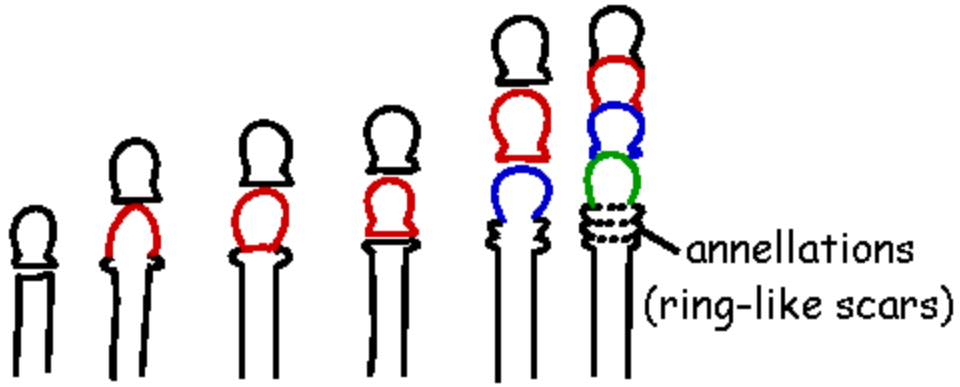
Aleuriospore formation



Annellospores

- In some species that form conidia in a manner similar to that described for aleuriospores a new growing point develop at the scar.
- A chain of spores may develop
- The conidiophore gets a little longer with each spore produced
- Annellations (ring-like scars) are observed around this elongating portion
- Each annellation represents the production of one annellospore

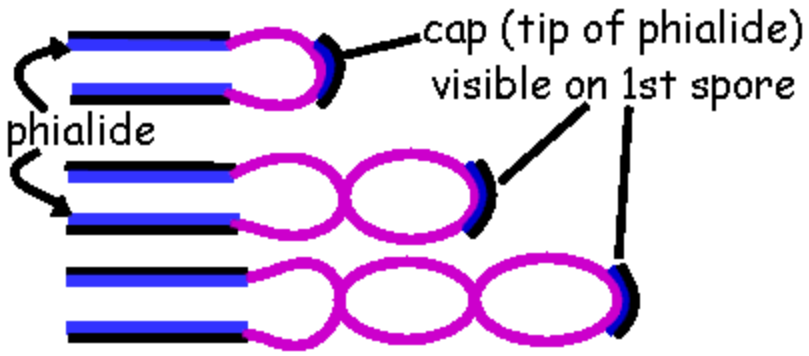
Annellospore

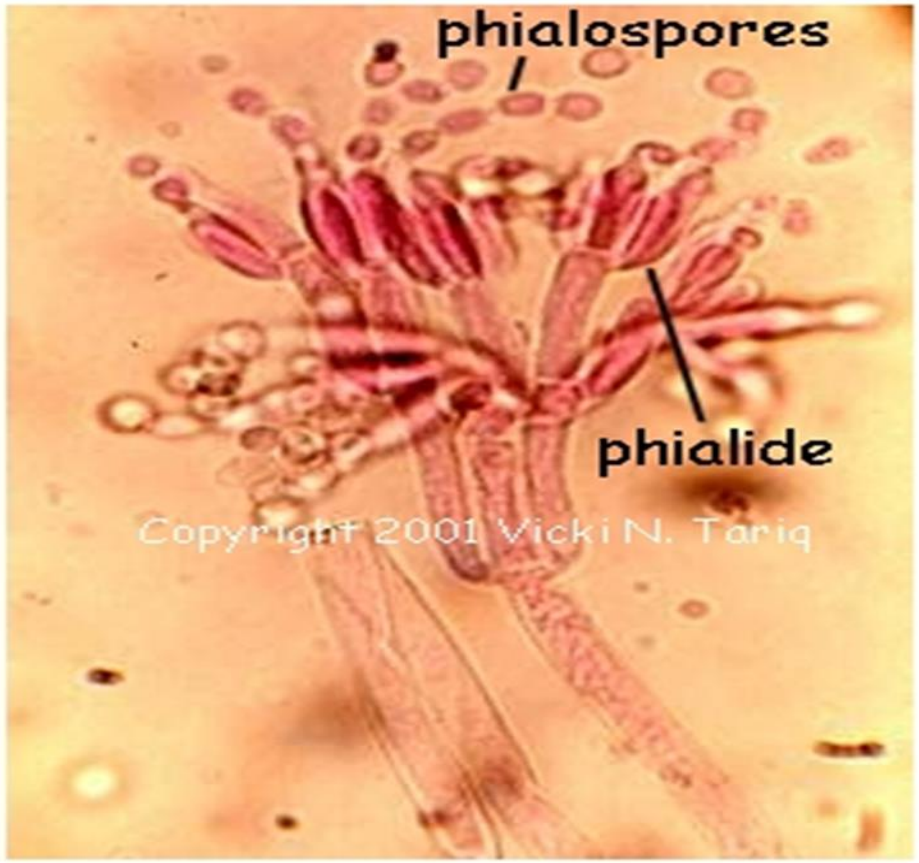


Phialospores

- Form in succession
- Each spore is pushed up from the tip of the conidiophore, which is now called a PHIALIDE
- The spore wall is new and distinct from both wall layers of the phialide
- The first spore has a cap, which represents the tip of the phialide wall through which the spore emerged - all other spores in the chain are smoothly rounded

Phialospores





Asexual sporulation in *Penicillium*
(note branching conidiophore).

Sexual Reproduction

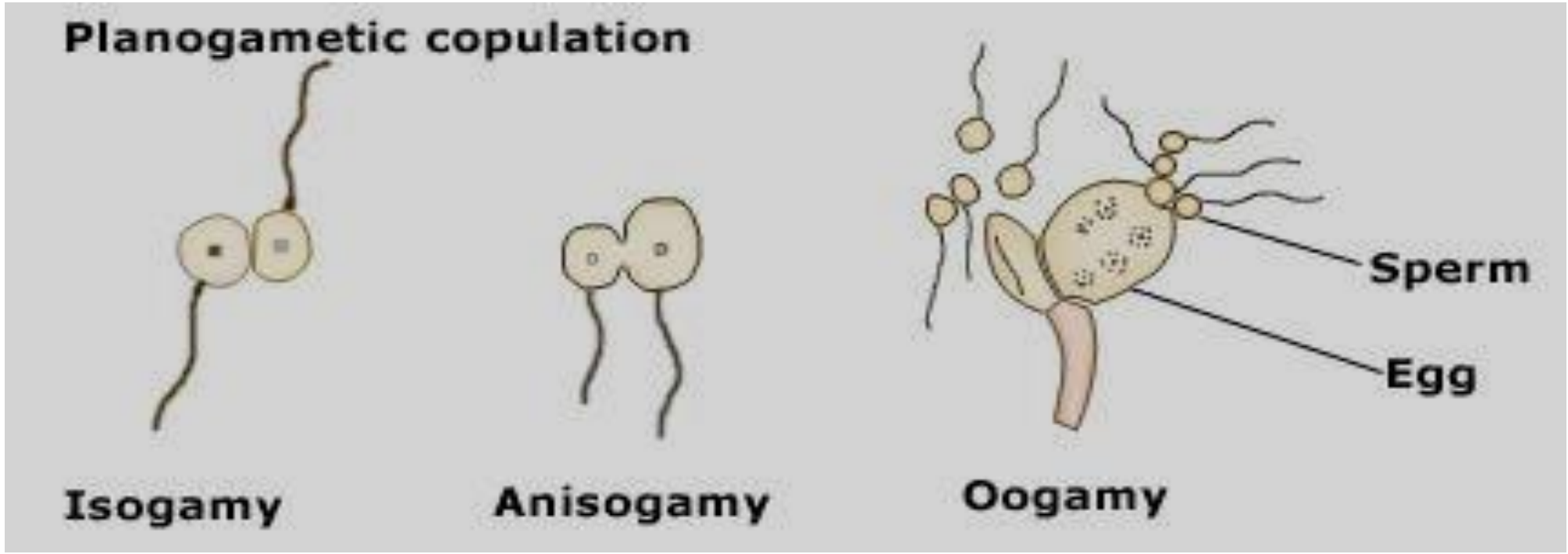
- **Plasmogamy followed by Fusion between two compatible nuclei**
- **Compatible nuclei are united by one of the following four methods, depending upon the group and species of fungus**

