People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

University 8 May 1945 Guelma

Faculty of Natural and Life Sciences and Earth and Universe Sciences (SNV & STU)

Department of Ecology and Environmental Engineering

Courses Name :

Parasitic plant diseases

Course handout for Master I Phytopharmacy and plant protection

Directed by

Dr. MALEK Insaf

2024-2025

Summary

Figures list :

Figures **Page**

Table list :

Tables **Page**

Introduction :

Fungi, represent one of the largest groups of organisms on Earth. These are unicellular or multicellular eukaryotic organisms, including macroscopic species (macromycetes) and other microscopic ones (micromycetes) with a filamentous or yeast-like appearance. These organisms are devoid of chlorophyll and are all heterotrophs, with a sexual or asexual mode of reproduction. They produce a large number of spores, which gives them considerable contamination power.

From a morphological point of view, there is a wide variety of mushrooms.

1. They are classified into two main categories: the unicellular yeast form and the multicellular mycelial form made up of hyphae.
2. From a metabolic point of view, fungi are chemoheterotrophs, meaning they use organic carbon as an energy source.
3. Their mode of nutrition is by absorption, initially releasing hydrolytic enzymes into the external environment. The vast majority are aerobic organisms, but certain yeasts can be aero-anaerobic and participate in fermentation processes.
4. Fungi can also be classified according to their habitats, their geographical locations, according to the ecological concept of the species. All of the phenotypic characteristics mentioned above no longer necessarily require a total revolution. When several species risk bringing together organisms sharing especially where the ecological constraints are the same. In addition, lineages or morphoanatomical characters evolve rapidly, particularly when a species changes environment. Consequently, numerous studies have aimed to develop identification tools based on the study of nucleic acids.

These molecular techniques have made it possible to repair a major anomaly in the classification of fungi. With DNA sequencing, a multitude of new characters are available for those who want to classify taxa. The sequences provide a large amount of characters. On the phytopathological side, most fungi and bacteria live in relation with other organisms, in several ways: saprophytic, symbiotic and parasitic. The latter feed on the living tissues of plants (hosts), so can clearly be characterized as biotrophs. These hosts contribute to the spread of the parasite in nature.

The presence of pathogens on a host plant can lead to different types of symptoms : necrosis, drying, loss of vigor, wilting, rot, deformation of organs (galls), mosaics, on different organs, leaves, stems, flowers, fruits and roots. These parasites, when they cause disease and damage to plants, can have a strong impact on agricultural production. Yield losses caused by these microorganisms are difficult and require numerous criteria. The climatic, edaphic and ecological factors which act on the crop, the parasite and the host/parasite relationship must be taken into account.

It is remarkable that fungal diseases and bacterial conditions are distributed unevenly between the plant and animal kingdoms. Indeed, major plant diseases are most often due to fungi, rarely to bacteria. In humans, on the other hand, the opposite occurs and bacterial infections are the most numerous.

This unequal distribution is the consequence of the normal process of infection which is not the same within the animal kingdom as within the plant kingdom.

CHAPTER I : FUNGAL DISEASES

Chapter I: FUNGAL DISEASES

Reminders on the biology of fungi

1. The vegetative system or thallus

The fungi thallus can take different forms:

1.1. Filamentous thallus (multicellular)

Most fungi, however, have a filamentous (**Fig 1)**, multicellular fungal thallus, called mycelium, shaped like filaments. In certain groups of fungi, the filament, which is called siphoned (called coenocytic), is made up of numerous nuclei, because the cells are not separated from each other.

In so-called higher fungi, the filaments, called hyphae, are on the contrary compartmentalized. Hyphae of this type can contain one, two or more nuclei.

The septate hyphae (septate) characterize the Ascomycota and the Basidiomycota.

Septa are absent in the hyphae of most Oomycota, Chytridiomycota and Zygomycota.

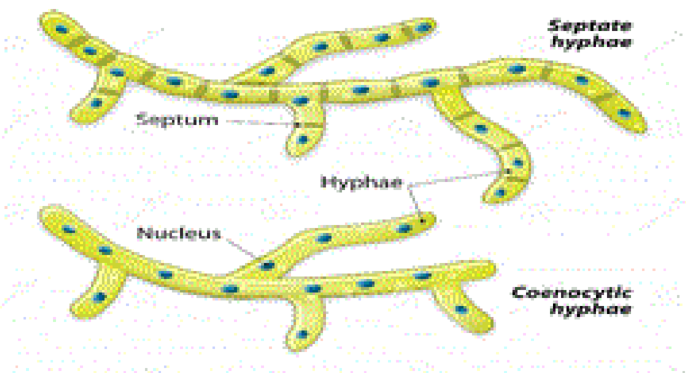

Figure 1 : The two types of filamentous thallus **[1]**

1.2. Yeast thallus (unicellular)

The thallus of certain fungi is made up of a single cell (unicellular), called a yeast cell, since this is the usual morphology of yeasts. This unicellular thallus is found in certain Ascomycetes, Basidiomycetes and Zygomycetes (**Fig 2)**.

It is unicellular round or oval, multiplies by budding, example: yeasts.

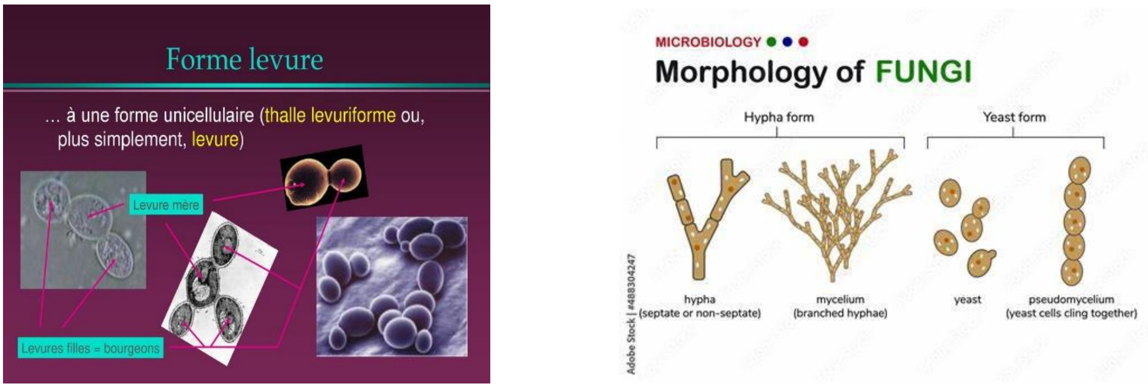

Figure 2: Yeast thallus (unicellular) **[2]**

1.3. Plasmodial thallus

A plasmodium (= plasmodial thallus) is a mass of soft, deformable cytoplasm, characterizing pseudo-fungi **(Fig 3)** belonging to the Protozoa such as Plasmodio-phoromycota **(Fig 4)**. It is formed by cytoplasmic masses, containing several nuclei, without cell wall

Figure 3 : Plasmodial thallus **[3]**

Figure 4: Protozoa example of Plasmodiophoromycota **[4]**

2. Fungi reproduction

Fungi reproduce using spores. These come either from sexual reproduction (called perfect, teleomorphic fungus) or from asexual multiplication (called imperfect or vegetative, characteristic of the anamorph).

2.1. Asexual reproduction (anamorph)

Asexual reproduction in fungi can occur by budding, binary fission, fragmentation, or by spore formation

- Budding and binary fission:

Budding and binary fission (**Fig 5**) are the simplest forms of asexual reproduction. Budding is an unequal division of the cytoplasm, resulting in a parent cell and a daughter cell, the latter being smaller than the parent cell. Binary fission, on the other hand, results in two identical cells.

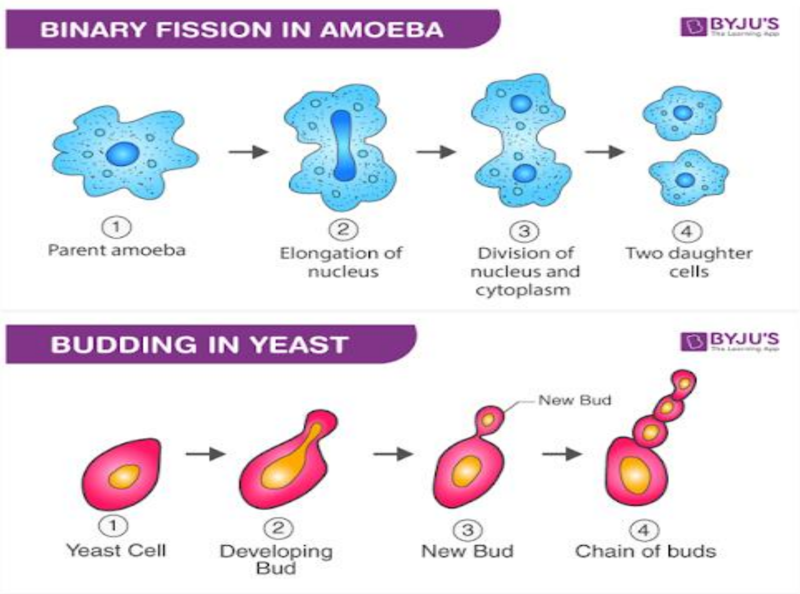

Figure 5: Illustration of binary fission and budding in yeast **[5]**

- Cuttings: (cuttings)

The simplest mechanism is cuttings (**Fig 6**). In this case, the vegetative thallus fragments and the released articles, containing the nuclei, act as spores. They disperse and can settle on a favorable substrate. This mechanism remains limited in nature, perhaps due to the fragility of the items.

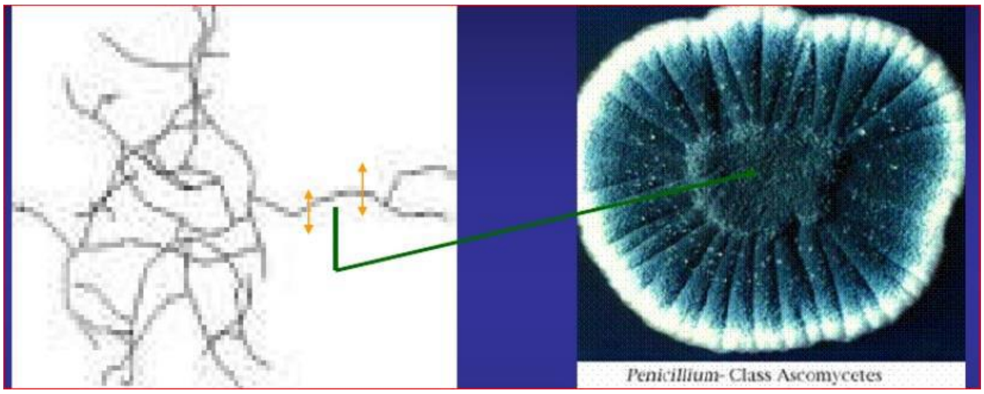

Figure 6: The cutting mechanisms **[6]**

- Sporulation

Sporulation is the most important form of asexual reproduction in fungi (**Fig 7)**. It occurs through asexual spores, formed during the asexual phase of the life cycle of fungi (anamorphic phase).

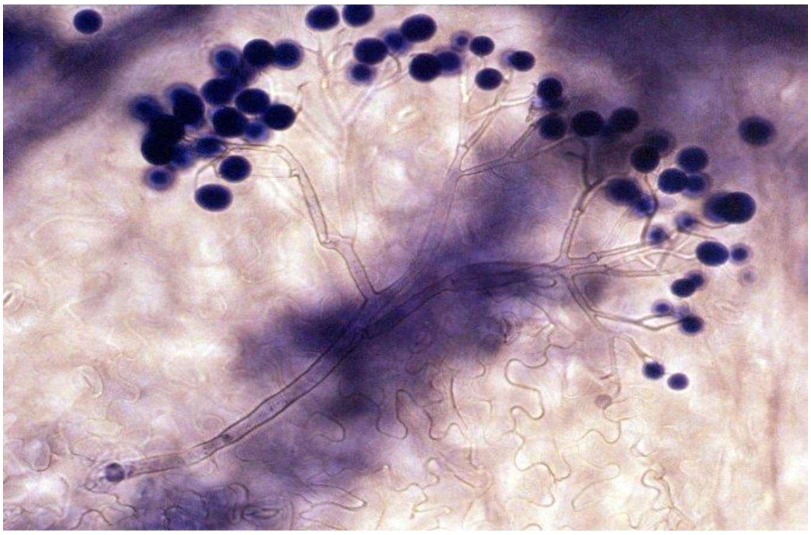

Figure 7 : Sporulation of *Hyaloperonospra parasitica* (Downy mildew) in an Arabidopsis thaliana leaf **[7]**

- Most fungi have the ability to multiply by means of mitotic spores without fusion of gametes produced in the normal cycle of vegetative mycelium (most often haploid).

  These spores, small dehydrated cells with reduced metabolism and surrounded by a protective wall, their diameter varies from 2 to 250 µm, they are produced in large quantities by specialized structures developed from the mycelium. In this category, there are two types of spores:

- 1. Spores can also be produced endogenously inside specialized cells or sporocysts (sporocystiophores) (**Fig 8).**

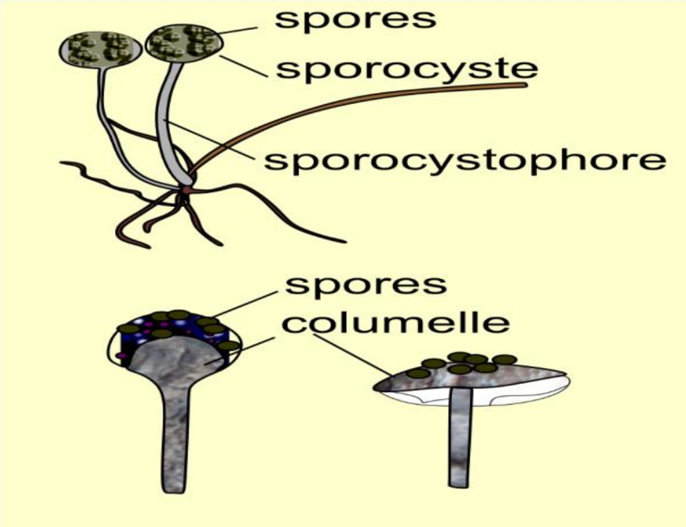

Figure 8: sporocystophores **[8]**

- 2. Or exogenously (conidiogenesis) produced either on the surface of the mycelium (**Fig 9)** or on specialized filaments (conidial apparatus or conidiophore) free or grouped in a specialized structure called pycnidium

Figure 9 : Conidiophore *Aspergillus niger* **[9]**

- Spores, produced in very large quantities and resulting from asexual reproduction (**Fig 10)**, play an essential role in the dispersal of fungi and the colonization of new plants. In fact, a spore germinates and emits a filament which grows, elongates at the apical end and branches to give a new mycelium. In this respect we distinguish spores with a dry wall, non-wettable (xerospores) and easily transported by the air; and spores with a hygrophilic wall, slimy and dispersed by water or by contact with insects, mites, etc.

- Spore production occurs by apical growth and elongation of the filaments from their ends in all directions. These spores are known as thallospores or thallic spores. In anamorphic fungi, spores are called conidia and the terms sporogenous cells and sporophores are replaced by conidiogenous cells and conidiophores, respectively,

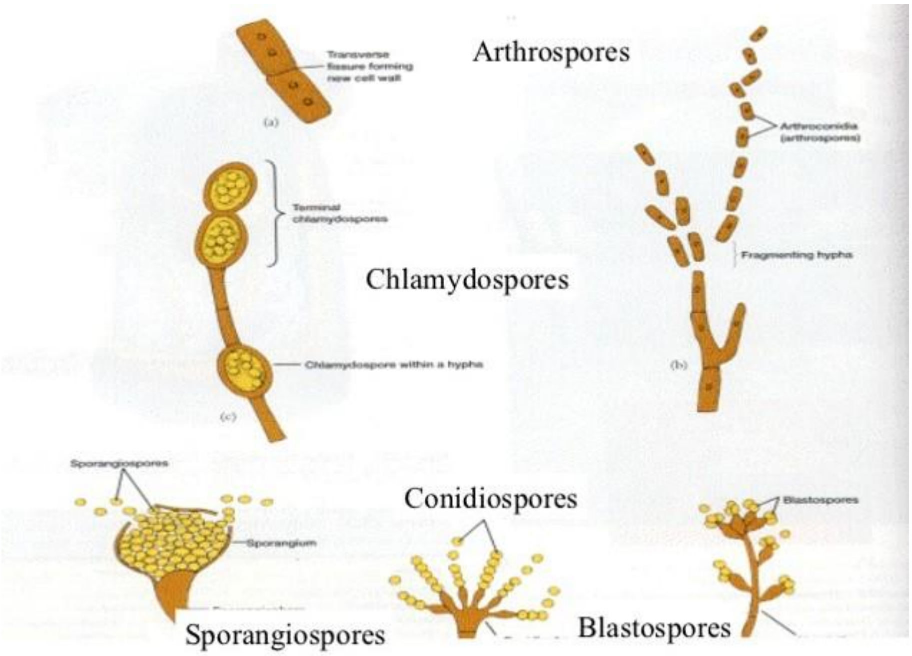

Figure 10: Types of asexual reproduction in fungi **[10]**

The spores produced by Ascomycetes and Basidiomycetes are carried in sporangia and are then called sporangiospores. Zygomycete sporangiospores are not mobile and are called aplanospores. Certain groups of fungi (Oomycete, Plasmodiophoromycete and Chytridiomycete) produce naked vegetative spores, mobile in water thanks to one or two flagella (zoospores) which form inside sporangia

2.2. Sexual reproduction (teleomorph)

The sexual cycle of fungi takes place in three stages: plasmogamy (involves the meeting of specialized filaments), karyogamy (the conjugation of nuclei) and meiosis (a chromatic reduction) followed by one or more mitoses (**Fig 11)**.

Plasgamamy corresponds to the fusion of two protoplasts of two compatible haploid cells. The resulting cell is called a dikaryon because it has two types of haploid nuclei.

The two nuclei will fuse during karyogamy (karyogamy: a nucleus with 2n chromosomes) then meiosis will convert a diploid cell into four haploid cells (4 nuclei with n chromosomes). These nuclear phenomena generally occur in more or less differentiated fruiting bodies

The major groups in the classification of mushrooms are based on the nature and morphology of these fruiting bodies. This sexual reproduction results in the production of specialized spores with particular names as zygospores, ascospores, basidiospores and oospores

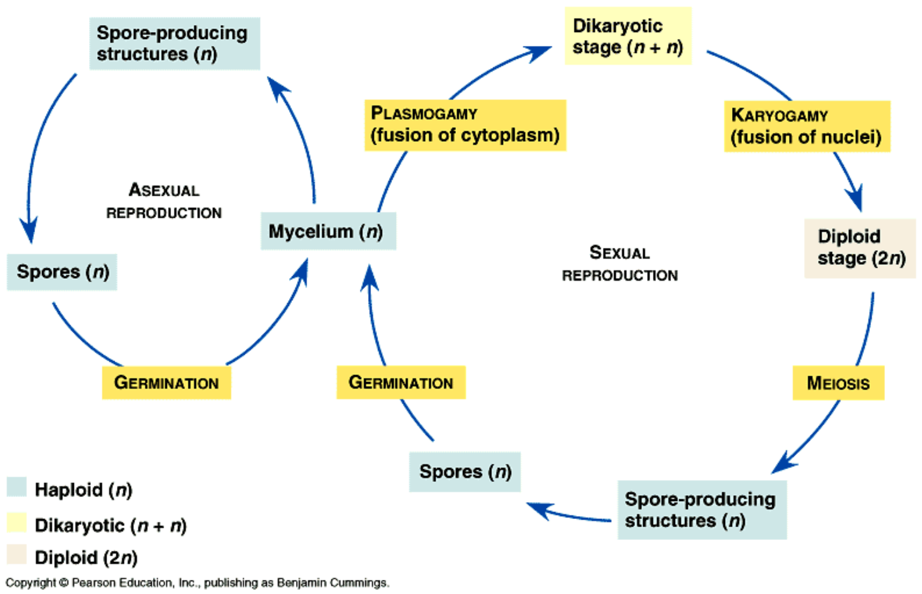

Figure 11: “Teleomorphic” sexual reproduction in fungi [11]

2.2.1 The different modes of spore formation

Sexual reproduction can result in 4 types: An oospore, a Zygospore, ascospore and a basidiospore

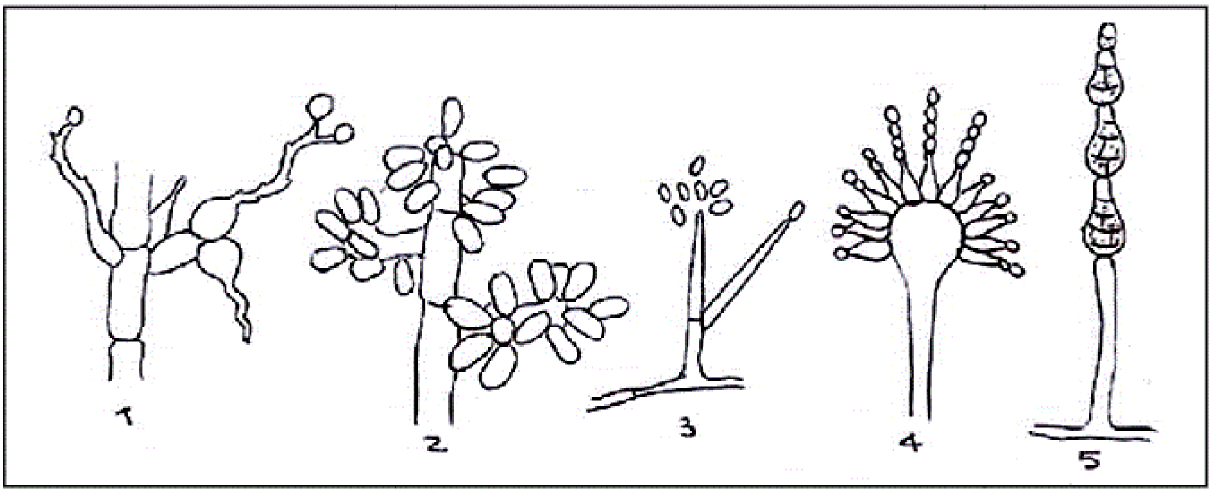

Figure 12 : Conidia grouping mode of filamentous fungi

1. clusters (*Beauveria*), 2. Masses (*Botrytis*), 3. Basipetal head (*Aspergillus*), 4. Chain (*Aspergillus*), 5. Acropetal chain (*Alternaria*) **[12]**

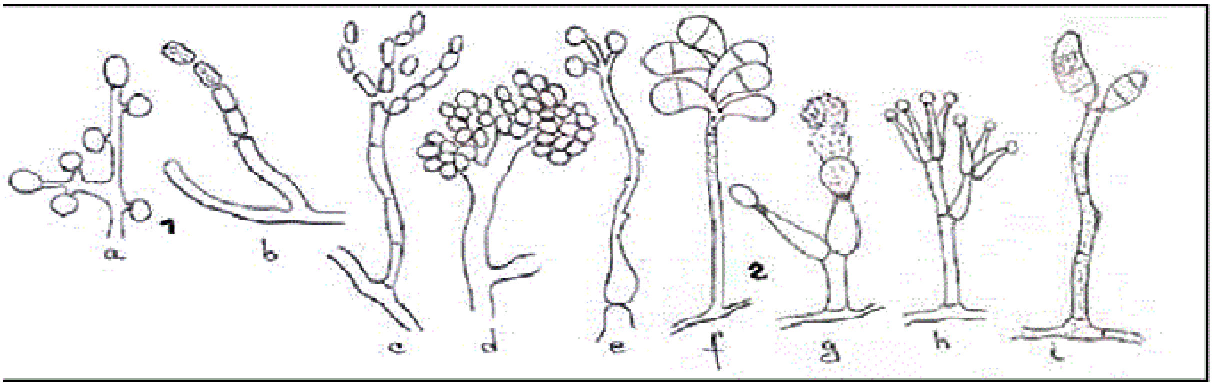

Figure 13: Mode of formation of conidia.

Thalic formation a : solitary (*Chrysogenum*), b : arthritic (*Geotrichum*).

Blast formation : c : acropetal (*Cladosporium*), d : sinchronous (*Botrytis*), e : sympodial (*Beauveria*), f: regressive (*Trichoderma*), g: annelidic (*Scopulariopsis*), h: phialidic (*Penicillium*), i poric (*Curvularia)* **[13]**

3. Nutrition and host-parasite associations

Certainly! The nutritional interactions between hosts and parasites are fascinating. Let's delve into some key aspects:

3.1. Nutrient Assimilation by Parasites : Parasites acquire nutrients from their hosts through various mechanisms :

3.2. Active Feeding : Some parasites directly consume host tissues, akin to a predator-prey relationship.

3.3. Passive Assimilation : Parasites absorb products derived from the host's metabolism.

3.4. Shared Food Source : In certain cases, parasites share the same food as the host, representing a form of commensalism.

3.4. Haustorium Physiology :

Parasitic plants rely on their hosts for nutrition. The haustorium, a specialized organ, plays a crucial role in nutrient absorption. Depending on the species, materials obtained from the host may include resources needed for parasite growth.

Details of haustorium physiology remain partially unexplored, but it's a central aspect of resource acquisition in parasitism

Fungi do not have chlorophyll and cannot feed on air and sun, they move away from the Plant Kingdom; they do not ingest prey, no plants, and also move away from the Animal Kingdom. So how do they eat? Let's discover the modes of nutrition of the Fungal Kingdom.

3.5. Heterotrophic organisms

Living beings need water, carbon, oxygen, hydrogen and nitrogen mainly. Only chlorophyll plants, autotrophic, are autonomous in their carbon supply, depending on carbon dioxide from the air and solar energy.

3.6. The organic matter produced by green plants

Circulates between heterotrophic organisms, herbivores, carnivores, parasites, decomposers, symbionts. Mushrooms have opted for the last 3 feeding methods, sometimes with a surprising carnivorous side.

***Parasitic fungi**

Parasitic fungi develop on living beings, plants, animals and even other fungi. The mycelium, the hidden vegetative part, settles on weakened, injured, sometimes healthy and vigorous individuals. Its fine, branched filaments absorb carbonaceous and nitrogen molecules, water and mineral elements from the host. This becomes exhausted and is bound to perish; the benefit is one-way.Downy mildew, rusts and powdery mildews are parasitic fungi that cause regular damage to the garden. The orchards and trees of our forests are not spared, with formidable attackers, **Plum Phellin, Honey-colored Armillaria, Ash Chalarose, Amadouvier and other polypores, cankers** respectively in the next figures.



*Saprophytic mushrooms

Saprophytic fungi develop on dead organic matter, wood, stumps, branches, twigs, leaves, excrement, humus, old mushrooms but also cardboard, wallpaper... Any carbon source is welcome. The mycelium settles, branches and diffuses fine, long filaments inside its nourishing support, increasing as much as possible the contact surface with the material that it decomposes and absorbs. The fungus feeds while contributing to the recycling of dead organisms, a fundamental role preventing them from being buried under mountains of waste. Among the saprophytes we will find many edible ones, button mushrooms, **Coprins, Rosé-des-prés, Morels,** respectively in the next figures, and most of the cultivated varieties





***Symbiont or mycorrhizal fungi**

Symbiotic fungi develop mycorrhiza, a mutually beneficial association with a host that is itself autotrophic. The vegetative apparatus of the fungus, the mycelium, comes into close contact with the roots of surrounding plants. Glucose, sucrose, all carbon molecules, are supplied to the fungus which distributes to its partner(s), depending on the symbioses, root protection, water supplements, nitrogen, mineral elements, large-scale mycelial diffusion network. Exchanges benefit and are essential to both partners, in a complex and evolving balance.**Truffles, Fly Agaric, Boletas (Suillus, Leccinum, Xerocomus), Milkweeds, Russulas** ; respectively in the next figures**,** and many others are mycorrhizal fungi.





4. **Systematic and classification systems**

- The traditional classification of filamentous fungi based on phenotypic (physical) criteria has been supplanted by the development of genotypic (hereditary) methods.

- Phylogenetic classification based on criteria has allowed a revision and modification of the classification of fungi.
- Historically, mushrooms were recognized based on their morphology according to the morphological concept of species. Mushrooms can also be described according to their habitats, their geographical locations and according to the ecological concept of the species.
- Phenotypic classification is often long and difficult, lacks precision and objectivity, due to the great diversity of mushrooms.

The characters convergent morphological structures sometimes bring together different organisms, while they separate closely related species.

In addition, lineages or morpho-anatomical characters evolve rapidly, particularly when a species changes environment.

- The macroscopic analysis of colonies obtained after cultivation of filamentous fungi is based on several aspects of the vegetative system: appearance, relief, size and color. During the microscopic analysis of the colonies, several structures of filamentous fungi are observed such as the vegetative apparatus, the fruiting bodies and the spores.
- Another criterion for the classification of fungi is based on the mode of sexual reproduction. Fungi have been classified for several centuries essentially on the basis of sexual reproduction; we then speak of teleomorphic fungi, which are relatively stable during evolution and in a population. For certain fungi called anamorphs, the mode of reproduction only occurs asexually or vegetatively. All of these fungi are grouped within the division of Deuteromycota (anamorphs), which are also called "imperfect fungi
- The development of molecular methods has enabled the emergence of new tools for classification, induces a profound erosion in traditional systematics, notably through the PCR (Polymerase Chain Reaction) technique. This technique also made it possible to reorganize the classification of fungi on the basis of genotypic and no longer phenotypic
  - The phylogenetic concept of the species consists of comparing the DNA sequences between several individuals in order to compare it. The analysis of a DNA bank comprising several species must make it possible to validate the taxonomy in order to verify the reliability of the phylogenetic tree of fungi (Table 1).

Table 1 : Classification of fungi according to (Hibbett et al., 2007)

Division	Classe	Ordre	Famille	Espèces Exemple
Ascomycota (spores contenues dans des asques)	Taphrinomycètes	Taphrinal	Protomycétacées Taphrinacées	Cloque du poirier
	Dothidéomycètes	Botryosphaeriales (ou Dothidéales)	Botryosphaeriacées	*Botryosphaeria obtusa* *Botryosphaeria stevensii*
		Capnodiales	Davidiellacées Mycosphaerellacées	*Cladosporium cucumerinum* *Cercospora carotae*
		Myriangiales	Elsinoacées	*Sphaceloma rosarum*
		Pléosporales	Didymellacées Leptosphaeriacées Mélanommatacées Phaeosphaeriacées Pléosporacées Venturiacées	*Ascochyta avenae* *Septoria avenae* *Pyrenochaeta lycopersici* *Parastagonospora nodorum* *Alternaria alternata* *Venturia inaequalis*
	Eurotiomycètes	Eurotiales	Trichocomacées	*Aspergillus flavus*
	Léotiomycètes	Erysiphales	Erysiphacées	*Blumeria graminis*
		Hélotiales	Dermatéacées Sclérotiniacées	*Oculimacula acuformis* *Botrytis cinerea*
		Rhytismatales	Rhytismatacées	*Blumeriella jaapii*
	Sordariomycètes	Diaporthales	Diaporthacées Valsacées	*Phomopsis citri* *Valsaria insitiva*
		Hypocréales	Clavicipitacées Glomérellacées Nectriacées	*Claviceps purpurea* *Colletotrichum coccodes* *Fusarium graminearum*
	Ustilaginomycètes	Urocystidales	Glomosporiacées Urocystidacées	*Thecaphora solani* *Urocystis agropyri*
		Ustilaginales	Ustilaginacées	*Ustilago muda*
ZYGOMYCOTA	Zygomycètes	Mucorales	Choanéphoracées Mucoracées	*Choanephora cucurbitarum* *Rhizopus stolonifer*
CHYTRIDIOMYCOTA	Chytridiomycetes	Chytridiales	Synchytriacées	*Synchytrium endobiotium*
		Spizellomycétales	Olpidiacées	*Olpidium viciae*
BLASTOCLADIOMYCOT	Blastocladiomycetes	Blastocladiales	Physodermatacées	*Physoderma alfalfae*
GLOMEROMYCOTA	Gloméromycètes	Glomerales	Glomeraceae Entrophosporaceae	*Archaeospora, Geosiphon.*
		Diversisporales	Diversisporaceae Sacculosporaceae Pacisporaceae Acaulosporaceae	
		Paraglomerales	Paraglomeraceae	
		Archaeosporales	Archaeosporaceae Ambisporaceae Geosiphonaceae	
MICROSPORIDIA	Rudimicrosporea	Microsporida Minosporea		*Enterocytozoon bieneusi* *Brachiola connor* *Nosema ocularum*
NEOCALLIMASTIGOMYCOTA	Neocallimastigomycetes	Neocallimastigales		

		Magnaporthales	Magnaporthacées	*Pyricularia oryzae*
		Méliolales	Méliolacées	*Meliola citricola*
		Microascales	Cératocystidacées	*Chalara paradoxa*
		Ophiostomatales	Ophiostomatacées	*Ophiostoma ulmi*
		Phyllachorales	Phyllachoracées	*Phyllachora graminis*
		Xylariales	Diatrypacées Xylariacées	*Eutypa lata* *Xylaria hypoxylon*
BASIDIOMYCOTA	Agaricomyètes	Agaricales	Cyphellacées Physalacriacées Schizophyllacées Typhulacées	*Chondrostereum purpureum* *Armillaria mellea* *Schizophyllum commune* *Typhula incarnata*
		Athéliales	Athéliacées	*Athelia rolfsii*
		Cantharellales	Cératobasidiacées	*Rhizoctonia solani)*
	Pucciniomycètes	Pucciniales	Mélampsoracées Phakopsoracées Phragmidiacées Pucciniacées Uropyxidacées	*Melampsora lini* *Phakopsora euvitis* *Gymnoconia nitens* *Puccinia graminis* *Tranzschelia pruni-spinosae*
	Exobasidiomycètes	Entylomatales	Entylomatacées	*Eballistra oryzae*
		Exobasidiales	Exobasidiacées	*Exobasidium vexans*
		Tillétiales	Tillétiacées	*Tilletia caries*

- Historically, fungi were classified in the Plants group and were considered close to plants; their first classification as Reign dates from 1969 (Whittaker, 1969). On the contrary, the analysis of the Tree of Life carried out by Baldauf (2004) on molecular and structural databases shows that fungi belong to the Opisthokontes group, within the Eukaryotic Empire.

- Currently, fungi are classified among the Opisthokonts constituting a special group of eukaryotes. Different taxonomic ranges are used for the classification of living things. These hierarchical ranks are: reign, branch or division, class, order, family, genus and species. The nomenclature used to determine the scientific name of species is binomial. It refers to the genus then the species. This nomenclature follows the rules set out by the naturalist Carl Von Linné in 1753. We thus distinguish:

  -mycota for division,

  - mycotina for subdivision
  - fungi for class
  - ales for order
  - aceae for the family.