Types of Plasmogamy

1. Planogametic Copulation:

Here gametes called planogametes undergo fusion

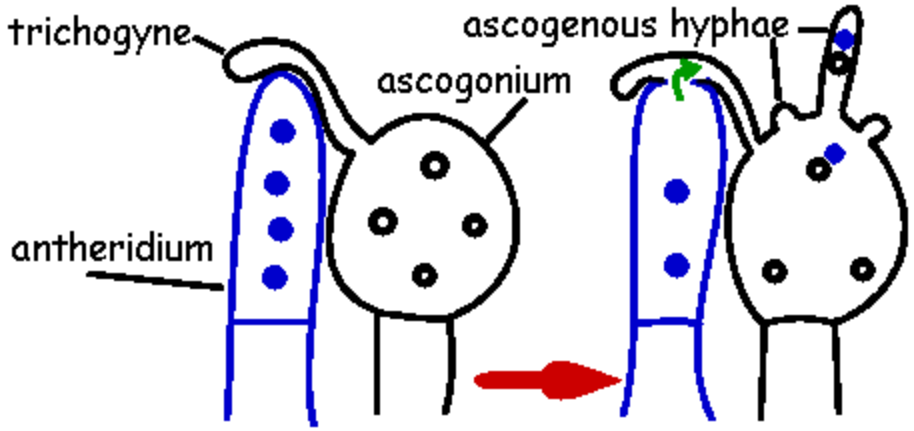
Three types: Isogamy, Anisogamy, Oogamy

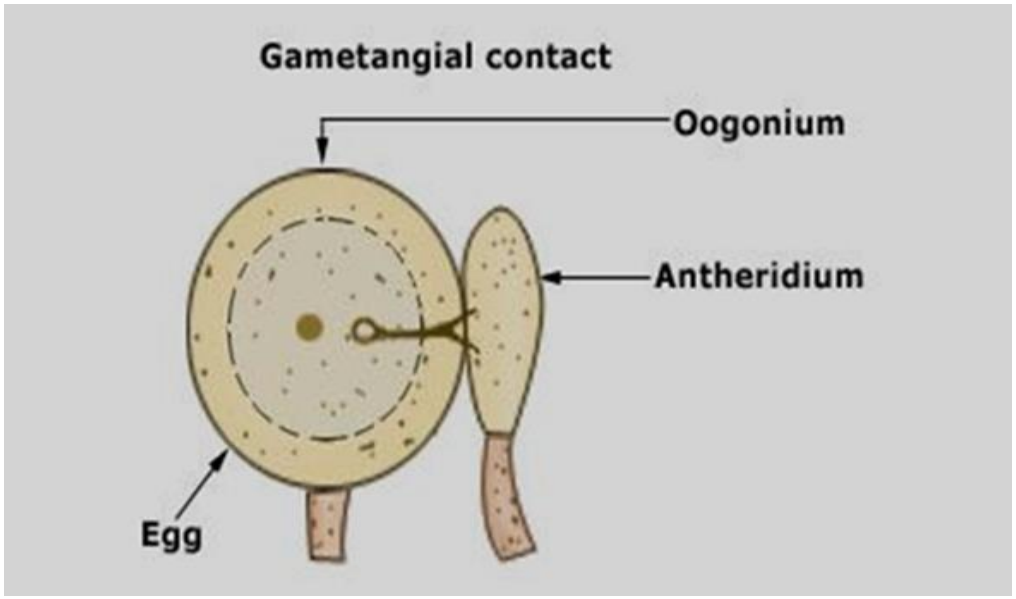


2. Gamtangial Contact:

- **Here, gamete bearing structures called gametangia come closer to each other and develop a fertilization tube through which the male gamete migrates into the female gametangium**
- **In this case morphologically distinct gametangia are formed - called ANTHERIDIA (male) and ASCOGONIA(female).**
- **The TRICHOGYNE (receptive neck of the ascogonium) receives the male nuclei from the antheridium.**
- **Upon passing along the trichogyne into the ascogonium each male nucleus pairs with a female nucleus in the ascogonium, but the pairs of nuclei don't fuse.**
- **ASCOGENOUS HYPHAE emerge from the ascogonium and the nuclei, still in their compatible pairs, pass into these hyphae - which are now dikaryotic.**
- **The ascogenous hyphae are destined to develop into asci**

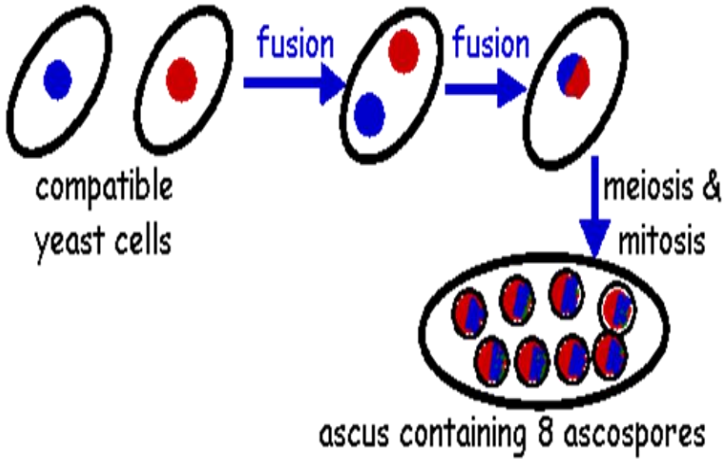
Gametangial contact

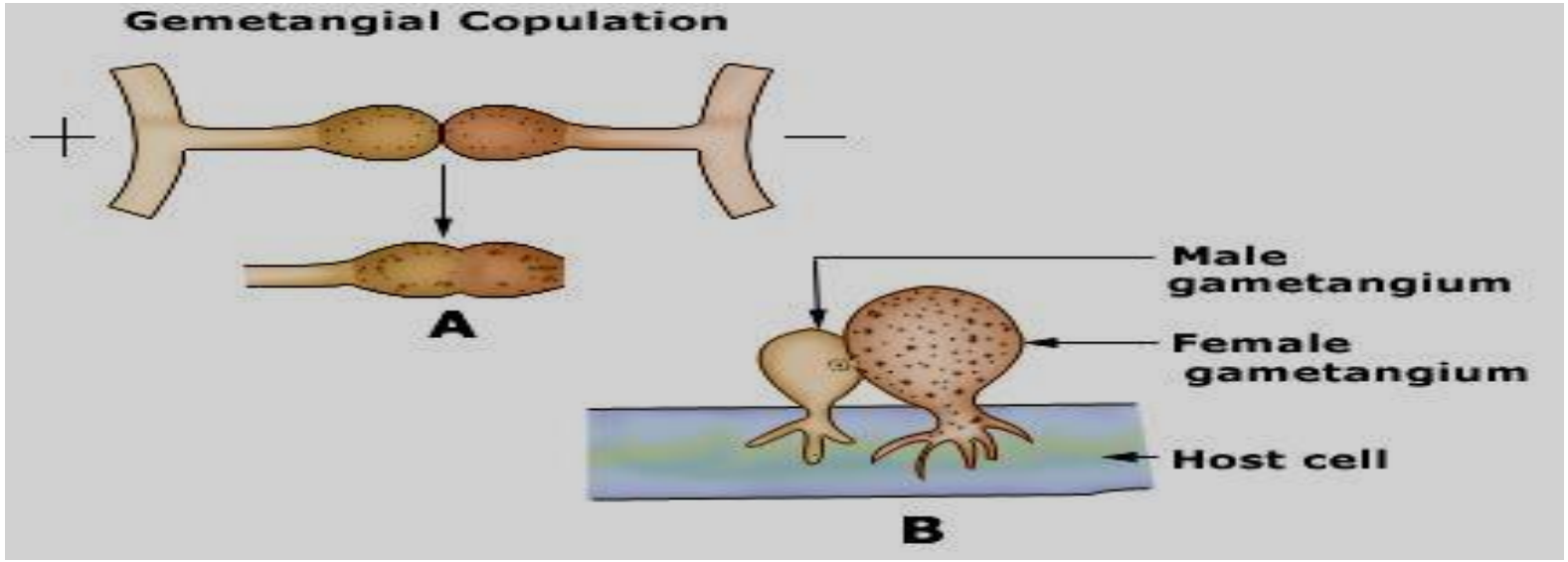




3. Gametangial Copulation:

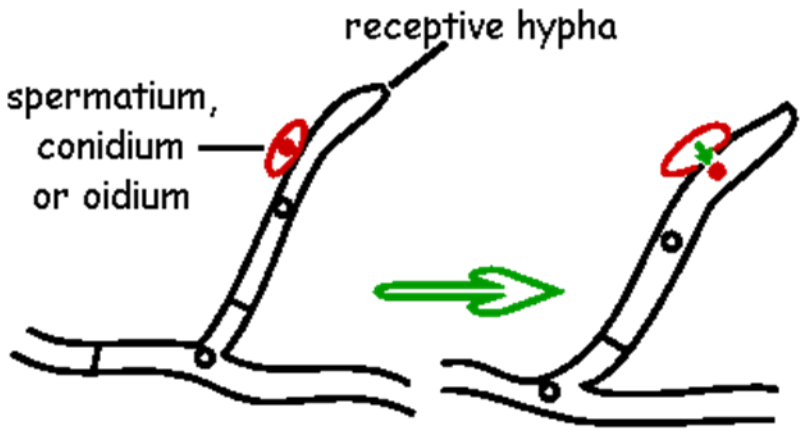
- Here, the gametangia fuse with each other, lose their identity and develop into a zygospore
- Two similar gametangia come into contact with one another and fuse.
- There is no prolonged dikaryotic phase in this instance, since nuclear fusion occurs immediately after fusion of the gametangia.
- In the example illustrated, two yeast cells of different but compatible mating types behave like gametangia and fuse - resulting in a diploid zygote, which is transformed directly into an ascus (containing eight ascospores).