The kingdom of "mushrooms" or Fungi, called Eumycota, currently includes 8 divisions (Phylum) **(Table 1):**

- Phylum of Microsporidia
- Phylum Neocallimastigomycota
- Phylum Chytridiomycota
- Blastocladiomycota Phylum
- Phylum Zygomycota
- Phylum Glomeromycota
- Phylum Ascomycota
- Phylum Basidiomycota

Anamorphic fungi (Deuteromycetes) are no longer considered a formal taxonomic category since they do not form a monophyletic unit. These are fungi which have lost the ability to reproduce sexually or which are anamorphs of other phyla, mainly Ascomycota and rarely Basidiomycota.

5. Fruiting body

There are 5 types of ascocarps depending on the mode of organization of the stroma : perithecia, cleistothecia, apothecia, pycnidia and acervulus (**Fig 14)**.

Protective structures resulting from sexual reproduction:

- A Cleistothece : The cleistothece is a sphere-shaped organ which contains the asci and ascospores.

- Apothecia : is a sexual formation specific to certain ascomycete fungi. It is characterized by its cup shape, within which the hymenium is located.

- The Perithecium : is the fruiting body, shaped like a bottle, containing the asci. It is an organ formed after the meeting of two mycelial filaments and in which the asci develop.

The protective structures resulting from asexual reproduction are the pycnidia and the acervuli:

- Pycnidia : round, sac-shaped structure, with an apical opening (ostiole), inside which conidia are formed.

-The acervuli are aggregates of tangled mycelial filaments, firmly attached to a plant delimiting a cavity with an opening. Inside, we find a layer of conidiophores producing conidia.

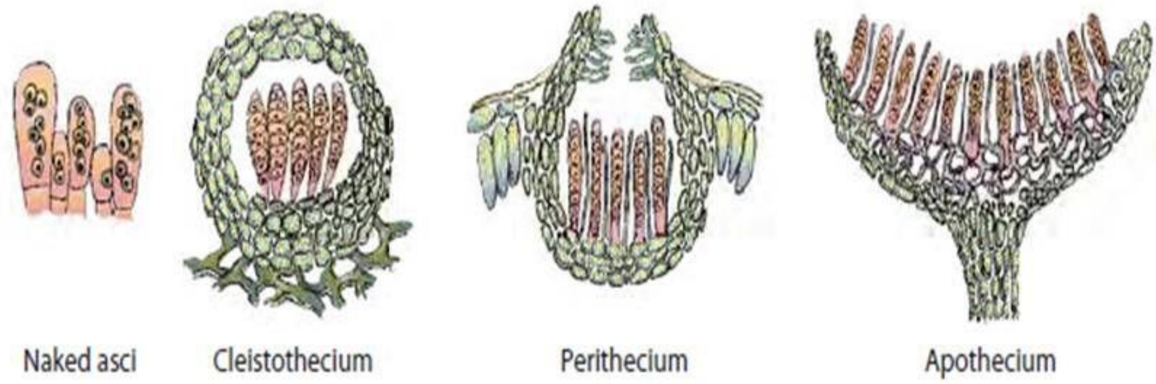

Figure 14 : The different fruiting bodies in mushrooms **[14]**

6. The main groups of phytopathogenic fungi

Phytopathogenic fungi are species of parasitic fungi that cause fungal diseases in plants. These fungi belong to the different groups of the kingdom of eumycocetes or "true fungi": ascomycetes, basidiomycetes, chytridiomycetes, zygomycetes and deuteromycetes (imperfect fungi)

6.1.Diseases caused by Ascomycetes

The fungi Ascomycota (having anamorphs or not) and Deuteromycetes (having teleomorphs or not) cause the greatest number of plant diseases worldwide. The diseases due to these two large fungal groups cannot be separated because the majority of these diseases are caused by species that belong to the Ascomycota (as teleomorphs) as well as to the Deuteromycetes (as anamorphs).

1- Ascomycota or Ascomycetes

Ascomycetes are higher fungi whose spores (ascospores) for sexual reproduction are formed in a kind of sac called asci **(Fig 15)**. Each ascus produces, at maturity, eight spores or ascospores.

Like many fungi, Ascomycetes have a sexual (perfect) stage and an asexual (imperfect) stage. Frequently, for Ascomycetes, the same organism is designated by 2 different names, each corresponding to one of its stages.

- After germination, the spores give rise to hyphae (mycelia) which will themselves produce multiple-nucleated structures, respectively the ascogonia and the antheridia.

- As soon as the environmental conditions are favorable, the ascogonium then emits an extension which merges with an antheridium; the nuclei then penetrate the ascogonium and pair without fusing, this is what is called plasmogamy.

- The ascogonium will then produce septate hyphae into which the paired nuclei migrate (two per cell = n + n chromosomes). All of these septate hyphae form an ascocarp or mushroom, strictly speaking. This is the dikaryotic stage (n + n chromosomes). In each dikaryotic terminal cell of the septate hyphae, the 2 nuclei will finally fuse (= karyogamy) and thus give a mononuclear cell with 2n chromosomes. This will transform into an ascus. This is the diploid stage (2n chromosomes).

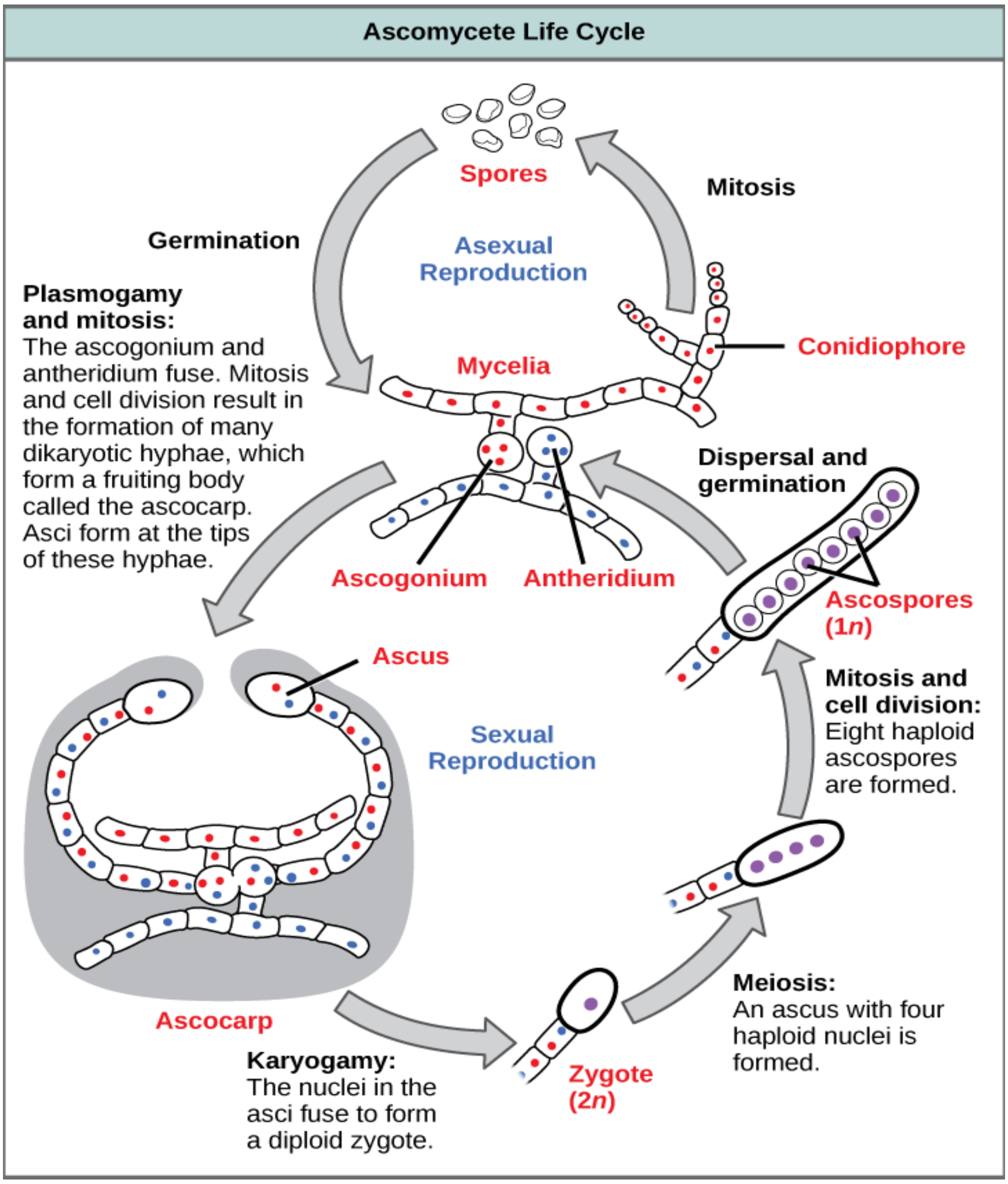

Figure 15: Mode of formation of ascospores **[15]**

- In each dikaryotic terminal cell of the septate hyphae, the 2 nuclei will finally fuse (= karyogamy) and thus give a mononuclear cell with 2n chromosomes.

- This will transform into an ascus. This is the diploid stage (2n chromosomes). In each ascus, the nucleus will undergo two divisions, a "chromatic reduction or meiosis" and a mitosis, to give eight spores, or ascospores, with n chromosomes. After meiosis, the haploid stage (n chromosomes) begins here, which will last until the formation of the dikaryon hyphae **(Fig 16)**.

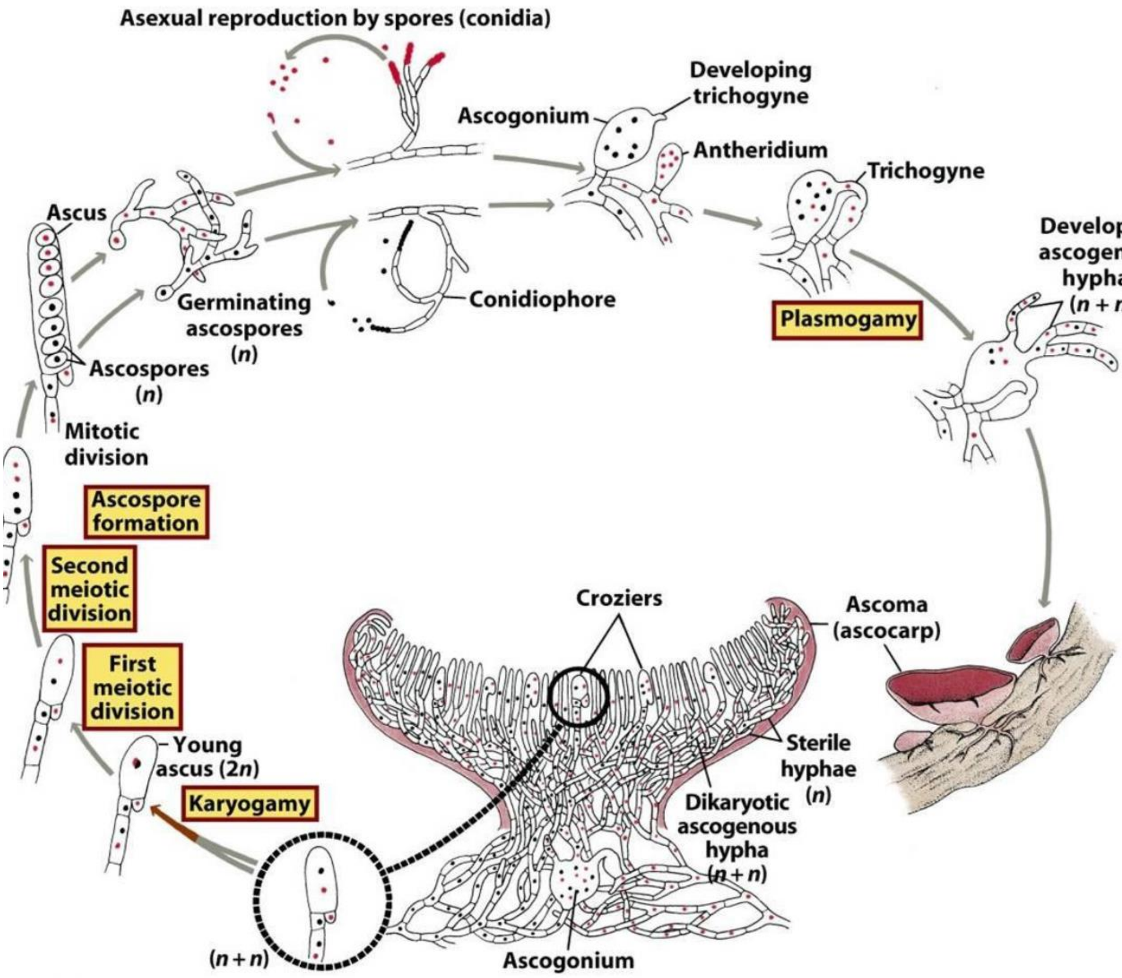

Figure 16: Biological cycle of ascomycetes **[16]**

I. SACCHAROMYCETES AND THEIR ANAMORPHS

Saccharomycetes contain some phytopathogens such as Galactomyces sp. (Anamorph : Geotrichum candidum), the causal agent of citrus acid rot and Spermophthora gossypii which causes stigmatomycosis of cotton **(Fig 17)**.

Figure 17 : Galactomyces sp. (Anamorph : Geotrichum candidum) orange and tomato [**17**]

II. TAPHRINOMYCETES AND THEIR ANAMORPHS

Taphrinomycetes contain many pathogenic species that are responsible for the deformation of plant organs such as leaf curl, leaf roll, fruit pouches and witches' broom. Most of these diseases are caused by species of Taphrina (anamorph: Lalaria) among which peach leaf curl is the best known **(Fig 18).**


Figure18 : Some deformations of plant organs such as leaf curl, leaf roll **[18]**

- **Peach leaf curl**

This disease **(Fig 19)** is characterized by infected plants producing leaves that are completely or partially curled, distorted, and thickened. These infected leaves first appear reddish or purplish, then become reddish yellow or powdery gray. Later, they turn yellow and then dark brown and drop. Flowers and young fruits also drop after being attacked. The current year's twigs may also be affected; they swell, stunt, and die during the summer.

Figure 19 : Peach leaf curl diseases **[19]**

- **Powdery mildew of barley**

As on other host plants, powdery mildew of barley appears as a cottony, grey-white fungal growth **(Fig 20)** on small isolated areas on the leaf. These spots then spread until the leaves become completely covered.

Figure 20 : Powdery mildew of barley diseases **[20]**

III. BASIDIOMYCETES AND THEIR ANAMORPHS

Cultivated plants are generally affected by three genera of Basidiomycetes : Armillaria, Athelia (anamorph : Sclerotium) and Thanatephorus (anamorph : Rhizoctonia). These fungi usually cause rotting of the roots and trunks of trees.

6.2.Diseases caused by Basidiomycetes

These are fungi, mostly macroscopic, whose spores for sexual reproduction are produced in club-shaped sacs called BASIDIA.

Each basidium produces, at maturity, four spores or basidiospores **(Fig 21)**. There are about 30,000 known species. Sexual reproduction occurs in 2 stages: The cytoplasms of the cells fuse, this is called plasmogamy. This gives rise to a dikaryotic mycelium (=secondary mycelium), i.e. made up of cells with two haploid nuclei. This dikaryotic phase specific to fungi constitutes the sporophytic generation. The dikaryotic mycelium is organized into pseudo tissues and forms the carpophore. At the level of the sporocysts, the fusion of two haploid nuclei, or karyogamy, takes place, followed by meiosis which will generate four exogenous meiotic spores **(Fig 22)**.

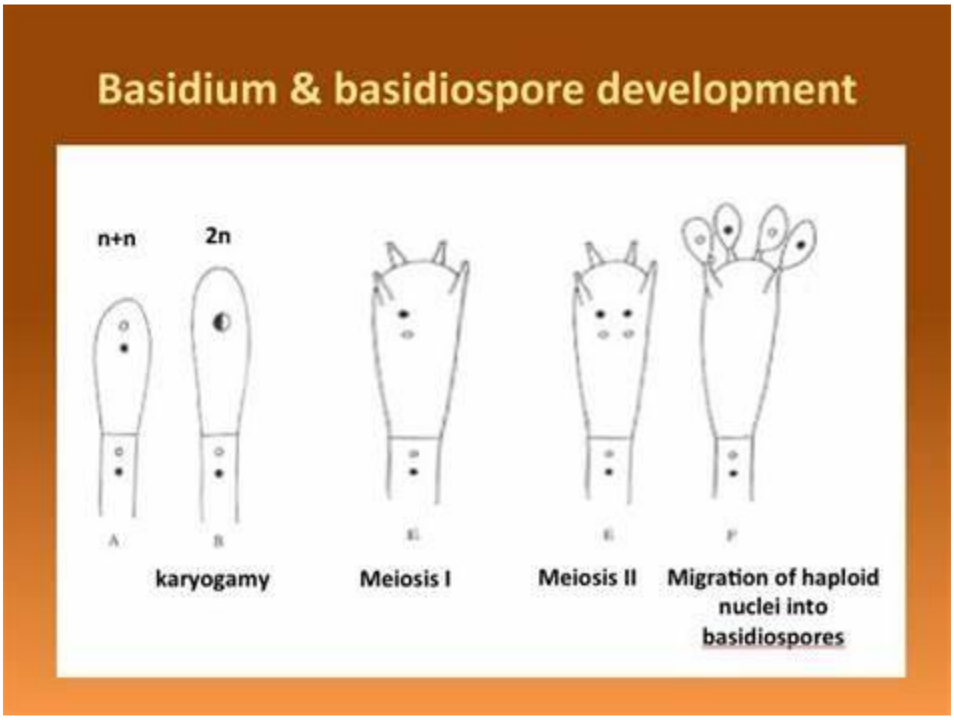

Figure 21 : Stages of development of basidiospores within a basidium **[21]**

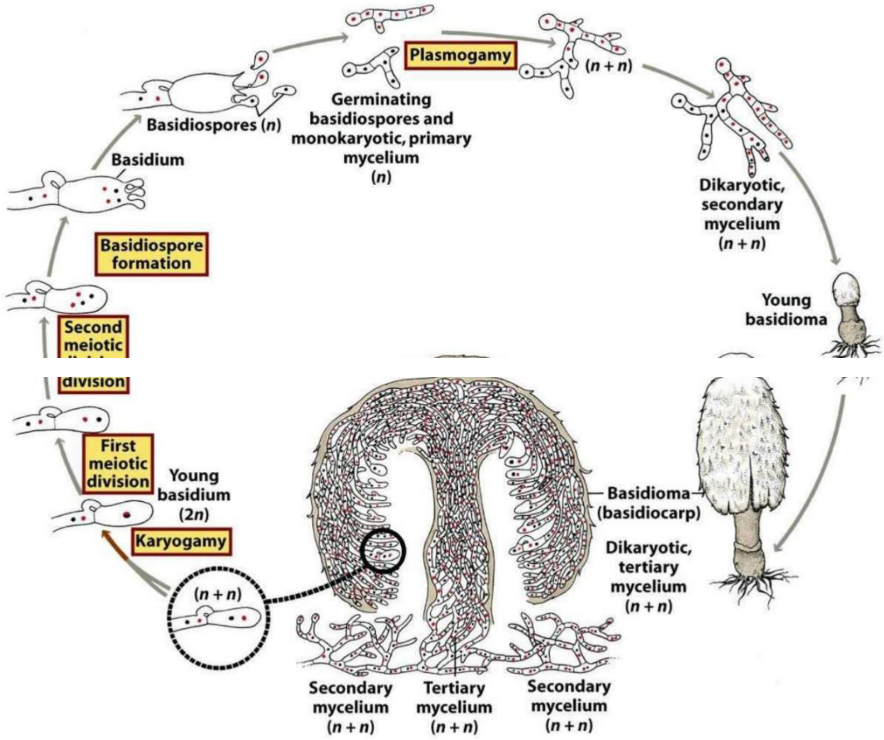

Figure 22: Biological cycle of basidiomycetes **[22]**

- **Armillaria rot**

This disease usually affects forest trees **(Fig 23)**, but can also attack fruit trees, grapevines and even plants such as potatoes and strawberries. The most common species is Armillaria mellea (Basidiomycetes, in the order Agaricales). It causes root rot (root rot) of trees resulting in reduced growth, small and yellow leaves, drying of twigs and branches and gradual or sudden death of the tree.

The fungal mycelium can extend into the phloem and cambium of the base of the trunk, but the most characteristic sign of the disease is the formation of reddish-brown to black rhizomorphs that form a branching network around the roots. At the base of dead or dying trees, a few to several macroscopic honey-coloured fungal structures develop from the trunks or on the ground near the infected roots. These are the spore-forming structures of the fungus.

Figure 23: Armillaria rot Diseases **[23]**

- **Sclerotium Diseases**

Sclerotium species **(Fig 24)** attack many annual plants, causing great losses. One of the most common species is Sclerotium rolfsii (Deuteromycetes, Agonomycetes, Agonomycetales), whose teleomorph is Athelia rolfsii. It causes rot of roots, stems, and other organs. Infection usually begins on succulent stems as a dark brown lesion just below the soil line. Later, the leaves turn yellow or wilt and may die from the tip downward. At the same time, the fungus grows upward in the plant and covers the stem lesions with a mass of white cottony mycelium. The fungus also moves downward and destroys the root system. On all infected tissues and in the soil, the fungus produces numerous small, uniformly sized, round sclerotia that are initially white and mature to dark brown to black.

This pathogen persists primarily as sclerotia that are spread by running water, contaminated tools, and other vectors. It attacks the host plant tissues directly after disintegrating them by enzymes such as pectinases, cellulases, and others. It moves from plant to plant, producing mycelium and sclerotia.

Figure 24 : Sclerotium Diseases **[24]**

- **Rhizoctonia**

This disease is caused by Rhizoctonia species that affect most annual plants and many perennial plants. The most common symptoms caused by these species are damping off, root rot, rot and stem canker. The most important species is Rhizoctonia solani (Deuteromycetes, Agonomycetes, Agonomycetales) whose teleomorph is Thanatephorus cucumeris. It attacks several plant species and causes different symptoms. For example, it can cause brown rotten areas on some plants, which can be superficial or extend into the middle of the root or stem. The rotting tissues usually decompose and dry out, forming a hollow area filled with dry pieces of the plant mixed with the mycelium and sclerotia of the fungus.

Rhizoctonia solani Kühn, the most important species within the genus Rhizoctonia **(Fig 25)**, is a soil-borne plant pathogen with considerable diversity in cultural morphology, host range, and aggressiveness. Despite its history as a destructive pathogen of economically important crops world-wide, our understanding of its taxonomic relationship with other Rhizoctonia-like fungi, incompatibility systems, and population biology is rather limited. Among the host of diseases it has been associated with, seedling diseases inflicted on soybean are of significant importance, especially in the soybean growing regions of North America.

Due to the dearth of resistant soybean genotypes, as well as the paucity of information on the mechanisms of host-pathogen interactions and other molecular aspects of pathogenicity, effective management options have mostly relied upon a combination of cultural and chemical control option

Figure 25 : Diseases caused by Rhizoctonia **[25]**

- **Black (or stem) rust of wheat**

Among several cereal rusts, black (or stem) rust is the most studied. It is caused by Puccinia graminis, which attacks barberry (Berberis vulgaris) as a secondary host and wheat (and other cereals) as a primary host. On barberry, the fungus produces a few spermogonia, which are dark-coloured structures, on the upper surface of the leaves, and on the lower surface, it forms groups of cup-shaped, orange-yellow aecia. On wheat **(Fig 26)**, elliptical pustules (uredinia) develop parallel to the axis of the length of the stem, leaf and sheath

Figure 26 : Diseasess of wheat ; Black (or stem) rust of wheat **[26]**

6.3. Diseases caused by Oomycetes

Oomycetes cause various diseases such as white "rust", mildew, root rot, blight, etc. Some of them are very destructive (mildew) while others are less serious (white "rust").

Oomycetes come from a lineage called pseudo-fungi or false fungi because they do not have the same ancestor as true fungi, despite their morphology and nutrition by absorption similar to those of fungi. They live alongside unicellular taxa and certain algae. They are facultative or highly specialized parasites of plants, root rot, rusts and mildews.

Nearly 1000 described species are known. They contain cellulose, and produce sexual gametes. The septa are absent except at the base of the reproductive structures. The species that attack plants develop intracellularly or intercellularly. The vegetative apparatus consists of non-septate filaments (or siphons), however septa may be present at the base of reproductive structures or in old compartments.

The cell wall is mainly composed of cellulose compounds, β-1,3- and β-1,6-glucans, and the amino acid hydroxyproline but devoid of chitin. The cytoplasm contains diploid nuclei, mitochondria, the Golgi apparatus and vacuoles.

They are responsible for mildews, serious epidemic diseases (e.g: Plasmopara viticola on grapevine, Peronospora tabacina on tobacco, Bremia lactucae on lettuce).

- The asexual multiplication of Oomycetes occurs through zoospores **(Fig 27)** that develop in the sporangia. Two types of morphologically distinct biflagellate zoospores are produced by most Oomycetes depending on their particular life cycle. The first is called primary zoospore and is pear-shaped with the flagella attached to the anterior end of the spore. The second type is called secondary zoospore and is produced by practically all Oomycetes that form zoospores. It is reniform with the flagella inserted laterally in a groove on the surface of the spore. The function of zoospores in the life cycle of Oomycetes is to swim short distances in water.

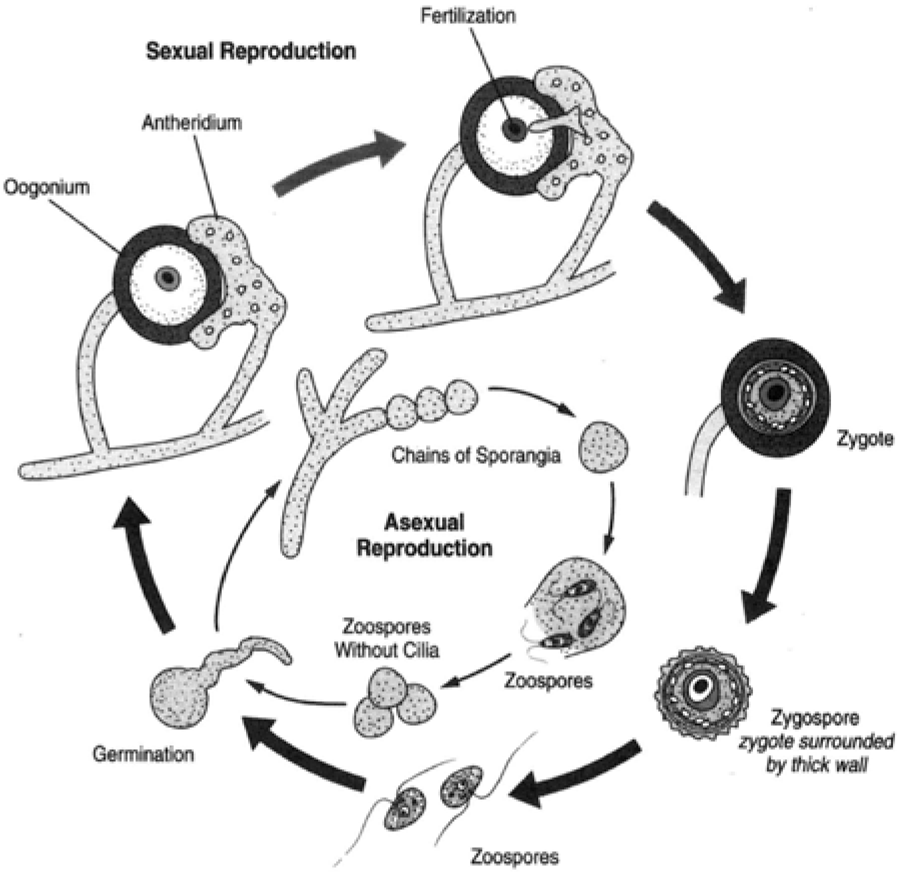

Figure 27: Life cycle of oomycetes **[27]**

- Sexual reproduction occurs directly, without the participation of zoospores, inside sacs produced by the hypha, called gametocysts. The operation is carried out between a male gametocyst, the spermatocyst, and a female gametocyst, the oogonium, via copulatory tubes that penetrate the oogonium. After production of gametocyst nuclei (by meiosis), the copulatory tube (or siphon) allows a fusion of the protoplasms (or plasmogamy) followed by a fusion of the haploid nuclei (or karyogamy) within the oogonium. The gametes remain inside the protoplasm, safety at the most vulnerable stage of the reproductive cycle. The eggs formed are called oospores.

- ✓ **Downy mildew diseases**

It depends on the presence of a water film on plant tissues and high relative humidity in the air during cold or mild periods. Symptoms are burns that appear and spread rapidly in young, green tissues of leaves, stems, and fruits.

Downy mildew fungi produce sporangia on sporangiophores that branch in a distinctive manner for each fungal genus. In most cases, the sporangia germinate either by producing zoospores or, at higher temperatures and lower humidity, by producing germ tubes such as conidia.

- ✓ **Downy Mildew**

Downy mildew **(Fig 28)** is a type of oomycetes or water mold. Once considered a fungal disease, it is now classified in the family Peronosporaceae. There are thousands of different types of water molds, most of which are called downy mildew. Most specialize in a particular species or a group of plants. They are a significant cause of plant pathology.

Downy mildew is harmful. It is an obligatory parasite and has to have living plants while going through its life cycle. These plant diseases can devastate a crop and kill most of the plants within a week. It is considered an economically important group of pathogens for that reason.

- ✓ **Symptoms**

The symptoms of this pathogen differ somewhat on different hosts. However, they all cause yellow spots on the upper leaf surface between the leaf veins. These spots spread everywhere but the veins and eventually turn brown. The plant cannot photosynthesize on these yellow or brown spots. When the leaf is totally brown, it drops. If the plant loses too many leaves, the plant dies.

The bottom of the leaf surface has a fuzz on it that varies from white to purple, depending on the species of mildew. Many of the fruits on the plant rot from the mildew or get sunscald and quit growing because the leaves no longer shade them.

If you cut an infected plant, you will see the vascular system is totally choked with spores, making it impossible for the plant to transport water from the roots to the leaves.

Figure 28 : Downy mildew diseases **[28]**

- **Life Cycle**

The lifecycle is a bit complicated but it is essential to stop downy mildew.

1. The mildew overwinters as mycelium (filaments of tissue) or oospores (thick-walled round structures) in or on the plant. When the temperature is between 50-75, and the relative humidity is 85% or above, the oospores germinate.
2. Germinating oospores produce sporangiophores.
3. Sporangiophores emerge from the plant stoma, or pore, and look like a bunch of grapes.
4. These sporangia are wind and water-borne. Each individual sporangia holds many zoospores.
5. Zoospores blow to a leaf surface during wet and mild weather.
6. The zoospores germinate on the plant.
7. Zoospores swim from infected plants or soil to new plants and infect them.

This cycle can take as little as four days in favorable weather but typically takes 7-10 days. An entire field can be infected before the first symptoms appear.

✓ **Disease transmission**

Downy mildews are air and water-borne pathogens. They cannot overwinter in the northern part of the United States. They do overwinter in the southern United States, usually in fallen leaf litter. Downy mildews spread progressively north once the weather warms until they cover much of the United States by August. When the cold winter comes, they die back in the north.

Spores can also be transmitted by tools or hands that have come into contact with infected plants and are not sterilized before moving to a healthy plant. Enclosed environments such as greenhouses can spread spores to fields.

✓ **Important Strains of Downy Mildews**

These types of downy mildew are economically important. They often attack home gardens as well as commercial growers.

❖ **Cucurbit (Pseudoperonospora cubensis)**

Cucurbit downy mildew infects cucumber, melon, gourds, pumpkin, and squash. In watermelons, the leaves curl more than on other crops as well as displaying the rest of the symptoms.

❖ **Brassicas (Hyaloperonospora parasitic)**

These include cabbage, broccoli, Brussel sprouts, kale, kohlrabi, Chinese cabbage, turnip, radish, cauliflower, and mustard.

❖ **Grapes (Plasmopara viticola)**

This infects the leaf, stem, flowers, and fruit and kills off the vines.

❖ **Basil (Peronospora belbahrii)**

First reported in Uganda in 1930, it really took off in Italy in 2004 and has been increasing in prevalence since then all over the world. This is what powdery mildew looks like the next figure. Note the difference in appearance from downy mildew

Downy mildew symptoms include yellow spots on the upper leaf surface between the leaf veins.

- **Prevention**

Stopping downy mildew is much easier than controlling it. Help prevent downy mildew in your landscape by following these tips.

- Resistant Plants

Scientists have bred some resistant cultivars of plants that are susceptible to this disease. While every type of plant does not have a choice that is resistant, use resistant cultivars wherever possible. Make sure that you do not get any infected seed by buying from a reputable nursery.

- Scout Plants

It is important to scout your plants often. If you see symptoms, remove that plant immediately, put it in a plastic bag, and put it in the trash. Do not compost diseased plants as most home compost piles are not hot enough to kill the downy mildew pathogen.

- Air Circulation

Wet leaves are necessary for this type of mildew to invade plants. Eliminate moisture by pruning plants to improve air circulation. In row crops, make sure to space plants to allow for good air circulation even after they are mature. Make sure the rows are far enough apart, as well.

- **Watering**

One of the worst things you can do is water plants from the top. A whole host of diseases must have wet leaves to infect the plant. Overhead irrigation wets the leaves. If you must water from the top, water in the early morning hours, before 10:00 a.m. so the leaves will dry before nightfall.

- **Phytophthora diseases**

Phytophthora species cause a wide variety of diseases on a wide range of hosts, including both herbaceous and woody plants. The best known species is Phytophthora infestans which causes potato blight, but several other species can also cause destructive diseases on a variety of host plants.

Species such as Phytophthora cactorum, P. cinnamomi, P. citrophthora and P. fragariae cause mainly root and basal stem rots, but also branch blights and fruit rots of several woody and herbaceous plants. Several other species, such as P. capsici and P. parasitica, cause stem and fruit rots of many herbaceous and some woody plants.

- **Potato Late Blight**

In wet weather, water-soaked spots form on the edges of the lower leaves of the potato, which then spread rapidly to form areas of brown burn. On the undersides of the leaves, a white cottony growth of the fungus appears at the edges of the lesions. If wet conditions persist, all tender aerial parts of the plants become burnt and rotted. If dry weather occurs during disease development, existing lesions stop spreading, turn black, curl and wilt. Fungal growth does not appear on the undersides of the leaves.

When affected, tubers show purple to brown spots that extend into the flesh. Later, these rotted areas become hard, dry and sunken. In wet conditions, the rot continues to develop after the tubers are harvested. Despite its appearance, potato late blight **(Fig 29)** is called late blight. It is caused by the fungal species Phytophthora infestans.

The fungus persists over winter as a mycelium in infected potato tubers.

Figure 29 : Potato Late Blight diseases **[29]**

6.4. Diseases caused by Zygomycetes

Zygomycetes are weak parasites of certain plants and plant products on which they cause rot or soft mold. The species that are pathogenic belong to the genera Choanephora, Rhizopus and Mucor.

- **Rhizopus mold of fruits**

Many soft molds of fleshy fruits (strawberry, cucurbits, peach, cherry, etc.) are caused by Rhizopus species **(Fig 30)**. The infected areas initially appear soaked with water, then they become soft and rotten. The hyphae of the fungus grow outside the rotten areas and cover them with gray tufts of sporangiophores and sporangia.