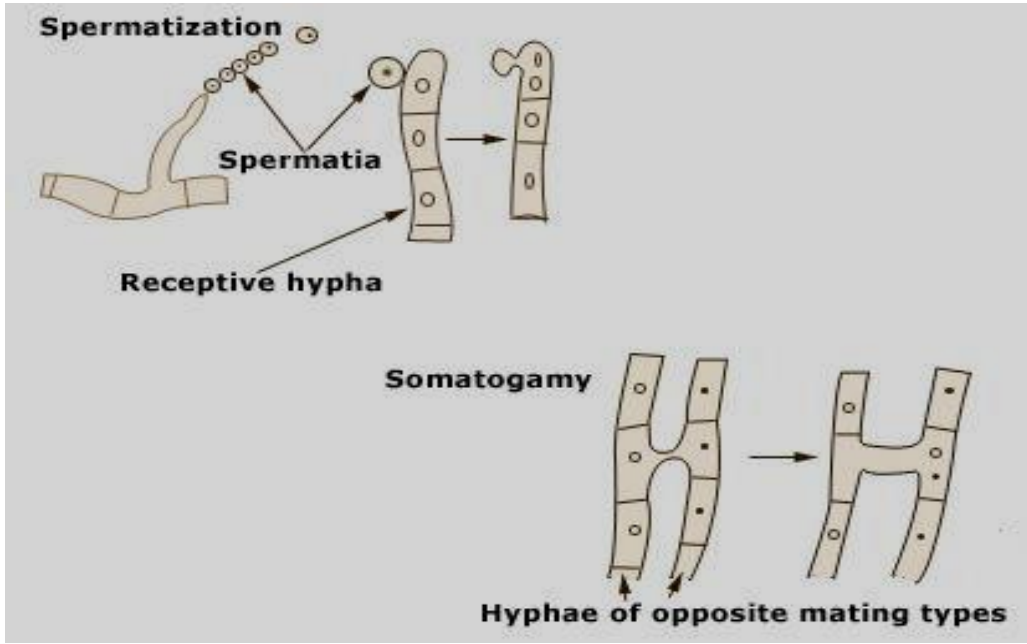




4. Spermatisation:

- In some fungi like Puccinia, tiny unicellular spore like structures called spermatia are formed
- They get transferred to female gametangia through various agencies
- In case of somatogamy, two cells of different hyphae of opposite mating type exchange their nuclei through a fertilization tube





Spermatization

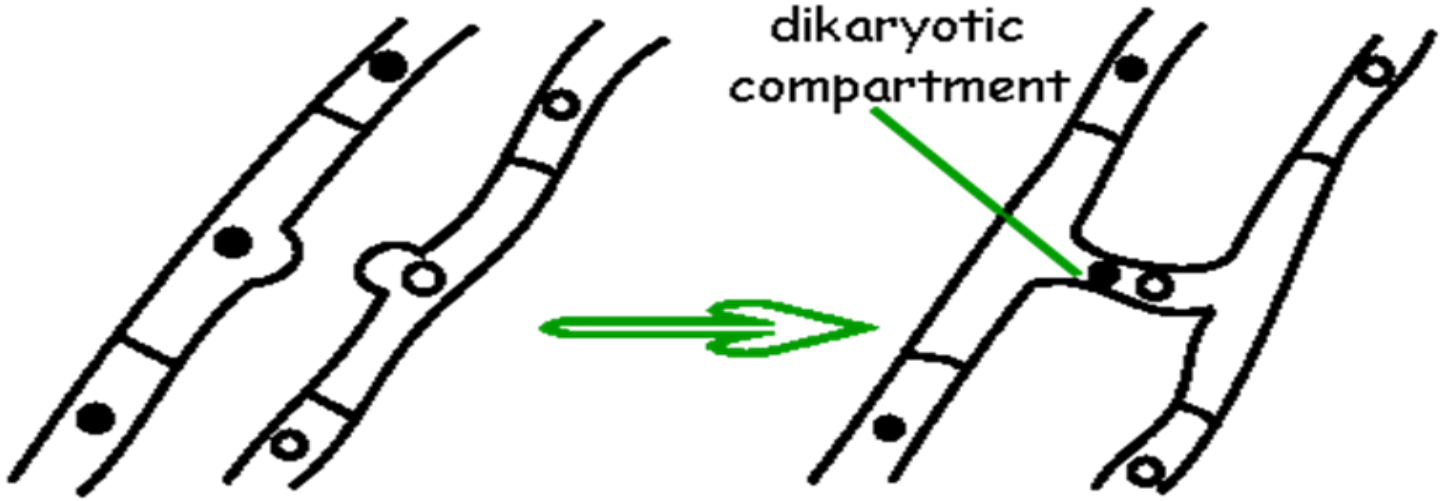
Occurs in some species in both the Ascomycota and Basidiomycota

- **Uninucleate spore-like structures (known as SPERMATIA in the Ascomycota and OIDIA in the Basidiomycota) are carried by air currents, water or insects to the sides of somatic receptive hyphae**
- **A pore develops at the point of contact between the hypha and the 'spore'**
- **The contents of the 'spore' (including its nucleus) pass into the hyphal compartment, which as a result becomes dikaryotic**
- **Some conidia have the potential to behave like spermatia, but unlike true spermatia, conidia are asexual spores and capable of germinating to produce germ-tubes**

5. Somatogamy:

Occurs in both the Ascomycota and Basidiomycota

- **The fusion of somatic hyphae of two compatible mycelia results in a dikaryon from which a dikaryotic mycelium may develop**



Somatogamy

- In the Ascomycota, the dikaryotic phase is limited to mycelium within the fruiting body (ascocarp)
- But in the Basidiomycota the mycelium continues to grow in the dikaryotic state for some time and fruiting bodies (basidiocarps) form only at a much later stage
- We are now at a stage where in the Ascomyciota we have a number of dikaryotic compartments (i.e. ascogenous hyphae) in a fruiting body (ascocarp), and where in the Basidiomycota we have a dikaryotic mycelium and dikaryotic hyphae forming the fruiting body (basidiocarp)
- The next stage in sexual sporulation involves the formation of ascospores and formation of basidiospores

- **All methods of Sexual reproduction Resulted in the formation of**

➢ **Oospore**

➢ **Ascocarp**

➢ **Basidiocarp**

LIFE CYCLE IN FUNGI

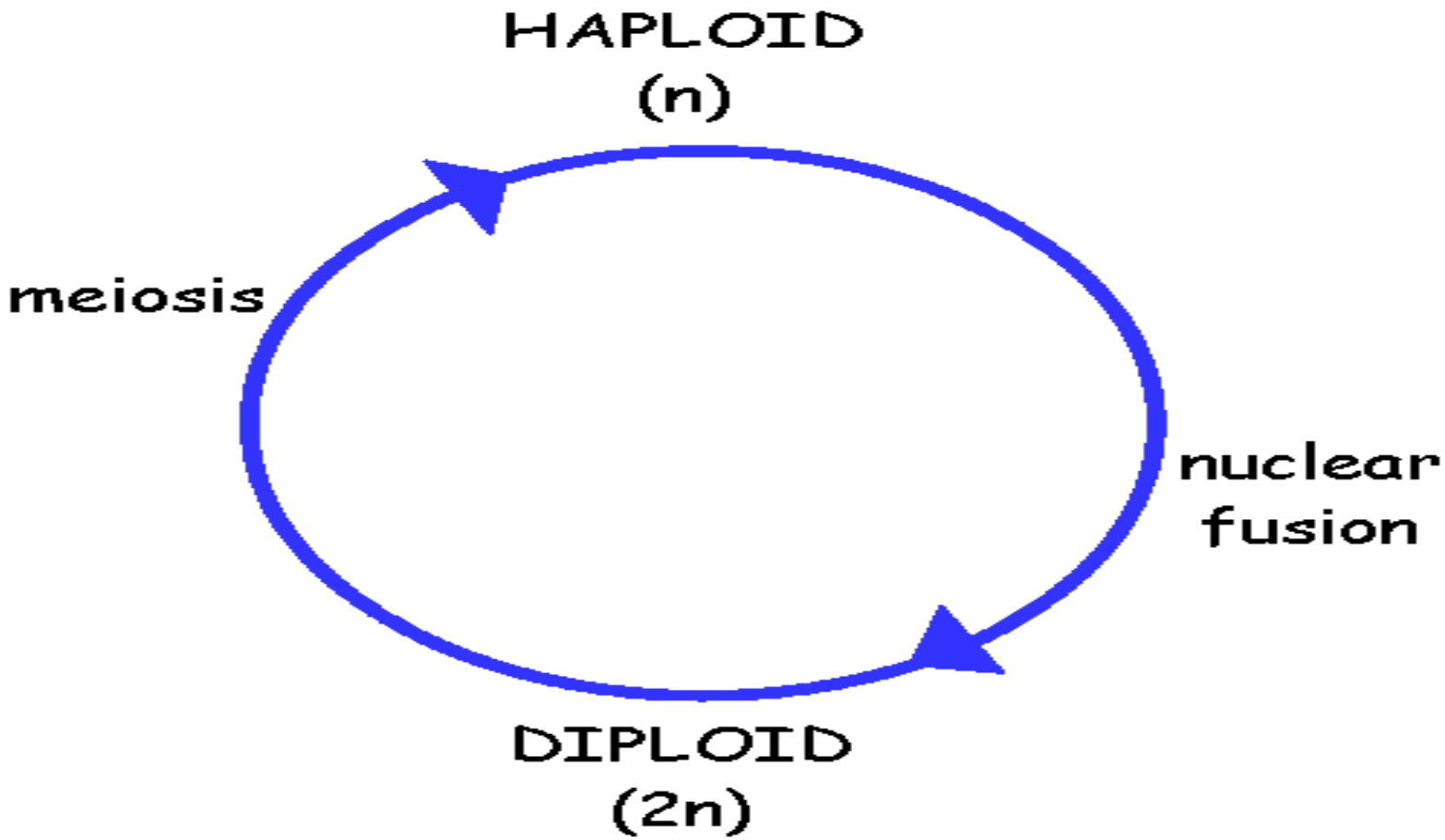
- **Asexual cycle – Imperfect fungi**
- **Haploid cycle – many lower fungi**
- **Haploid cycle with restricted dikaryon – Neurospora**
- **Haploid dikaryotic cycle – Ustilaginales**
- **Dikaryotic cycle – Yeasts and smut fungi**
- **Haploid-diploid cycle – Allomyces and some yeasts**
- **Diploid cycle – Some yeasts**

EXAMPLES

Life cycle of a primitive unicellular organism

- The basic life cycle of a primitive unicellular organism may have consisted of two phases - haploid and diploid
- such an organism may have increased in complexity and evolved into a multicellular organism in either the haploid or the diploid phase

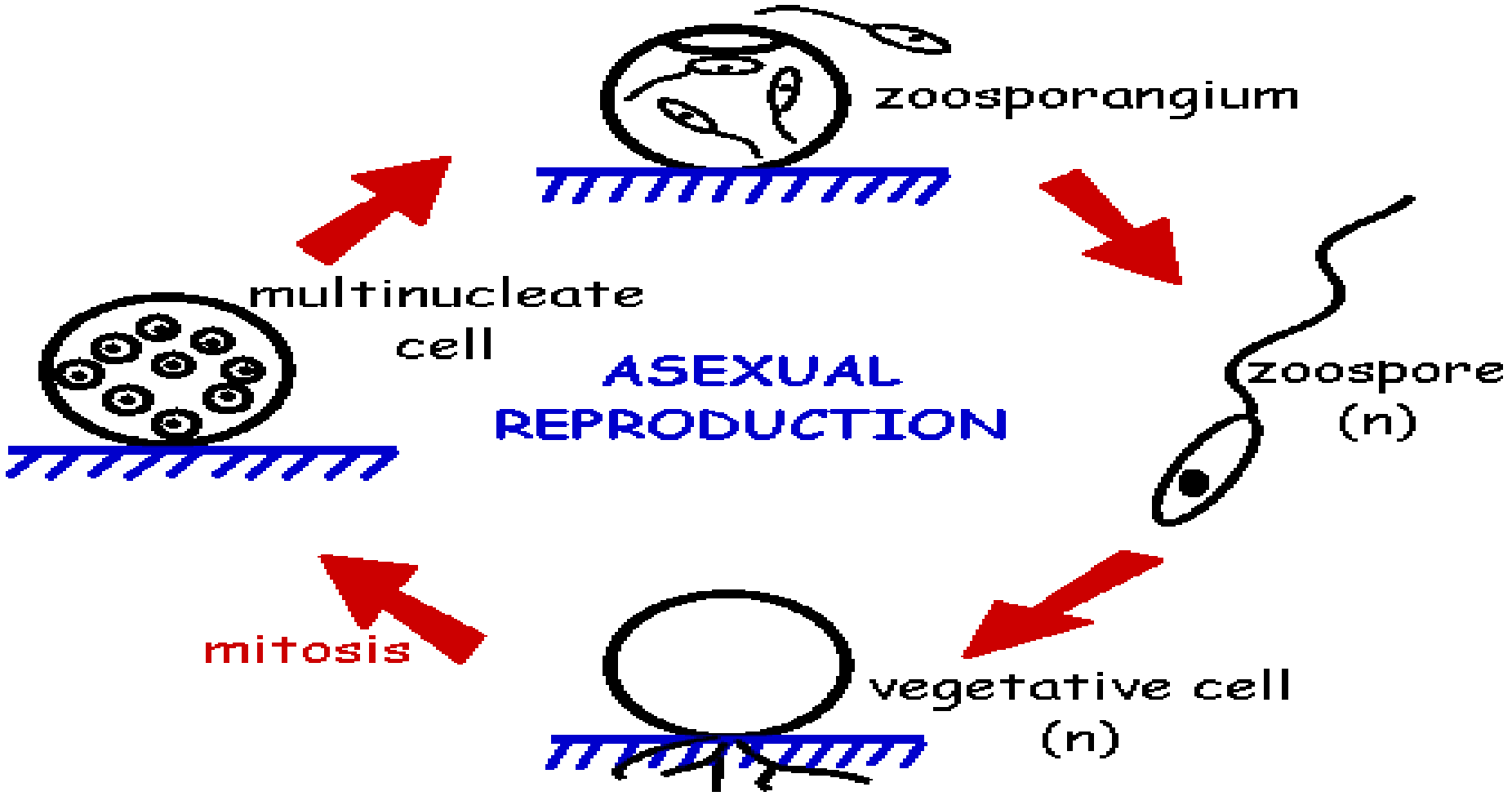
Life cycle of a primitive unicellular organism



Asexual Sporulation in the Chytridiomycota

- In unicellular species (see diagram below) the whole somatic cell becomes isolated from its rhizoids and is converted into a zoosporangium
- The nucleus undergoes several mitotic divisions - resulting in a multinucleate cell
- cleavage of the protoplasm around individual nuclei is followed by each portion of nucleate protoplasm developing a single flagellum
- once mature, the zoospores are released from the zoosporangium - after a period of swimming to locate a fresh substrate, each will eventually lose its flagellum, form a wall and develop into the somatic (normal vegetative) form of the species.
- in those species which exist as primitively branched chains of cells only cells near the ends of branches develop into zoosporangia

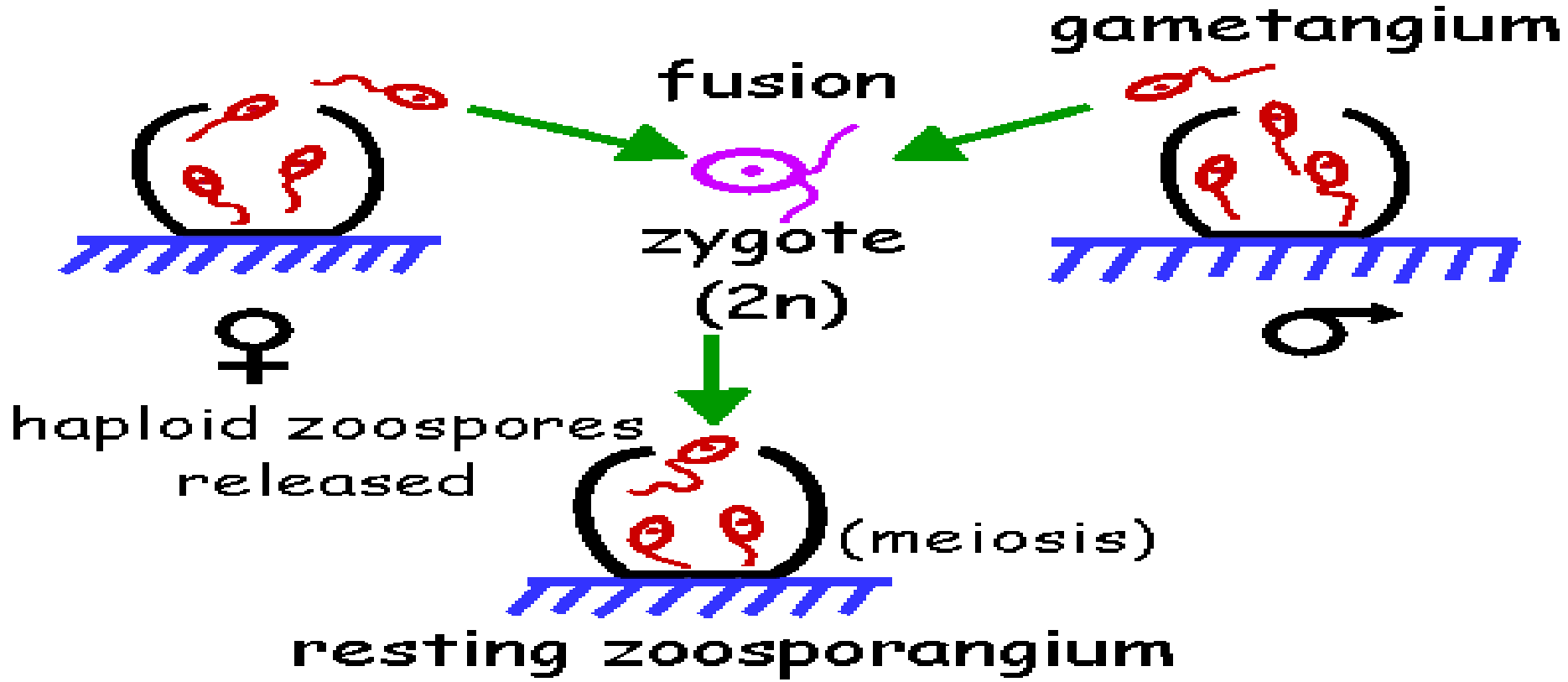
Asexual Sporulation in the Chytridiomycota