The sporangiospores of Rhizopus spp. in contact with fleshy fruits, germinate and produce enzymes that degrade the cell wall. This results in a loss of cohesion between cells and the development of soft mold. On the rotting tissue, the fungal pathogen develops sporangiophores and sporangia that release sporangiospores that can reinfect other fruits.

To preserve themselves, two mating types produce a zygospore through sexual reproduction. After preservation in the rotting tissue, the zygospores develop sporangiophores and sporangia that release new sporangiospores.

Figure 30 : Rhizopus mold of fruits (strawberry) **[30]**

- Zygomycota are a group of fungi that are most often saprophytic. Some species are parasites of insects and contribute to the regulation of their populations (Entomophthorales).
- More than 600 species have been described to date, which represents less than 1% of the fungi described.
- Sexual reproduction of zygomycetes, or fungi with non-septate mycelium, occurs by the conjugation of male hyphae (+) and female hyphae (-). When two compatible hyphae touch (progametangia), they merge (gametangia) and give rise to a prozygosporangium by plasmogamy, a nucleus (+) and a nucleus (-) and thus form a diploid nucleus (2n).
- This young zygosporangium begins to enlarge to form the mature zygosporangium which contains a single zygospore. This zygospore germinates, forming a sporangium from which the haploid spores germinate in turn **(Fig 31, 32)**.
- In the asexual reproduction cycle, the spores, under favorable conditions, germinate and give rise to a germ tube, which develops to form an aerial mycelium. The mycelium emits aerial stolons that develop rhizoids at certain points, with one or more sporangiophores being formed. Then, the tip of each sporangiophore begins to swell and give rise to a sporangium. After its maturity, it breaks, releasing its spores into the air **(Fig 33)**

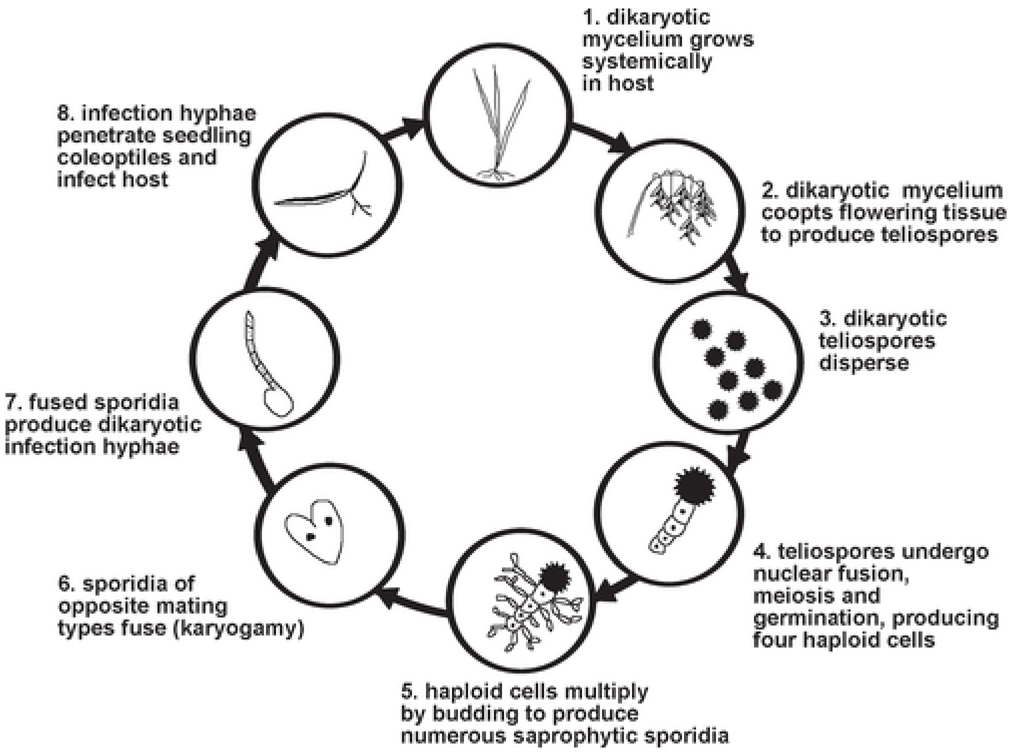

Figure 31 : Mode of formation of zygospores **[31]**

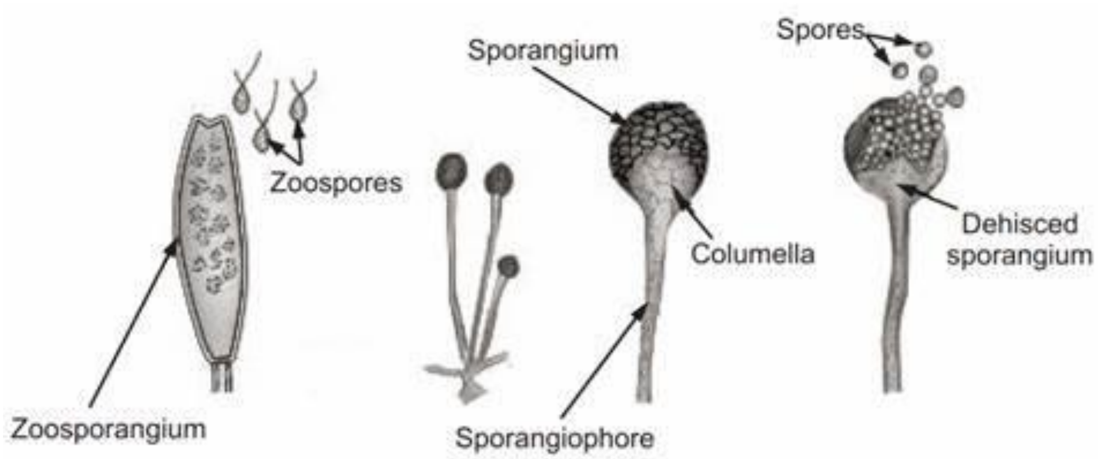

Figure 32 : zygosporangium contains sporocyst **[31]**

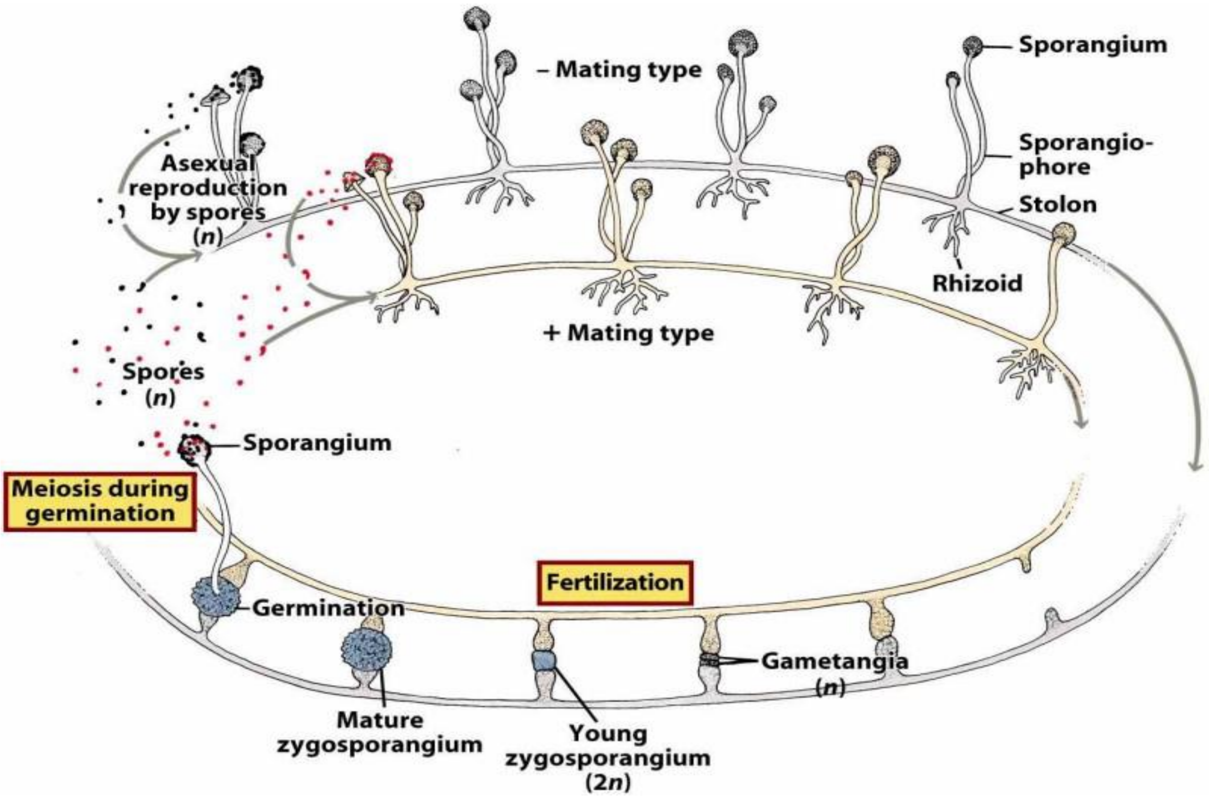

Figure 33: Biological cycle of zygomycetes **[31]**

CH II : BACTERIAL DISEASES

CH II: BACTERIAL DISEASES

1. Introduction

In bacteria, we distinguish obligatory structures, present in all bacteria and structures whose presence is optional and characterize certain bacterial groups **(Fig 34)**.

Concerning the obligatory structures, we find the cytoplasm, generally made up of a hyaloplasm where ribosomes are essentially bathed and sometimes additional elements such as reserve substances **(Table 2)**.

In the cytoplasm, we find the diffuse nuclear apparatus not surrounded by a membrane. The cytoplasmic membrane that surrounds the cytoplasm has two phospholipid sheets containing proteins.

Above the cytoplasmic membrane, we find the wall (except in mycoplasmas) which forms a rigid envelope.

The facultative structures, on the other hand, can be surface polymers such as the capsule, appendages such as flagella and pili or genetic structures such as plasmids (extrachromosomal DNA molecules). Endospores characterize some bacterial genera (Bacillus and Clostridium); they are only elaborated when the living conditions become unfavorable**.**

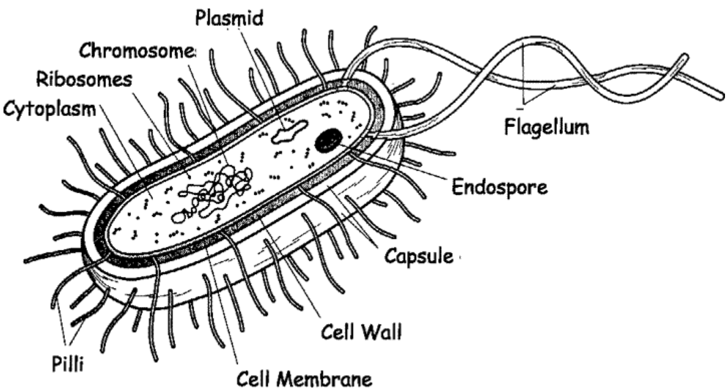

Figure 34: Schematic representation showing the different bacterial structures **[32]**

Table 02 : Constant (mandatory) and non-constant (optional) elements of bacteria

Canstant element	Non canstant element
Wall	Capsule
Plasmic membrane	Plasmid
Cytoplasme	gas vacuole
Ribosoms	Mesosom
Polysoms	pilli
Chromosoms	flagellum
periplasm	endospore (sporulating bacteria)

Cellular morphology : bacteria come in various shapes and sizes, genetically determined and characteristic of the species.

Shape : bacteria are single-celled organisms of various shapes : **(Fig 35)**.

- Spherical or cocci, isolated, in a chain or in a cluster (variable number of cells) : *Staphylococci, Streptococci*, etc.
- Rod or bacillus, isolated, in a chain or in a cluster, of variable length and diameter : *E.coli, Salmonella, Bacillus*.
- Spiral : *spirillae, spirochetes*, such as T*reponema*.
- Filamentous: having a biological organization of fungi (mycelium): Actinomycetes.

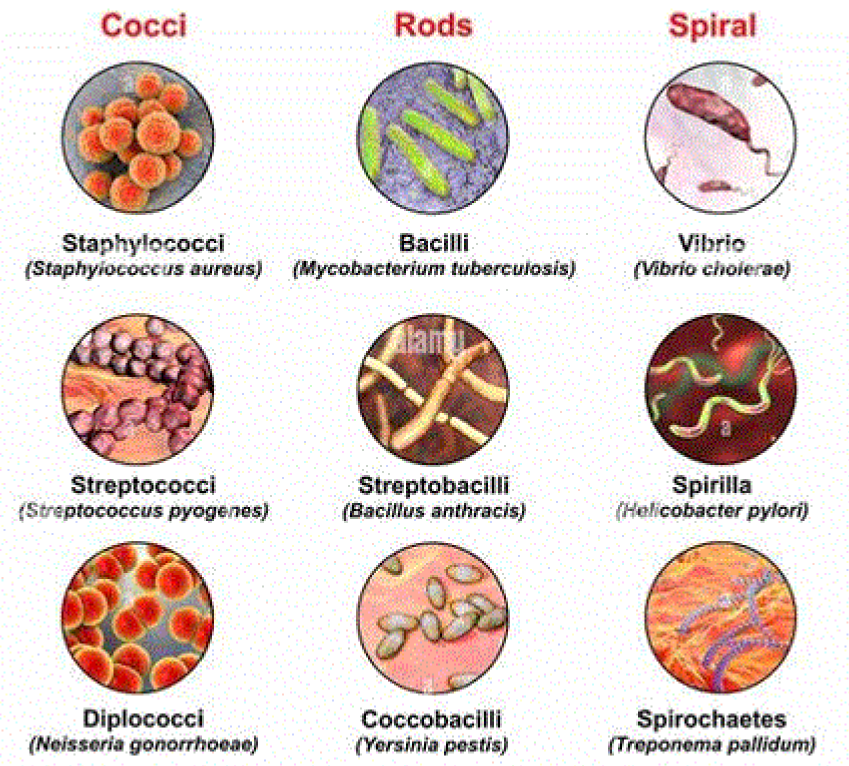

Figure 35 : Examples of shapes commonly found in nature **[33]**

2. Bacterial cell observation techniques:

The study of bacteria requires techniques and a process to follow:

2.1. Bacterial culture : bacterial growth can be obtained in the laboratory in culture media, composed of an aqueous solution of nutrients, bringing together all the substances required for growth (carbon, energy, nitrogen, trace elements and others).

2.2. Observation **:**

There are 2 types :

Macroscopic observation is carried out with the naked eye and consists of the description of the colonies (shape, perimeter, color, surface, etc.), as well as counting.

Microscopic observation allows the characterization of the morphology and certain cellular structures. ➢ **Direct observation**: in the fresh state between slide and coverslide, without any preparation of the sample, allows the observation of the shape, mobility and type of cell grouping ➢ **Observation by staining**: the sample undergoes a preparation treatment before its observation, includes a fixation and a staining which highlights a given cellular structure.

- Simple staining : obtained by using a single dye (e.g. methylene blue), allows the determination of the shape, size and type of cellular arrangement
- Differential staining : allows the separation of bacteria into distinct groups, based on specific staining properties.

There are specific stains for the microscopic observation of particular cellular structures : capsule (**BORREL staining**), flagellum (**LEIFSON or RHODES staining**), reserve granules (**NEISSER staining**), nucleus (**MAY-GRUNWALD-GIEMSA staining**), spores (**MOELLER staining**) and the wall (**GRAM staining**).

These observations concern photonic (optical) microscopy, based on the absorption of light radiation) but the resolving power remains limited, to reveal elements with a size of 5 to 10 nm, electron microscopy is used (the property of the different structures to retain or let an electron beam pass through)

3. Molecular structure and biology of bacteria

A bacterium is a small single-celled being (prokaryote), with variable morphology that has its own characteristics.

1. The size of a bacterium varies between 1 and 10 µm

2. The weight of a bacterium is approximately 10-12 g. It contains 70% water. In relation to dry weight

3. A bacterium is made up of proteins (55%), lipids (10%), lipopolysaccharides (3%), peptidoglycan (3%), ribosomes (40%), RNA (20%) and DNA (3%).

3.1. Molecular structure of bacteria

Prokaryotic cells do not have a nucleus but have nuclear material in the form of a single, circular chromosome, about 1 mm long.

3.1.1. Plasmids

Plasmids are small double-stranded circular DNA molecules, which necessarily have an origin of replication (ORI-R). They carry a reduced number of genes, which are not essential for the survival of the cell, but which give it greater adaptive capacities.

Conjugative plasmids are transferable from one bacterium to another by conjugation: they carry the genes necessary for the synthesis of sexual pili and the conjugation genes, as well as an origin of transfer (ORI-T)

3.1.2. Transposons

Transposons are DNA elements capable of changing location in the genome without appearing in the free state unlike plasmids.

The simplest transposons are DNA fragments of 750 to 1600 bp, containing the transposase gene (enzyme allowing the insertion of the transposon into the target DNA), framed by inverted repeat sequences.

Composite transposons contain genes other than the transposase gene, antibiotic resistance genes for example.

Transposons cannot leave their host cell and can only be transmitted by division (mitosis, meiosis) or fusion (fertilization) of the latter.

3.1.3. Prophages

These are DNA sequences from bacterial viruses called "bacteriophages". During the lysogenic cycle, the viral genetic material is inserted into the cell genome.The prophage is therefore transmitted vertically during bacterial division. A lysogenic bacterium can acquire an additional characteristic.