Sexual Sporulation in the Chytridiomycota

- During the sexual phase of the life cycle, zoospores from different compatible zoosporangia are attracted to one another, come together in pairs and fuse to form a motile, biflagellate, diploid zygote
- The zoospores (gametes) as being of opposite sexes, although in many species they are morphologically indistinguishable from one another
- Eventually, the biflagellate zygote stops swimming, loses its flagella, rounds up, develops a thick wall and becomes converted into a resting zoosporangium which is capable of surviving adverse environmental conditions
- When environmental conditions are once again favourable for the species, meiosis occurs within the resting zoosporangium and haploid zoospores are released
- These haploid zoospores will develop into the haploid somatic form of the species

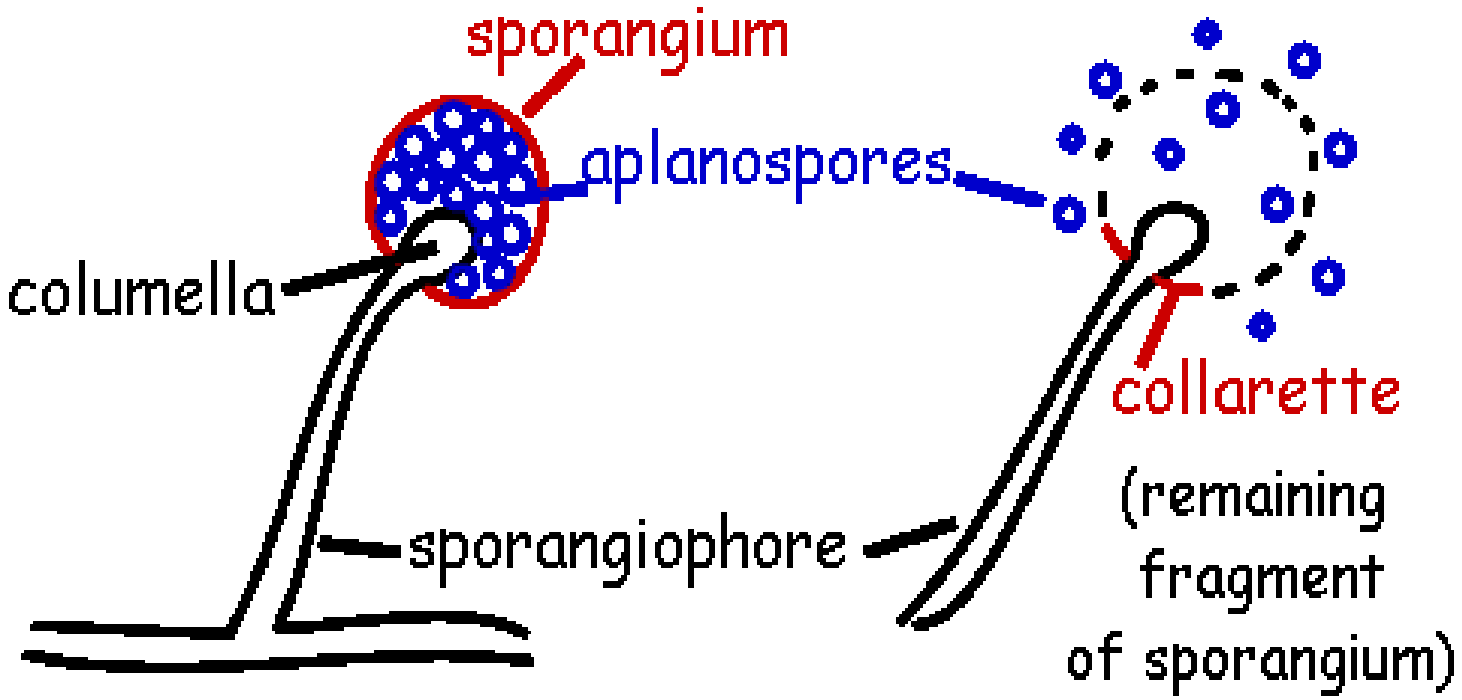
Sexual Sporulation in the Chytridiomycota



Asexual Sporulation in the Zygomycota

- **Fungi belonging to this group produce non-motile sporangiospores called aplanospores within sporangia these are the result of cleavage of the sporangium protoplasm around one or more nulcei**
- **Each uninucleate or multinucleate (depending on the species) portion of protoplasm becomes enclosed by a rigid wall and matures into an aplanospore**
- **Eventually, the sporangium wall bursts to liberate the spores, which are dispersed by air currents. a fragment of the sporangium wall (collarette) may remain**
- **in some species the sporangium contains a columella, a curved cross-wall (septum) which bulges into thesporangium, providing a larger surface area than a normal flat septum, facilitates increased diffusion of nutrients to the developing spores within the sporangium, which is particularly important in larger sporangia.**
- **An example is *mucor***

Asexual Sporulation in the Zygomycota



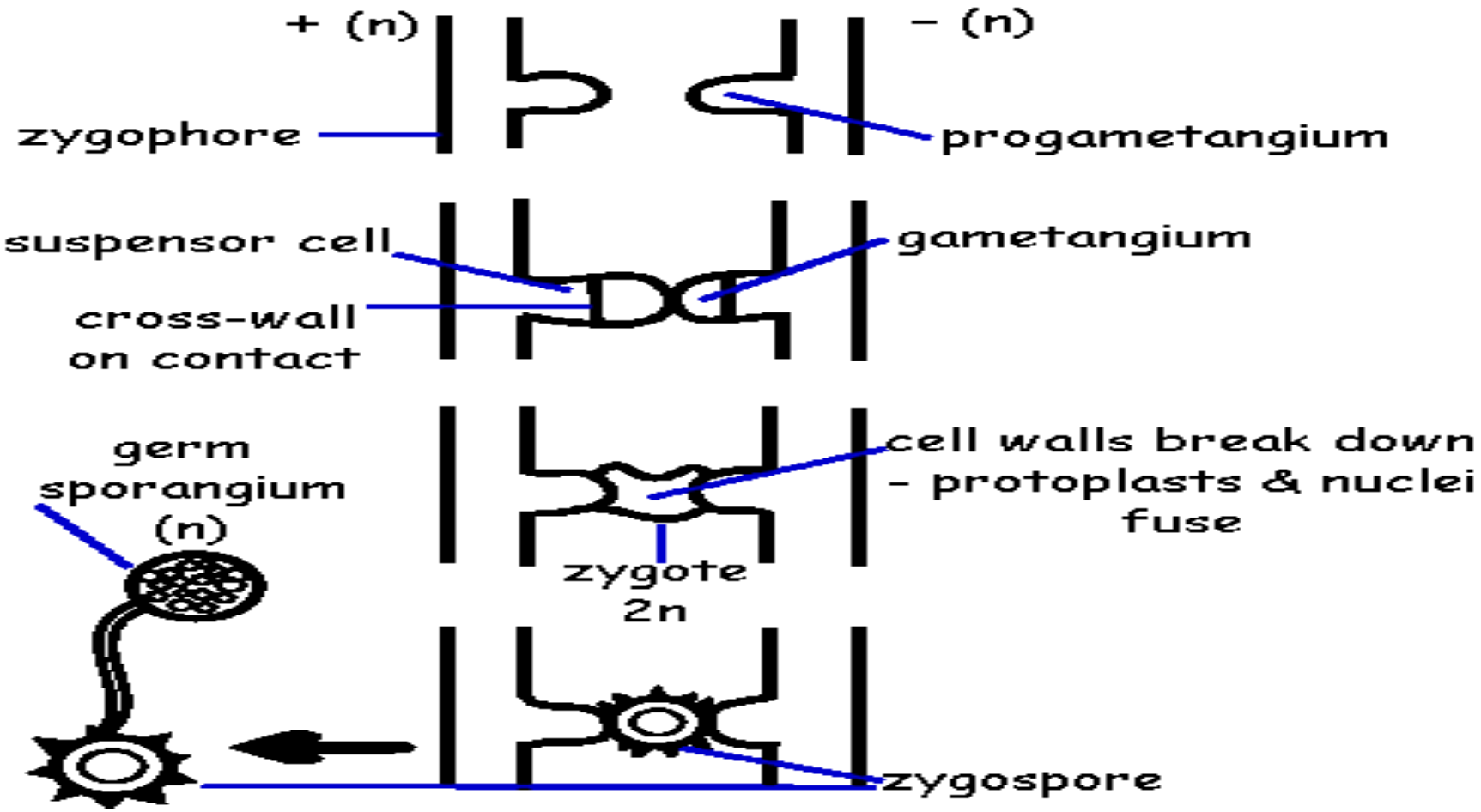
Sexual Sporulation in the Zygomycota

- The zygote cell enlarges, its wall thickens and becomes pigmented and in many species the wall becomes highly sculptured - this structure is the maturing zygospore
- After a period of dormancy the zygospore germinates, producing a sporangiophore and sporangium (germ sporangium)
- Meiosis occurs during formation of the germ sporangium - so it contains haploid sporangiospores, which will upon germination give rise to haploid mycelia (colonies)
- Some species within the zygomycota are homothallic (self-fertile), while others are heterothallic (self-sterile)

Sexual Sporulation in the Zygomycota

- Sexual sporulation in heterothallic species requires the presence of two physiologically compatible colonies (mycelia), usually designated + (plus) and - (minus); remember that mycelia of fungi belonging to the zygomycota are haploid
- Specialized aerial hyphae, called zygophores, form small branches called progametangia, which are mutually attracted and grow towards one another
- Upon contact with one another, the tips of the progametangia enlarge
- A cross-wall (solid septum) develops behind the tip of each progametangium, dividing each into a gametangium and a suspensor cell
- The walls of the two contacting gametangia breakdown at the point of contact and the two protoplasts fuse - the nuclei then pair and fuse (karyogamy) to form a diploid zygote

Sexual Sporulation in the Zygomycota



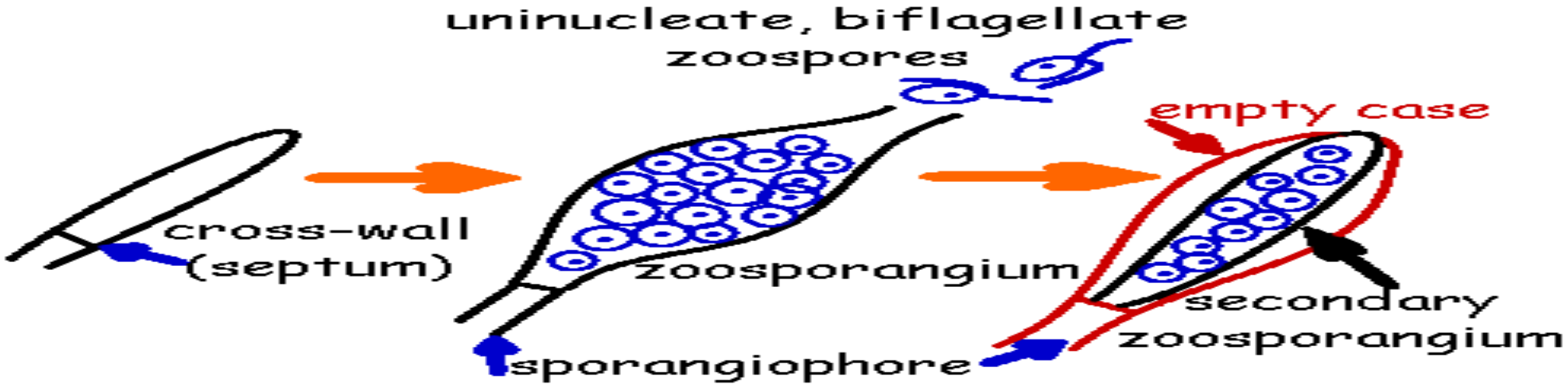
Asexual Sporulation in the Oomycota

- **An apical hyphal cell swells to become a zoosporangium - in which nuclear mitotic divisions are followed by cleavage of the protoplasm around individual nuclei**
- **The remainder of the supporting hypha is called a sporangiophore**
- **In *saprolegnia*, once a zoosporangium has liberated its zoospores a secondary zoosporangium often develops and grows through the now empty case of the first zoosporangium, maturing within it or growing beyond it prior to releasing its zoospores several zoosporangia may form, one within the other - a process known as percurrent proliferation.**

Asexual Sporulation in the Oomycota

- **Diplanetism: some oomycota fungi (e.g. *saprolegnia*) possess two motile stages with a resting stage between.**
- **This phenomenon is known as diplanetism.**
- **Primary zoospores are pear-shaped with both flagella attached at the apex**
- **Secondary zoospores are kidney-shaped with both flagella attached in the lateral groove on the concave side**
- **Monoplanetic species possess a single motile stage - a kidney-shaped biflagellate zoospore**

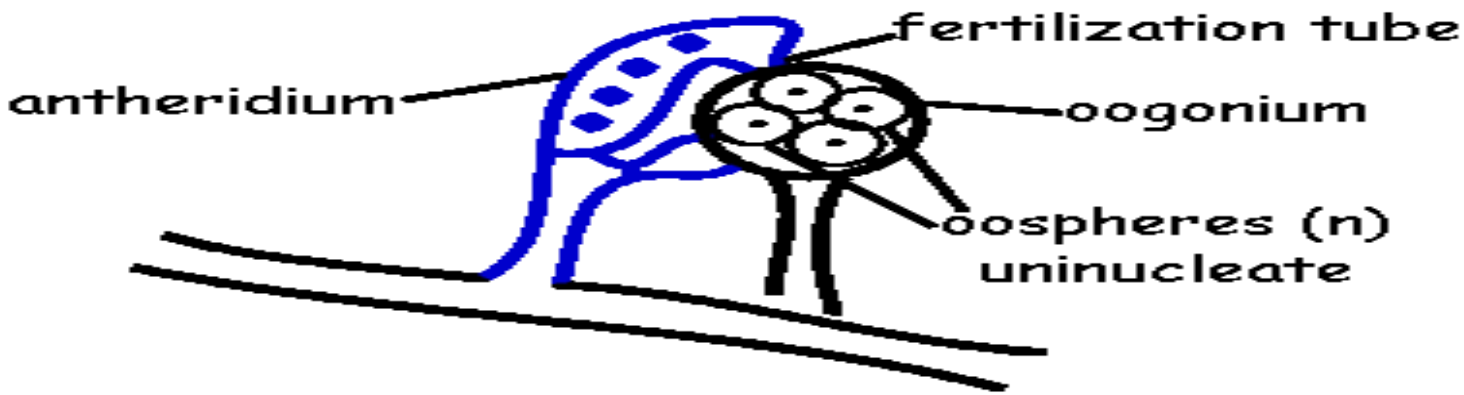
Asexual Sporulation in the Oomycota



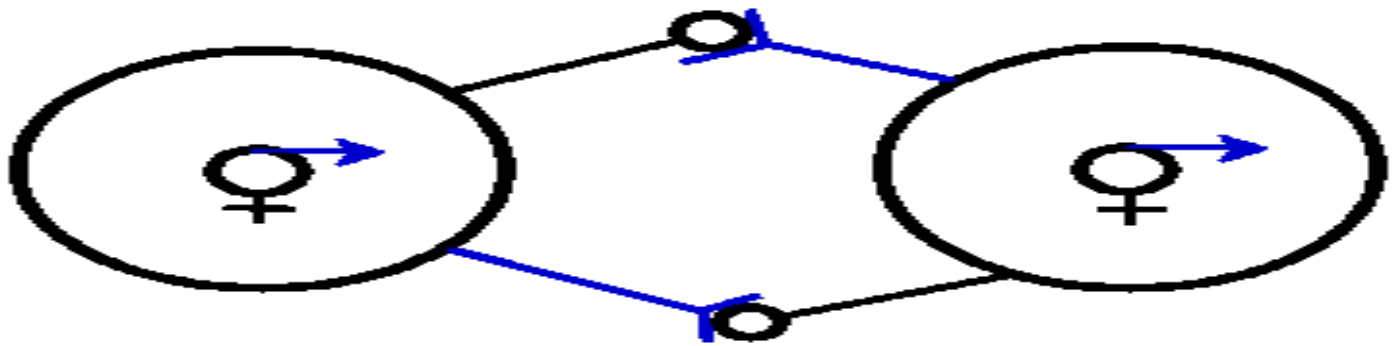
Sexual Sporulation in the Oomycota

- Oogonia are usually spherical and their entire contents differentiate into uninucleate haploidoospheres
- Antheridia are elongate, multinucleate structures which originate either:
  - on the same hyphal branch as the oogonium (homothallic species)
  - on a different hyphal branch within the same colony (homothallic species)
  - on a hypha from an entirely different colony (heterothallic species) self incompatibility
- The antheridia branch to form fertilization tubes, sending one nucleus into each oosphere within the oogonium where it fuses with the oosphere nucleus to form a diploid zygote
- Each fertilized oosphere now develops a thick wall and becomes converted into an Oospore
- After a period of dormancy the oospore germinates and the resulting germ-tube eventually gives rise to a diploid mycelium