4. Classification of bacteria

In this classification, the phenotypic characters used are few in number compared to the number of genes usually present in bacteria. In addition, these characters are hierarchical in relation to each other.

Bacteria can be classified according to their characters:

- ❖ Biochemical (classification into biotypes or biovars)
- ❖ Antigenic (classification into serotypes or serovars)

- Pathogenic (classification into pathotypes or pathovars)
- Enzymatic (classification into zymotypes or zymovars)
- Sensitivity to antibiotics (classification into antibiotics)
- Sensitivity to bacteriophages (classification into lysotypes or lysovars)
- Molecular: identification of DNA by ribotyping, DNA-DNA hybridization, DNA-RNA
- hybridization, ribosomal RNA sequencing, etc.

Bacteria can also be classified according to: the most used

- The respiratory mode
- The G+C% of the genom
- Nutritional need
- Growth temperature
- Gram staining
- Morphology
- The capacity for photosynthesis
- The capacity to sporulate
- Mobility
- The use of different sources of carbon or nitrogen

Prokaryotic organisms (Prokaryotae) include single-celled organisms that do not have an individualized nucleus, i.e. Bacteria and Archaebacteria. Eukaryotes (Eucarya) include all single-celled or multicellular organisms with an individualized nucleus

5. Symptomatology of bacterial diseases

Bacteria are responsible for the appearance of symptoms including leaf spots, necrosis and burns, tumors and galls, vascular wilting (tracheobacteriosis), cankers and gummy exudations, soft rots, scabs on underground storage organs. The same bacteria can cause different symptoms on different organs

1. **Necrosis and burns**: these are localized attacks that result in the slow death of cells; the leaf has small patches of dead and dry cells

2. **Oily spots or soft rot**: the attack of bacteria is materialized by a rapid proliferation which destroys the underlying tissues, the proliferation of bacteria is achieved in a viscous mass

3. **Galls or tumors**: this is an anarchic proliferation of the plant cells

4. **Tracheobacteriosis**: this is a proliferation inside the conductive tissues of the host plant; the leaves wilt on the side of the affected tissues

6. The main bacterial diseases of plants

6.1. Diseases caused by Corynebacterium sp.

Bacterial canker caused by Corynebacterium sp. Synonym *: Clavibacter michiganensis* sub *sp. Michiganensis* **(Fig 36).**

The main host plant of economic importance is tomato, but the pathogen has been reported, on other Lycopersicon spp. as well as wild plants such as Solanum douglasii, S. nigrum and *S. triflorum.* Reports on Phaseolus, peas and maize are doubtful.

Figure 36 : Bacterial canker caused by *Corynebacterium sp.* **[34]**

Infected tomato seeds produce infected seedlings. The spread of the disease in the field or greenhouse is facilitated by water (irrigation) and cultural practices. The bacterium enters the plant tissues through stomata or other natural openings, as well as through wounds or roots. After infection, a long latency period occurs before the first symptoms appear

The bacterium is localized in the xylem vessels. The infected vessels contain viscous granular deposits, tyloses and bacterial masses. The pathogen also produces a biologically active toxic glycopeptide. The bacterium can persist for a long time in plant debris, soil or on equipment and in greenhouses. It does not persist for long in the soil per se. However, it remains viable for at least eight months in seeds. Greenhouses, the first symptom is a reversible wilting of the leaves during periods of heat.

The leaves may then show necrotic interveinal areas, white then brown. The wilting quickly becomes irreversible and the entire plant dries up. In the open field, the first symptom is the drying of the edges of the leaflets, mainly in the lower leaves. The plant dries up slowly, generally without showing any wilting. The fruits may not develop and fall. On stems, petioles and peduncles, a creamy white, yellow or reddish brown discoloration of the vessels.

6.2.Diseases caused by Erwinia sp.

- **Rots**

❖ In temperate regions, soft rot is mainly caused by the bacteria Erwinia carotovora subsp. carotovora, while in warmer regions, Erwinia chrysanthemi is the main agent responsible for this disease.

❖ Erwinia carotovora are psychrotrophic bacteria that grow at temperatures between 5 and 36 °C with an optimum between 27 and 30 °C.

❖ E. carotovora are Gram-negative, motile rods (0.5-1 µm in diameter by 1-3 µm in length) (peritrichous flagella), facultative anaerobic and with strong pectolytic activity.

❖ After infection of the plant via the roots, stolons or lenticels of tubers, the bacteria can colonize the entire vascular system of the plant. This then results, in the event of low relative humidity of the soil, in wilting of the foliage by obstruction of the circulation of raw sap in the xylem

❖ In the event of an increase in relative humidity, bacteria can penetrate invasively into the parenchymal tissues and produce abundant pectinolytic enzymes, mainly pectate lyases and polygalacturonases. These enzymes will then depolymerize the pectin of the cell walls of the potato tissues and induce a dark brown rot on the lower parts of the stem, commonly called blackleg, as well as wet rot of the tuber.

- **Bacterial blight**

Bacterial blight, caused by the bacterium Erwinia amylovora **(Fig 37)**.

French name: feu bacterien

Synonyms : *Micrococcus amylovorus*

Erwinia amylovora

Bacillus amylovorus

Figure 37 : Bacterial blight, caused by the bacterium *Erwinia amylovora* **[35]**

- Fire blight, generated by the bacterium Erwinia amylovora, is one of the most serious diseases affecting pome fruit trees. Erwinia amylovora is capable of infecting more than 140 plant species belonging to 39 genera of the Rosaceae family. Pear, apple and quince are the most sensitive host plants
.

- The pathogen overwinters exclusively in the bark of plants infected the previous year. The attacked parts have cankers that are the most important sources of primary inoculum for the contamination of flowers in spring.

- The bacterium enters the plant through flowers, natural openings (stomata, lenticels, hydathodes) or wounds. The bacteria is spread by several means of dispersion such as: wind, rain, insects, birds, aerosols, humans can intervene via the use of contaminated plant material or by different cultural operations (pruning).

- The optimum temperature for the development of the bacteria is 18 ° C. Heavy contamination can occur at temperatures of 21 to 30 ° C. in sunny weather which favors insect activity. All aerial parts of host plants can be contaminated by the pathogen (flowers, leaves, shoots, trunks, collars and rootstocks). The most common and characteristic symptoms are:

1. **On flowers:** Withering and death of inflorescences. Dead flowers dry up and turn black-brown. They generally remain attached to the plant.

2. **On shoots**: Wilting and death of shoots and branches. Young shoots and twigs wilt, turn brown, and in most cases the tip of the shoot curls into a characteristic crooked shape.
3. **On leaves**: Leaf blight. Infected leaves show blackening of the petioles and main vein before invading the entire leaf.
4. **On fruits:** Fruit blight. Infected fruits turn brown, or even black, shrivel, and, like the flowers, remain attached and take on a mummified appearance.
5. **On branches** and trunk: Blight of trunks and frameworks with formation of cankers. Bacterial exudate: Can be observed on canker, fruit, leaf peduncles and flowers **(Fig 38)**.

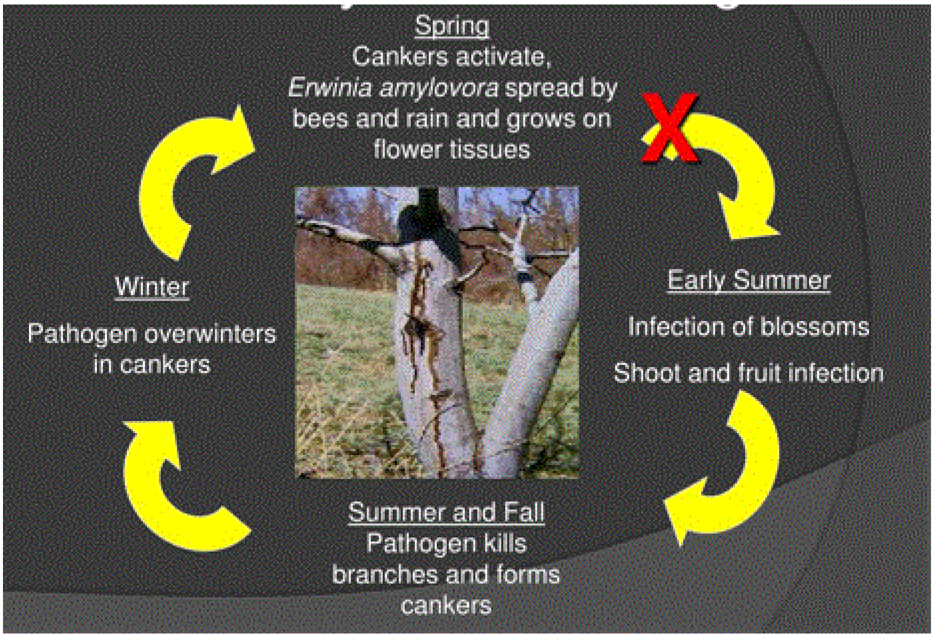

Figure 38 : Maloideae fire blight cycle, caused by the bacterium *Erwinia amylovora* **[36]**

6.3. Diseases caused by Pseudomonas sp.

6.3.1. Bacterial cankers of fruit trees

The Pseudomonas group consists of Gram-negative, motile, non-sporulating rods, they are obligate aerobes widely distributed in soil, water, and air. Some species such as Pseudomonas syringae, are phytopathogenic

Pseudomonas is considered to be an endophytic bacterium. Thus the genus Pseudomonas belongs to the Pseudomonaceae family, it includes about sixty species with the following characteristics:

- Gram-negative bacilli

- Strict aerobes

- Capable of multiplying on usual media

- Mobile by polar ciliature (except Pseudomonas mallei)

- Possessing an oxidase

- Unable to ferment glucose

- Producing pigments

Pathogens enter the tree through wounds, pruning wounds, scars made by leaves when they fall.

1. In spring, they infect buds, flowers and later young leaves. During the hot and dry summer months, bacterial populations are generally low.

2. In autumn, particularly when climatic conditions are humid and cool, bacteria multiply and can invade host trees through leaf scars up to two or three days after the leaves fall.Small cankers (decay on the twig bark) eventually form on the branches at the base of dead buds, often exuding gum in late spring.

3. In early summer, entire branches may die. Leaves at the ends of infected branches often wilt and eventually die during the summer or early fall.

6.3.2. Olive tree tuberculosis

Olive tree tuberculosis is the main bacterial disease of the olive tree. Caused by Pseudomonas savastanoi pv. Savastanoi **(Fig 39)**.

It is a phytopathogenic bacterium of the Pseudomonaceaes family. P. savastanoi; gram-negative bacillus (0.4 – 0.8 x 1.2 – 2.3µm), mobile, provided with one to four polar flagella. The bacterium survives from one season to another in tumors (because it does not form spores) it multiplies abundantly all year round and moves in the vessels of the plants thanks to the flow and thanks to the flagella.

This bacterium has 3 important properties: a pathogenic power, an ice-forming power and an aptitude for epiphytic life. Epiphytic ability is expressed by a capacity to colonize the surface of the aerial organs of plants, to multiply there significantly. Ice-forming power is expressed by a capacity to induce an early rupture of the supercooling of water.

Figure 39 : Olive tree tuberculosis caused by *Pseudomonas savastanoi pv. Savastanoi* **[37]**

6.3.3 Bacterial speck

The causal organism (Pseudomonas syringae pv. tomato) is listed among the pests of many vegetable crops belonging to a wide range of families (Solanaceae, Curcubitaceae Legume).

The species has also been isolated from diseased ornamental plants (iLilac, Rose, Magnolia) and observed in major crops (wheat, oats). Not all strains of P. syringae can infect the same hosts and there is a wide intra-specific variability in pathogenicity. It is currently present almost everywhere in the world.

The development of the disease is favored by cool (13-25 °C) and rainy weather or by sprinkler irrigation. Bacterial speck often appears in arid areas where sprinkler irrigation is used. The organism is able to survive on the roots or leaves of many crops and weeds. Seeds can be infected, however seed transmission is usually minimal.

The disease appears on leaves as small black dots usually less than 2 mm in diameter, surrounded by a yellow halo and as black spots rarely greater than 1 mm in diameter **(Fig 40)**, sometimes surrounded by a dark green halo, on fruits.

Figure 40 : Symptoms of bacterial speck on tomato caused by *Pseudomonas syringae pv.* Tomato **[38]**

6.4. Diseases caused by Xanthomonas sp.

6.4.1. Bacterial scab of Solanaceae

Bacterial scab of Solanaceae caused by bacteria Xanthomonas compestri pv. *Vesicatoria,* **(Fig 41)** are bacilli, gram-negative bacteria, belonging to the class of γ-Proteobacteria, to the genus Xanthomonas, to the family Xanthomonadaceae and to the order Xanthomonadales.

They are strictly aerobic and have a single polar flagellum. On nutrient agar, they have a relatively slow growth and form circular, smooth, mucous, fluid, yellow colonies with entire edges.

The bacterium is present on all continents, especially in warm temperate and tropical countries. In favorable climatic conditions, i.e. high temperature and humidity, the disease can lead to severe defoliation and early abscission of fruits which drastically reduce yields.

- **Symptoms** can appear on all aerial parts of the plant. On tomato leaves, stems and petioles, lesions appear as circular areas (1-5 mm) saturated with water, initially green, then brown and necrotic. Tomato fruits have suberized spots 2 to 10 mm in diameter, circular and with water-saturated margins. On pepper, the disease presents similar symptoms on stems and petioles. However, on pepper leaves, the size and shape of the lesions are variable. In general, the lesions are concave on the upper part of the leaf and slightly convex on the lower part

- On pepper fruits, although rarely visible, the symptoms appear as spots of 2 to 3 mm, green and circular at first, which become brown, rough
- The pathogen of bacterial scab of solanaceous plants is well preserved in seeds, plant debris and can serve as a primary inoculum for the disease. The survival of the bacterium in seeds can be up to 10 years. In plant debris present on and in the soil, the bacterium persists for up to 6 months.
- Bacteria enter leaves through natural openings or through wounds or insect bites. In the leaf, if conditions are favorable, the pathogen multiplies in the intercellular spaces of the mesophyll before colonizing the cells of the lower epidermis and particularly along the veins.

- The first symptoms appear between 5 and 9 days, first on the lower surface of the leaf which is very rich in stomata. In tomato plants, the beginning of the epidemic coincides with the physiological maturation of the first fruits. Stomata play an important role in the infectious process.

- The bacteria is summer-born and its optimum growth temperature is between 20 and 35°C. Warm nights between 23 and 27°C as well as high humidity following storms, dew or irrigation are the conditions appropriate for the development of the disease. Nighttime temperatures below 16°C limit the development of the bacteria.


Figure 41 : Symptoms of bacterial scab on peppers **[39]**

6.5. Diseases caused by Agrobacterium sp.

6.5.1. Crown gall of the vine

Crown gall is a disease affecting many cultivated plants, such as grapevines (**Fig 42**) or stone fruit trees. The pathogen responsible for the disease, called Agrobacterium tumefaciens. A. tumefaciens is a bacillus of about 1 x 3 microns, with a negative Gram stain, belongs to the Rhizobioaceae family, itself included in the class of alpha-proteobacteria within the phylum of proteobateria.

The bacterium is mobile, and strictly aerobic. They. Their optimum growth temperature ranges from 24 to 28 °. Thus, galls are formed locally, initially smooth and yellowish-green in color, but which gradually become cracked and tuberous at the same time as their size increases. These galls can be circular and form a continuous cord around the trunk or an arm, blocking the circulation of sap and ultimately causing it to wither or die.

Figure 42 : Crown gall of the vine **[40]**

The bacterium Agrobacterium tumefaciens infects plants through a wound. Phenolic compounds produced by the plant, on the contrary, attract Agrobacterium to the wound site.

Under the action of these phenolic compounds, Agrobacterium sets up a system for transferring a fragment of its DNA to the wounded cell. This DNA, called T-DNA, is carried by the Ti (tumor-inducing) plasmid and is integrated into the nuclear genome of the plant cell.

In addition, opines induce the transfer of the Ti plasmid from one agrobacterium to another by conjugation. Opines are therefore key chemical mediators of the Agrobacterium-plant interaction,

6.6.Diseases caused by Streptomyces sp.

6.6.1. Common Potato Scab

Common potato scab is a widespread disease worldwide. Tubers affected by common scab are considered to be of poor quality or are not marketable, which causes significant economic damage to potato-producing countries.

This disease (**Fig 43)** is characterized by superficial, raised or deep brownish lesions, developing mainly on tubers, roots and underground stems. Examples include carrots, beets, parsnips and radishes.

The primary causative agent of common potato scab is Streptomyces scabies. In fact, several strains responsible for common scab have been isolated in acidic soils. These strains are called Streptomyces acidiscabies. Pathogenic Streptomyces are filamentous bacteria that live in the soil. Streptomyces invade the tuber tissues and cause the epidermis to rupture, resulting in the appearance of lesions. These lesions enlarge as the tuber grows.

Figure 43 : Common Potato Scab **[41]**

Some environmental conditions favor common scab. Dry soil at the time of tube formation increases the severity of the disease. Dry soil may allow S. scabiei to better colonize tubers by reducing competition with motile bacteria that are favored by wetter soils. S. scabiei can grow at pH between 5.5 and 8.0 but prefers neutral pH. Generally, warm temperatures and neutral soil pH (pH 7) favor the growth of S. scabiei in soil and thus increase the severity of common scab, especially if these conditions are met at the time of tube formation.

CH III : VIRAL DISEASES

CH III : VIRAL DISEASES

1. History

The work of the German researcher Mayer on the germs of a plant pathology: tobacco mosaic.

Ivanowski (1892) and Beijerink (1898) demonstrated that this pathogen reproduced inside the plant (parasitism).