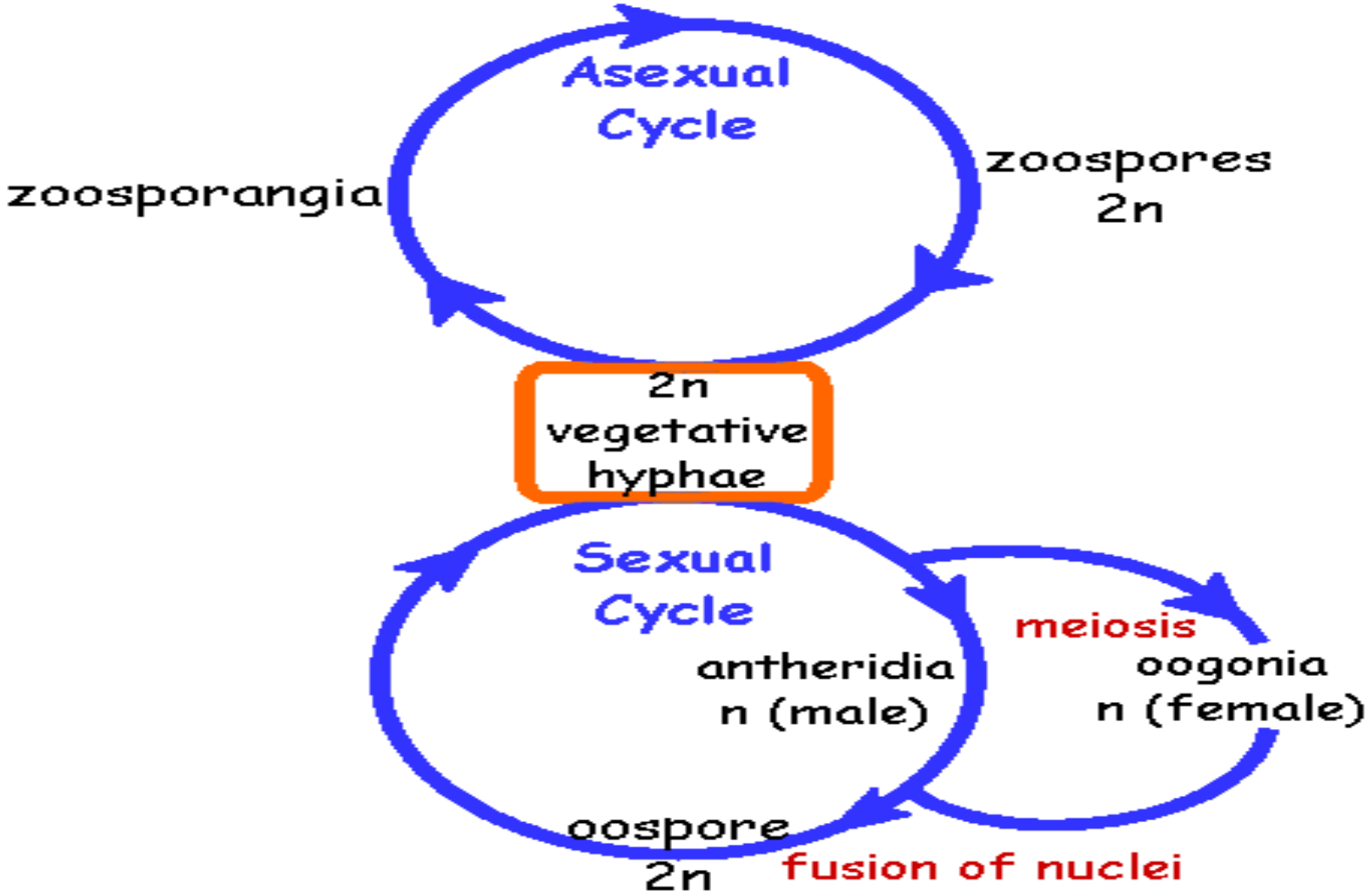
Sexual Sporulation in the Oomycota



Heterothallic Oomycete spp.



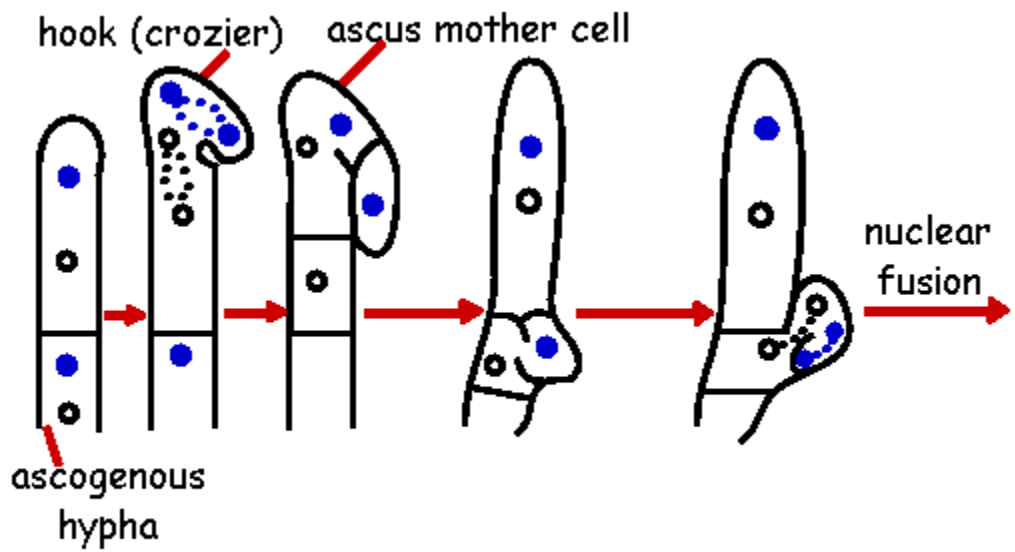
Life cycle of fungi belonging to the Oomycota



Sexual Reproduction in Ascomycetes

- The apical compartment of a dikaryotic ascogenous hypha elongates and bends over to form a hook (crozier)
- The two compatible nuclei in the apical compartment then undergo mitosis simultaneously
- Two septa develop in such a way that the crozier becomes divided into three compartments - the tip and basal compartments are uninucleate; the middle compartment is binucleate and is called the ascus mother cell (since it is destined to become an ascus).
- The nuclei in the ascus mother cell fuse to form a diploid nucleus, which then undergoes meiosis to form four haplid nuclei
- Each haploid nucleus then divides mitotically - resulting in eight haploid nuclei.
- A portion of protoplasm surrounds each nucleus - this becomes enveloped by a wall and matures into anascospore
- Meanwhile, another ascus mother cell will have been developing alongside the first
- The asci form in groups, surrounded by hyphae and are enclosed in fruiting bodies (ascocarps)

Sexual Reproduction in Ascomycetes



Sexual Reproduction in Ascomycetes

1. **Hemiascomycetes (includes yeasts)**
- **The asci are not enclosed in an asocarp**
- **The diploid cell of yeasts (zygote) is transformed directly into an ascus containing eight ascospores**

2. **Plectomycetes**
- **Fungi belonging to this group form cleistothecia**
- **These are round, completely closed ascocarps, possessing no natural opening**
- **the asci are arranged irregularly within them**
- **The mature cleistothecia burst open to release their asci and ascospores**

3. **Pyrenomycetes**
- **Fungi belonging to this group form perithecia**
- **Perithecia are spherical or flask-shaped ascocarps**
- **They open via a neck-like ostiole with a terminal pore through which the ascospores are liberated**
- **The asci are arranged in an orderly layer at the base of the cavity**

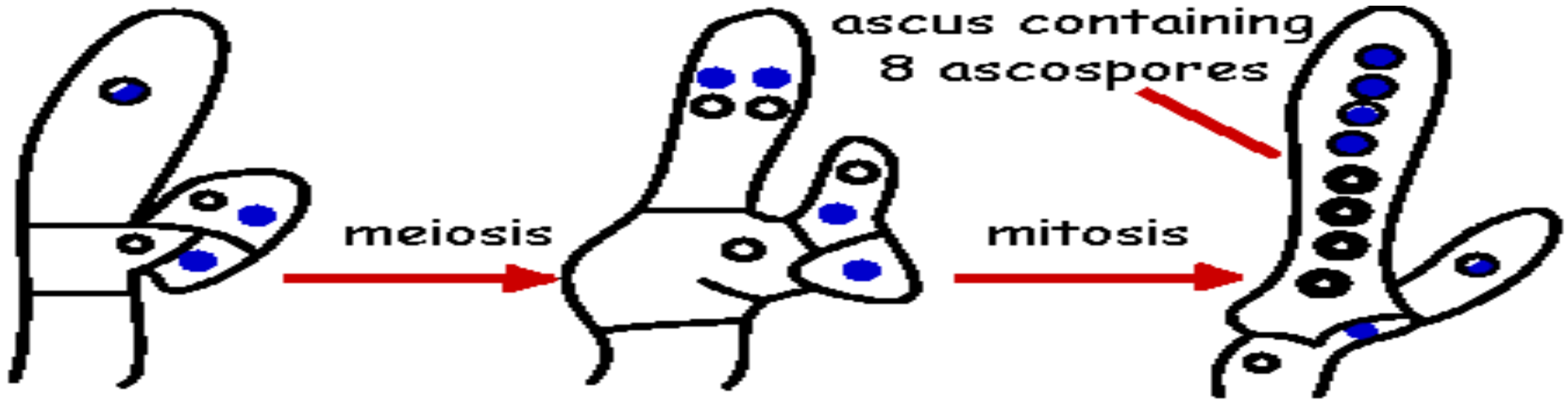
4. Loculoascomycetes

- Fungi belonging to this group form ascostromata(or pseudothecia)
- Ascostromata resemble perithecia but in the former there is no wall surrounding the central region of the ascocarp - only a cavity within the mass of hyphal tissue (stroma) in which the asci are located