Wendell (1935) ended up crystallizing the infectious particle. - The development of ME from 1945, the multiplication of viruses on cells in culture allows to explore work on virions.

It was in 1953 that André LWOFF stated the three fundamental characteristics making viruses original entities: 1. viruses contain only one type of nucleic acid (DNA or RNA) which constitutes the viral genome. 2. viruses reproduce from their genetic material and by replication.

2. Definition

The word virus comes from the Latin virus, which means "poison".The virus (acaryotic microorganism) is an infectious biological entity with a non-cellular structure incapable of reproducing autonomously, requiring a host cell, whose constituents it uses to multiply, hence the name obligate cellular parasite.

It is a microorganism consisting essentially of a nucleic acid (genetic heritage) surrounded by a protein shell. Their importance lies in the fact that they are responsible for various diseases (from influenza to poliomyelitis and AIDS in humans, tobacco mosaic in plants).

Virology is the field of microbiology that studies viruses. The virus exists in two forms:

Intracellular (inside the prokaryotic or eukaryotic host cell): the viral genetic material replicates and controls the synthesis of specifically viral proteins.

Or **Extracellular**: isolated showing no vital activity or virion.

The Virion: is the viral particle free in the external infectious environment, which has neither its own metabolism, nor capacity for replication, nor autonomous activity.

3. General properties of viruses

- Virion size between 10 and 400 nm in diameter
- Very simple organization

- Obligatory intracellular parasite
- Inability to replicate autonomously
- Nucleic acid content (DNA or RNA)
- Inability to synthesize proteins
- Inability to generate energy
- Insensitive to antibacterial agents (antibiotics)

4. Structure of viral particles

The virus is composed of:

1. A nucleic acid (DNA or RNA, single or double strand) in the form of a filament stabilized by basic nucleoproteins (seat of genetic information).

2. A compact protein protection structure to protect the nucleic acid, called: Capsid.

3. Sometimes surrounded by an envelope. Size: viruses are most often small, between 10 and 400nm.

5. Virus components

5.1. **Nucleic acid** : The nucleic acid filament can be : DNA or RNA (**Fig 44)** . It represents the viral genome (composed of a few genes to 1200 genes). Circular or linear. Single-stranded (single strand) or double-stranded (double strand).

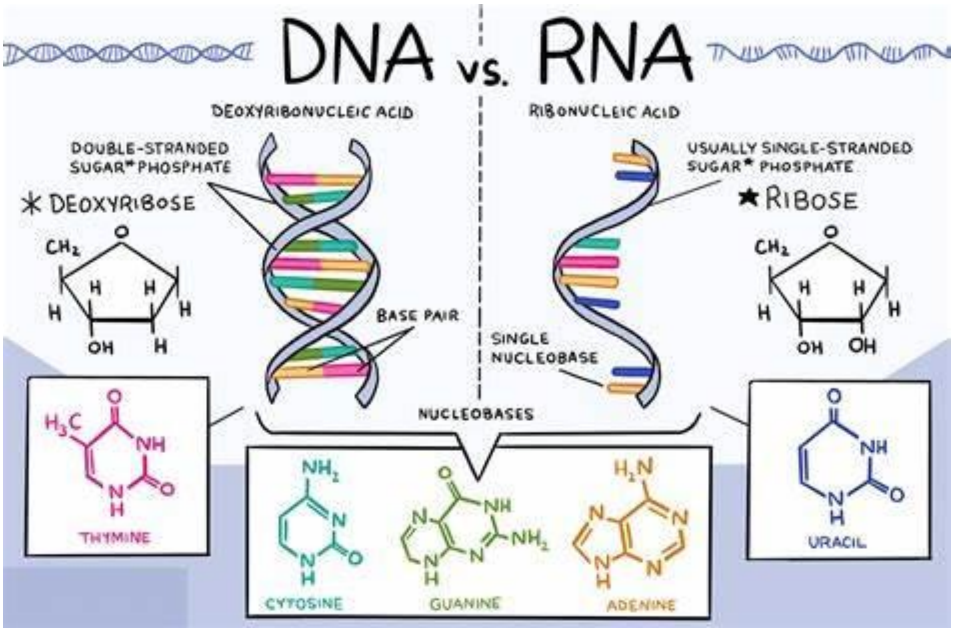

Figure 44 : The structure of nucleic acid **[42]**

5.2. The capsid: (from the Greek capsa: box)

The capsid is a shell that surrounds and protects the viral nucleic acid from various attacks from the external environment or from the cytoplasmic environment of the host cell. Representing most of the mass of the virus and responsible for its crystalline appearance in electron microscopy, and which is very stable. Made up of an assembly of protein structures.

The capsid and nucleic acid (**Fig 45)** assembly is called: nucleocapsid. The structure of the capsid determines the shape of the virus, which makes it possible to distinguish two main groups of viruses:

- Viruses with cubic or icosahedral symmetry.
- Viruses with helical symmetry.
- Viruses with cubic symmetry: These are icosahedrons, regular polyhedra made up of 12 vertices and 20 equilateral triangular faces.
- Viruses with helical symmetry: These are long hollow cylinders (200 to 300nm), made of the assembly of 200 identical proteins. The genetic material is housed inside the tube. Ex: tobacco mosaic virus.

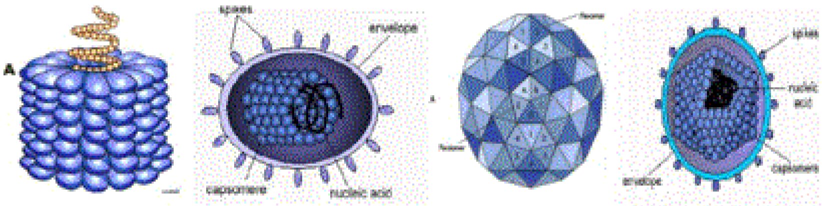

Figure 45 : Viruses symmetry [**43]**

5.3. Envelope (or peplos):

Many viruses are surrounded by an envelope that originates during the crossing of cell membranes.

A complex structure made of an assembly of phospholipids and proteins.It carries the viral determinants (glycoproteins) that bind to cell receptors in a specific manner allowing the introduction of the nucleocapsid into the host cell.

We distinguish: Naked viruses, not having an envelope. Ex: the polio virus (picovirus).

Enveloped viruses having an envelope. Ex: the influenza virus (orthomyxoviridae) and the AIDS virus (retroviridae family). The viral envelope presents, in fact, the fragility of the cell membranes from which it derives.

6. Nomenclature and classification

The Lwoff Horne and Tournier classification classified viruses according to three essential criteria :

The nature of the genetic material: we distinguish:

1. viruses specific to eukaryotes with RNA (single-stranded or double-stranded) or DNA (single-stranded or double-stranded). viruses specific to prokaryotes called bacteriophages.
2. the type of symmetry of the helical or cubic capsid.
3. the naked or enveloped character of the capsid.

A – RNA viruses: RNA viruses can be classified into four large groups: Double-stranded RNA viruses.

Single-stranded RNA viruses -: these are viruses with helical symmetry, the RNA is indirectly translated into proteins. Ex: paramyxovirus (mumps, measles).

Single-stranded RNA viruses + strand: these are naked icosahedral viruses, the RNA is directly translated into proteins, without prior transcription. Ex: picovirus (poliomyelitis, foot-and-mouth disease) (**Fig 46)** .

Retroviruses: single-stranded RNA is transcribed into DNA by an enzyme, reverse transcriptase. Ex: HIV.

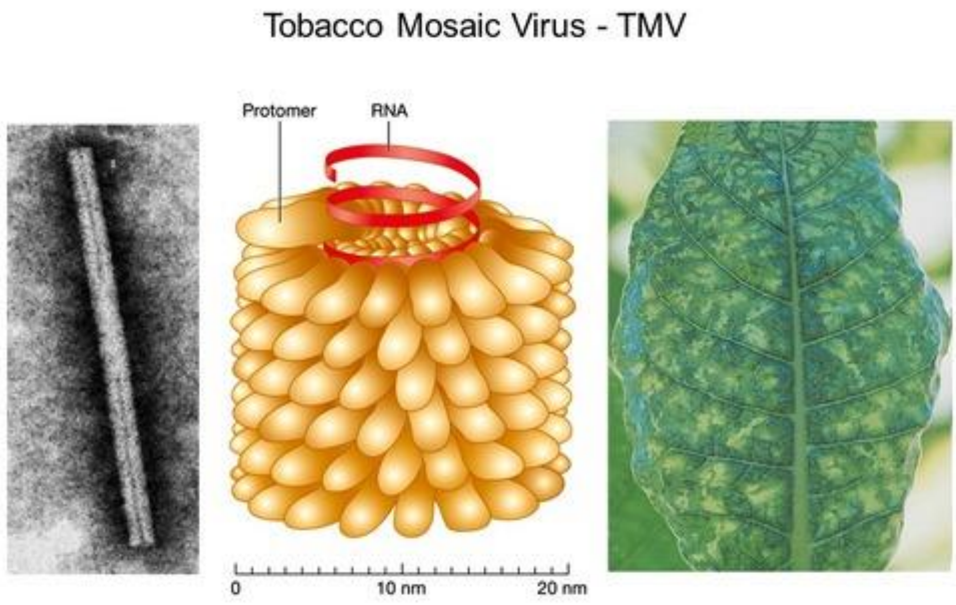

Figure 46: Nucleocapsid of tobacco mosaic virus (5%RNA, 95% Protein) **[44]**

B – DNA viruses: single-stranded or double-stranded

Pararetroviruses (PRV) are viruses with a double-stranded DNA genome, responsible for plant diseases, both temperate and tropical, which can be economically important.

7. Transmission or Virus Multiplication Modalities

Viruses can only multiply within living cells, by replication of their nucleic acid. It is the interaction of the viral genome and the host cell that results in the production of new viral particles. The infection of a cell by a virus, then viral multiplication can be summarized in six stages (**Fig 47)** :

1. **Attachment or adsorption**: this is the attachment of the viral surface to the cell surface. It is done by capsid proteins for naked viruses, by envelope glycoproteins for enveloped viruses on specific receptors located on the cytoplasmic membrane of the host cell.
2. **Penetration**: depending on the virus, there are several mechanisms for penetrating the virus inside the cell. The virus can penetrate by pinocytosis, this is the case for naked viruses. In the case of enveloped viruses, the virus enters either by fusion (of the viral envelope and the cell plasma membrane**) or by endocytosis (accumulation of viral particles in cytoplasmic vesicles).**

3. **Decapsidation:** after penetration or at the same time, all viral structures are degraded except for the genome which is released.
4. **Viral replication or multiplication:** the released genome takes the direction of the cell's syntheses. The cell directed by the viral genome will produce viruses, more precisely copies of the viral genome (capsid proteins and/or envelope glycoproteins). The mechanism of this viral replication varies depending on whether the virus is DNA or RNA, but in all cases, it is through viral messenger RNA that viral genomes transmit their information, give their orders to the cellular machinery: transcription and protein synthesis.

Retroviruses have a more complex replication, these viruses have a specific enzyme, reverse transcriptase which transcribes DNA from RNA. This DNA is integrated into that of the host cell.

5. **Assembly (maturation phase):** there is assembly and maturation of viruses in infected cells. There is encapsidation of the genome. Enveloped viruses acquire their envelope by budding, to the detriment of the plasma membrane of the host cell.
6. **Release**: these new viruses leave the cell by bursting for naked viruses, by budding for enveloped viruses. It is during budding that enveloped viruses acquire their envelope to the detriment of the plasma membrane of the host cell. A cell produces around 100 to 1000 viruses.

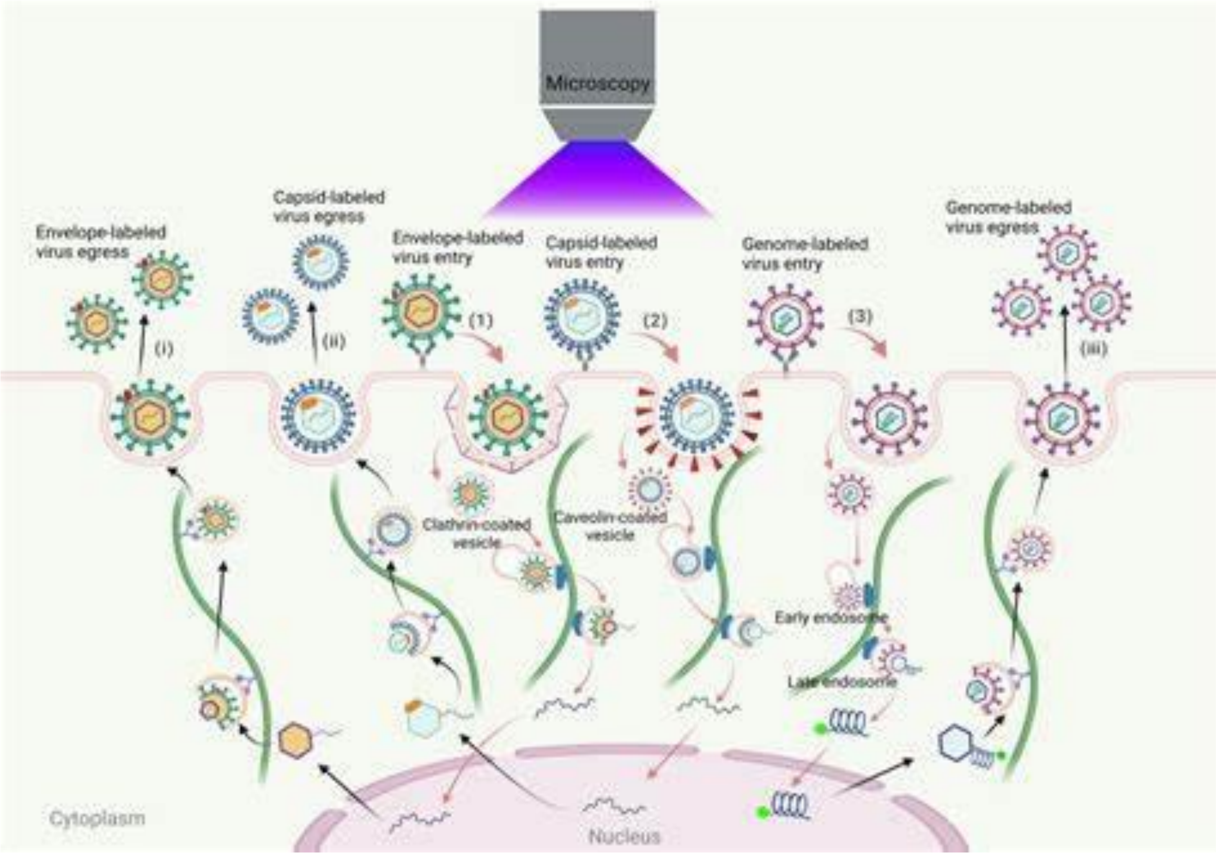

Figure 47 : Viral cycle **[45]**

8. Action of physical and chemical agents on virus activity

8.1.Physical agents

- **Heat**

Overall, viruses, when in an intracellular position, are well adapted to the temperature of 37°C, ideal for the functioning of replication enzymes. In an extracellular position, they are very sensitive to heat (the measles virus, for example, is inactivated in 45 minutes at 37°C).

Therefore, when we want to isolate a virus from a pathological sample, we must send this sample to the laboratory in a cooler at 4°C. Viruses outside a cellular system can be stored at -80°C for years, some can be freeze-dried

- **Desiccation**

Viruses are very sensitive to it (exception: the smallpox virus, present in scabs).

- **UV rays**

They cause alterations in viral nucleic acids, induce mutations and therefore a loss of infectious power (inactivation).

8.2. Chemical agents

- **Oxidants (such as bleach)**

HIV is very sensitive to them. Waterborne enteroviruses are resistant (e.g. polio virus and hepatitis A virus (HAV) which resist the usual chlorination of water).

- **Lipid solvents**

Ether and sodium deoxycholate inactivate viruses with envelopes.

IMPORTANT: Antibiotics that are effective on bacteria are inactive on viruses. Viruses pose a problem that is primarily therapeutic: many molecules that would have an antiviral effect also reach the target cells and therefore have a cytotoxic effect that is incompatible with therapeutic use. Despite these difficulties, chemotherapy is making considerable progress

9. The main viral diseases

Viruses are microorganisms formed of nucleic acid surrounded by a protein envelope of very small dimensions 15-30 um, their shape can be either rods (tobacco mosaic), or filament, with a length of up to 200 to 700um (potato ã virus), or spherical particle (cucumber mosaic), or bacilliform (alfalfa mosaic). They reproduce in the host plant by modifying the metabolism of the cell to their advantage. They are obligatory cellular parasites

9.1.Potyvirus group :

- Phytoviruses are viruses that attack plant organisms belonging to the Potyviridae family (**Fig 48)**. They are infectious macromolecules carrying genetic information.
- These pathogenic molecules are multiplied by contaminated plant cells, generally causing metabolic disturbances leading to the expression of symptoms that are in some cases masked.
- These viruses are in fact very simple structures, formed of a nucleic acid that can be either RNA or DNA, single-stranded or double-stranded, protected by a shell made up of capsid proteins.
- In some phytoviruses, this capsid can also contain molecules of an enzyme capable of ensuring the transcription of viral ribonucleic acid (viral RNA polymerase), while in rare cases, it is surrounded by a lipid envelope.

Potyviruses are particularly linked to their mode of transmission. They are viruses naturally transmitted by aphids, which limits any targeted control efforts.