5. Discomycetes

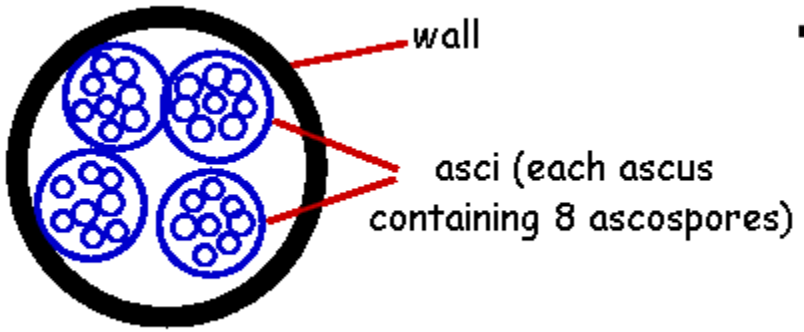
- Fungi belonging to this group form apothecia
- An apothecium is an open- or cup-shaped ascocarp
- The asci are arranged on the exposed surface (hymenium)

Sexual Reproduction in Ascomycetes

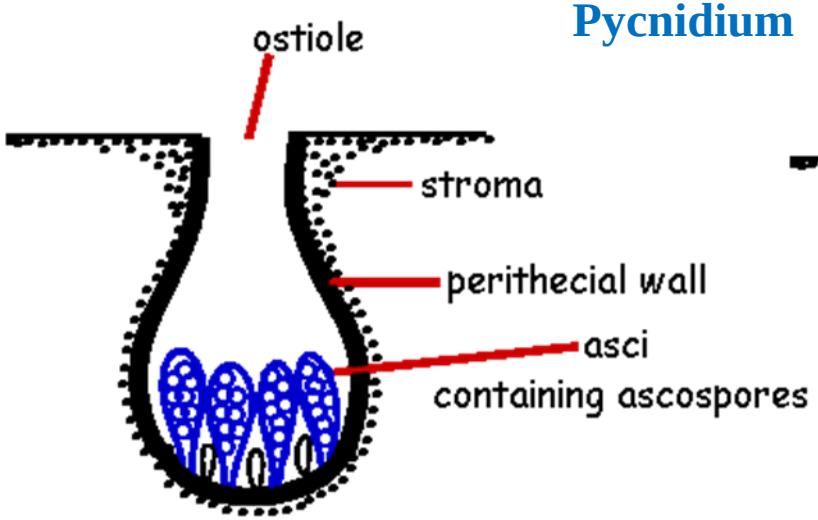


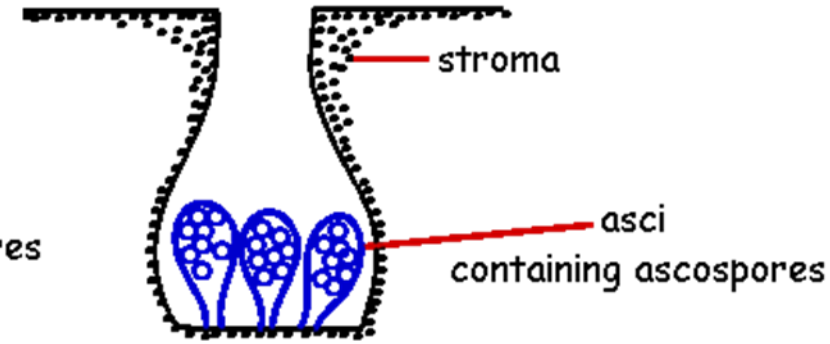
The fruiting bodies (ascocarps) in Ascomycetes

Clestothecium

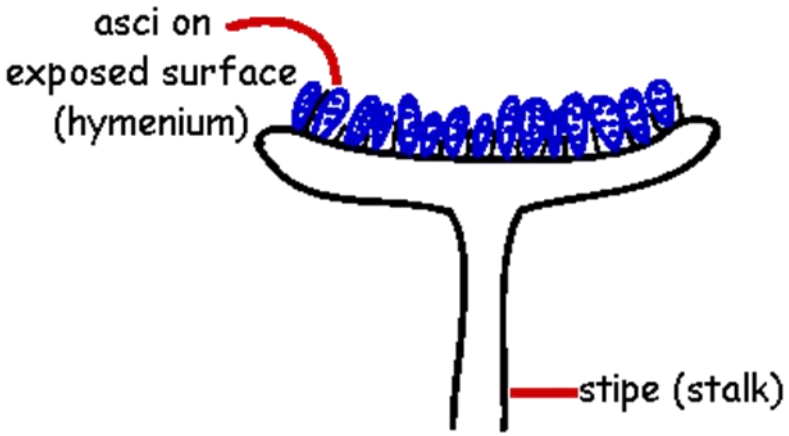


Pycnidium





Apothecium

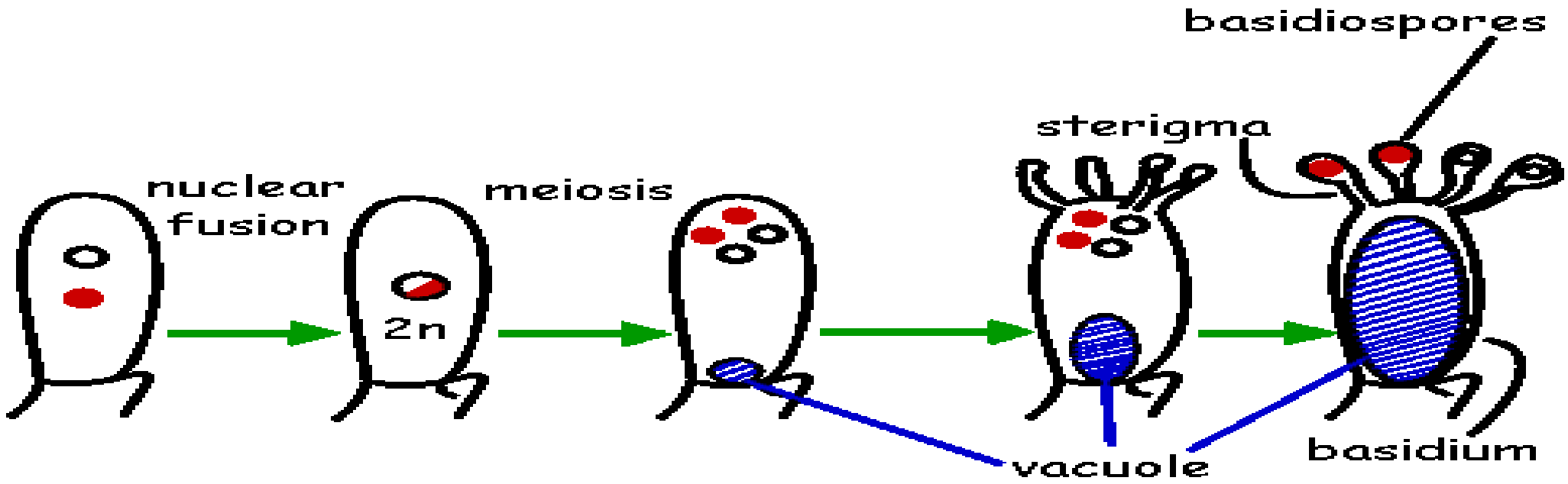


Sexual Reproduction in the Basidiomycota

Formation of basidiospores:

- **Two haploid nuclei in an apical dikaryotic hyphal compartment (often within a basidiocarp) fuse to form a diploid nucleus**
- **The diploid nucleus undergoes meiosis to yield four haploid nuclei**
- **Four small outgrowths - sterigmata - begin to form at the top of the hyphal compartment and the tip of each sterigma begins to inflate**
- **A fluid-filled vacuole develops near the base of the compartment and gradually enlarges and forces protoplasm into the inflated portions of the sterigmata**
- **When each swelling at the tip of a sterigma has almost attained its full size a nucleus passes into it**
- **The uninucleate swelling at the the tip of each sterigma matures into a basidiospore**
- **The compartment supporting the sterigmata and basidiospores is called a basidium**

Sexual Reproduction in the Basidiomycota



Classification of the Basidiomycota based on presence or absence of fruiting bodies and the type of basidiocarp formed

Basidiocarps are amongst the most familiar of fungal structures, including toadstools, brackets and puff-balls.

1. Teliomycetes

- No basidiocarp
- The uredinales and ustilaginales are two important orders of plant-pathogenic fungi belonging to the Teliomycetes

2. Hymenomycetes

- The basidia are arranged in a layer known as a hymenium that is fully exposed at maturity
- The hymenium may cover the surface of gills, line vertical downward-facing pores, or cover an erect club or system of vertical branches or teeth

3. Gasteromycetes

- Includes fungi known as puff-balls, earth-stars and birds' nest fungi
- The spore-producing hymenium is not exposed at maturity