Acronyms (in summary) of viruses infecting plants:

- Chilli veinal mottle virus (ChiVMV): Pepper vein mottle virus
- Lettuce mosaic virus (LMV): Lettuce mosaic virus
- Pea seed-borne mosaic virus (PSbMV): Bean yellow mosaic virus
- Potato virus Y (PVY): Potato virus Y
- Soybean mosaic virus (SMV): Soybean mosaic virus
- Tobacco etch virus (TEV): Tobacco etch virus
- Turnip mosaic virus (TuMV): Turnip yellow mosaic virus
- Plum Pox Virus (PPV): Sharka

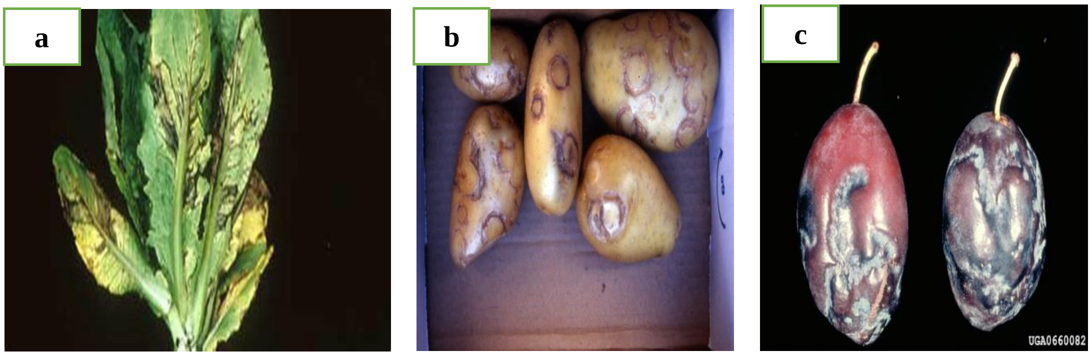

Figure 48 : **a.** Lettuce mosaic virus (LMV), **b**. Potato virus Y (PVY), **c**. Plum Pox Virus (PPV) **[46]**

9.2.Luteovirus group

Luteoviruses have been recognized as a group of plant viruses. They share a number of properties such as the isometric structure of their particles, their restriction to the phloem tissue of the host plant and their obligatory transmission by aphids.Depending on the region of the considered, the linear RNA segment comprises 5300 to 5800 nucleotides **(Fig49)** .

Replication takes place in the cytoplasm. The virions, non-enveloped, consist of round capsids with icosahedral symmetry, 26 to 30 nm in diameter. This group of viruses has a cosmopolitan distribution. These viruses are restricted to the phloem tissues of host plants. Symptoms consist of yellowing or reddening of the vegetative organs of the plant, and sometimes leaf rolling. It includes notably the barley yellow dwarf virus (BYDV) which is the type member.

The name Luteovirus derives from the Latin luteus, meaning "yellow", and refers to the symptomatic yellowing of plants infected by this virus.

The family Luteoviridae includes the following genera:

I. Luteovirus; type species: Barley yellow dwarf virus (BYDV)
II. Polerovirus; type species: Potato leaf roll virus (PLRV)
III. Enamovirus; type species: Pea enation mosaic virus (PEMV)

Figure 49 : **a**. Barley yellow dwarf virus (BYDV), **b**. Potato leaf roll virus (PLRV), **c**. Pea enation mosaic virus (PEMV) **[47]**

9.3.Closterovirus group

Closterovirus is a genus of pathogenic plant viruses belonging to the family. Closteroviridae. The virions are filamentous, flexuous, exceptionally long, 1250–2200 nm long and 10–13 nm in diameter. The genome consists of a single-stranded, positive-sense RNA of 15.5–19.3 kb1. This genus has a presumably worldwide distribution.

The family Closteroviridae comprises the following three genera:

1. Closterovirus: type species: beet severe yellows virus (BYV), transmitted by aphids.
2. Crinivirus: type species: lettuce infectious yellows virus (LIYV), transmitted by whiteflies.
3. Ampelovirus: type species: grapevine leafroll associated virus (GLRaV), transmitted by scale insects

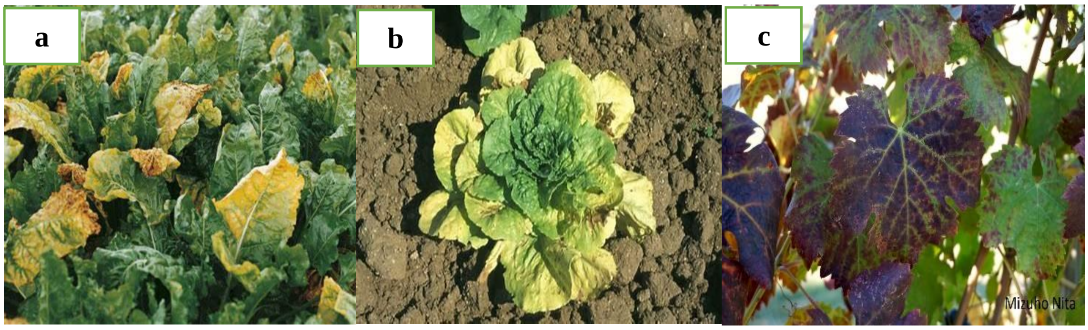

Figure 50 : **a**. beet severe yellows virus (BYV), **b**. lettuce infectious yellows virus (LIYV), **c**. grapevine leafroll associated virus (GLRaV) **[48]**

9.4.Nepovirus group

Nepovirus is the name of a genus of viruses that infect plants in the Secoviridae family and the Comovirinae subfamily (**Fig 52)**, comprising about thirty officially described species. They are linear, single-stranded, positive-sense RNA viruses (ssRNA), classified in group IV of the Baltimore classification.

The Secoviridae family includes the following genera:

- Cheravirus: type species: cherry dry leaf virus
- Sadwavirus: type species: satsuma dwarf virus
- Sequivirus: type species: parsnip yellow spot virus
- Torradovirus: type species: tomato torrado virus.
- Waikavirus: type species: rice tungro spherical virus.
- Comovirus: type species: cowpea mosaic virus
- Fabavirus: type species: broad bean wilt virus.
- Nepovirus: type species: tobacco ring spot virus

Figure 51: **a**. Sequivirus, **b.** cherry dry leaf virus **[49]**

In addition, the following species are related to the Secoviridae family without being assigned to a particular genus:

- Black raspberry necrosis virus, BRNV
- Strawberry latent ringspot virus, SRLV
- Strawberry mottle virus, SMV

9.5.Cucumovirus group

Cucumovirus (**Fig 52)** is a genus of viruses that infect plants (phytoviruses). This genus is part of the Bromoviridae family.These viruses are transmitted by insect vectors of the Aphididae family (aphids).

It includes three officially described species, including

- Cucumber mosaic virus (CMV)
- Peanut mosaic virus (PSV)
- Tomato aspermia virus (TAV)

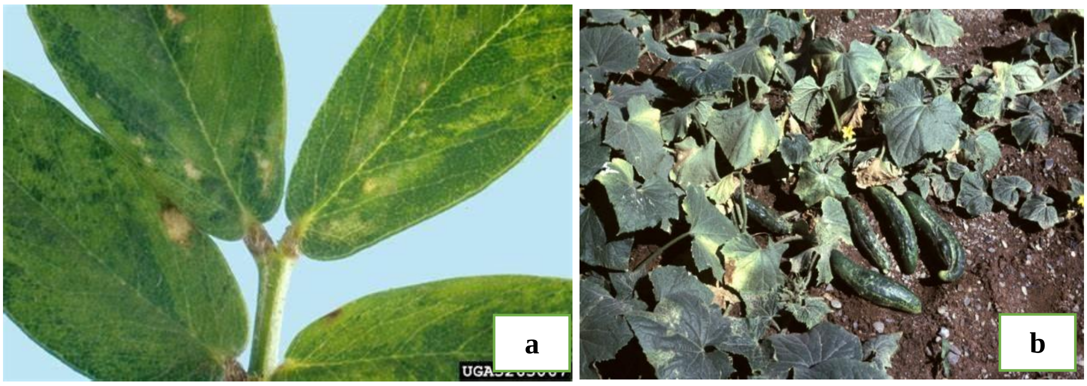

Figure 52: a. Peanut mosaic virus (PSV), **b**. Cucumber mosaic virus (CMV) **[50]**

9.6.Geminivirus group

Geminiviridae are a family of ambisense single-stranded circular DNA plant viruses (**Fig 53)**.

These viruses consist of a single segment of 2500 to 3000 nucleotides. They have an elongated capsid. The capsid is 18 to 20 nm in diameter and about 30 nm long.

Geminiviruses are transmitted by different insect vectors: leafhoppers (Cicadulina mbila), whitefly (Bemisia tabaci).

The Geminiviridae family includes the following genera:

- Mastrevirus: type species: Maize streak virus (MSV)
- Curtovirus: type species: Beet blossom end roll virus (BCTV)

- Begomovirus: type species: Bean golden mosaic virus (BGMV)
- Topocuvirus: type species: Tomato pseudo-leaf roll virus (TPCTV)

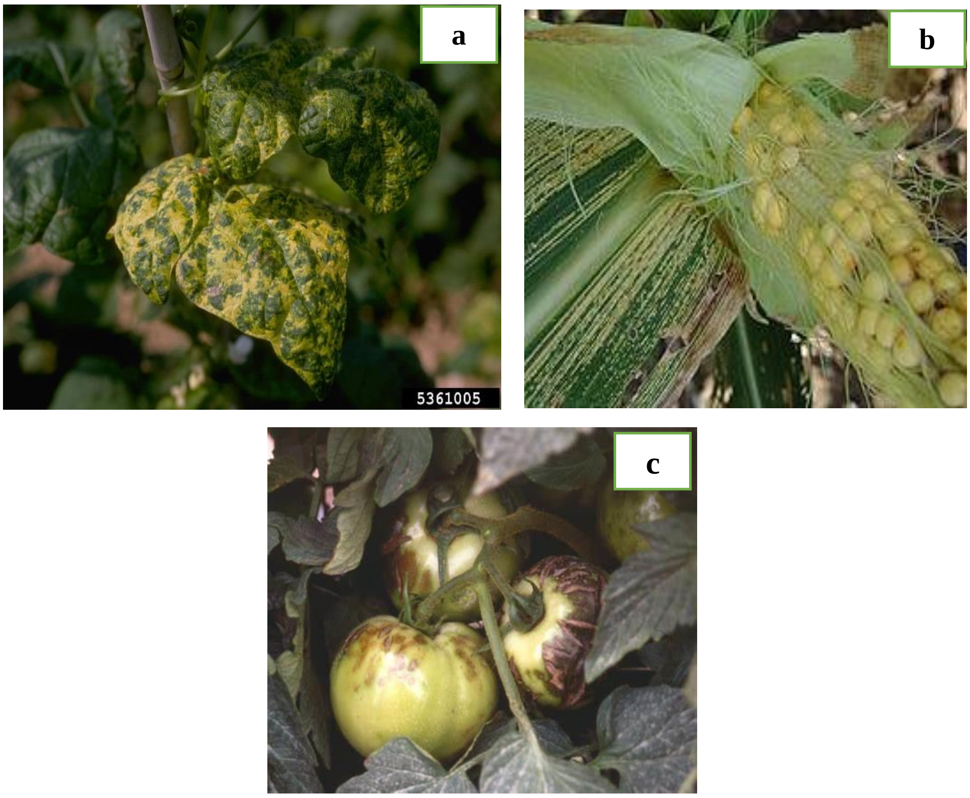

Figure 53: a. Bean golden mosaic virus (BGMV), b. Maize streak virus (MSV), c. Tomato pseudo-leaf roll virus (TPCTV) **[51]**

9.7.Ilarvirus group

Viruses of the genus Ilarviruses (isometric labile viruses) of which Tobacco streak virus (TSV) is the type virus differ considerably in their biological properties (**Fig 54)**. Most Ilarviruses infect a wide range of plants, most of which are perennials (Rosaceae). Ilarviruses can be transmitted by mechanical inoculation and seed transmission is common among Ilarviruses and some of them are pollen-borne. Ilarviruses have quasi-spherical particles, a slightly pleomorphic structure, with a diameter varying from 23-35nm.

The most important Ilarviruses affecting in the Mediterranean basin are:

- Plum necrotic ringspot virus (PNRSV)
- Prune dwarf virus (PDV)
- Apple mosaic virus (ApMV)

Figure 54: a. Apple mosaic virus (ApMV) **b**. Prune dwarf virus (PDV) **[52]**

10. Other groups

Phytopathogenic viroids

Viroids are pathogenic agents that have a small, circular noncoding RNA genome. They have been found only in plant species; therefore, their infectivity and pathogenicity in other organisms remain largely unexplored.

In study of Shuang Wei et al 2019, they investigate whether plant viroids can replicate and induce symptoms in filamentous fungi. Seven plant viroids representing viroid groups that replicate in either the nucleus or chloroplast of plant cells were inoculated to three plant pathogenic fungi, Cryphonectria parasitica, Valsa mali, and Fusarium graminearum. By transfection of fungal spheroplasts with viroid RNA transcripts, each of the three, hop stunt viroid (HSVd), iresine 1 viroid, and avocado sunblotch viroid, can stably replicate in at least one of those fungi.

The viroids are horizontally transmitted through hyphal anastomosis and vertically through conidia. HSVd infection severely debilitates the growth of V. mali but not that of the other two fungi, while in F. graminearum and C. parasitica, with deletion of dicer-like genes, the primary components of the RNA-silencing pathway, HSVd accumulation increases. We further demonstrate that HSVd can be bidirectionally transferred between F. graminearum and plants during infection.

The viroids also efficiently infect fungi and induce disease symptoms when the viroid RNAs are exogenously applied to the fungal mycelia. These findings enhance our understanding of viroid replication, host range, and pathogenicity, and of their potential spread to other organisms in nature.

Bibliographic references

A.

Ajayi-Oyetunde, O. O., & Bradley, C. A. (2018). Rhizoctonia solani: taxonomy, population biology and management of rhizoctonia seedling disease of soybean. *Plant Pathology*, *67*(1), 3–17. https://doi.org/10.1111/ppa.12733

Ajouz, S. (2009). *Estimation du potentiel de résistance de Botrytis cinerea à des biofongicides*

Apel K, Hirt H. (2004).*Reactive oxygen species: metabolism, oxidative stress, and signal transduction*. Annu. Rev. *Plant Biol*. 55:373–99.

B.

Bar-Hen A., Mariadassou M., Poursat M.A., Vandenkoornhuyse P. (2008). *Influence function for robust phylogenetic reconstructions*. Molecular Biology and Evolution. 25:869–873.

Bouzid N, (2015). *Les champignons et pseudo-champignons pathogenes des plantes cultivees* Biologie, Nouvelle Systématique, Interaction Pathologique. Publication de L'INAT.<www.nasraouibouzid.tn>

Bruns, R. et Barz, W. (2001). *Studies on cell number and nuclei in spores and on ploidy level in Ascochyta rabiei isolates*. Journal of Phytpathology 149 : 253-258.

H.

Hibbett, D. S., Binder, M., Bischoff, J. F., Blackwell, M., Cannon, P. F., Eriksson, O. E., Huhndorf, S., James, T., Kirk, P. M., Lücking, R., Thorsten Lumbsch, H., Lutzoni, F., Matheny, P. B., McLaughlin, D. J., Powell, M. J., Redhead, S., Schoch, C. L., Spatafora, J. W., Stalpers, J. A., … Zhang, N. (2007). *A higher-level phylogenetic classification of the Fungi*. *Mycological Research*, *111*(5), 509–547. https://doi.org/10.1016/j.mycres.2007.03.004

K.

Kator, L., Oche, O. D., & Hosea, Z. Y. (2015). Evaluation of three plant extracts in the control of fungal pathogens isolated from Garri (fried mashed fermented cassava) in Makurdi, Nigeria. *Archives of Applied Science Research*, *7*(9), 6–12.

Kator, L., Yula Hosea, Z., & Daniel Oche, O. (2015). Sclerotium rolfsii; Causative organism of southern blight, stem rot, white mold and sclerotia rot disease. *Scholars Research Library Annals of Biological Research*, *6*(11), 78–89. http://scholarsresearchlibrary.com/archive.html

O.

Ocaña-Fernández, Y., & Fuster-Guillén, D. (2021). The bibliographical review as a research methodology. *Revista Tempos e Espaços Em Educação*, *14*(33), e15614.

https://doi.org/10.20952/revtee.v14i33.15614

P.

Pernaci M. (2015*)*. Etude des traits d'histoire de vie de Melampsora laricipopulina, agent de la rouille du peuplier : de leur déterminisme génétique à leurs conséquences évolutives. *Thèse de Doctorat biologie végétale et foresterie*. Université Loraine : 261p.

Petit Y. (2017). *Comprendre l'implication des effecteurs fongiques dans l'infection d'une plante hôte : caractérisation fonctionnelle d'effecteurs de Leptosphaeria maculans, champignon pathogène du colza*. Thèse de Doctorat en sciences du végétal. Université Paris-Sud : 332p.

PhD Thesis (2013). Université d'Avignon et des Pays de Vaucluse, Avignon, France, 198 p. https://bu.univ-avignon.fr/revue/theses/Prot J.C. (nd.). *Les nématodes des cultures maraichères*. O.R.S.T.O.M. Dakar, Sénégal : 29p.

S.

Sabeh M. (2019). *Étude des déterminants génétiques de la pathogénicité chez les nématodes du genre Globodera*.Thèse de Doctorat en sciences biologiques. Université de Montréal 90: 11558-11562.

V.

Vincent M. (2017**).** *Durabilité de la résistance et mécanisme de tolérance au virus y de la pomme de terre (PVY) chez Nicotiana tabacum.* Thèse de Doctorat en Biologie Végétale. Université de Bordeaux : 275p.

W.

Wei, S., Bian, R., Andika, I. B., Niu, E., Liu, Q., Kondo, H., Yang, L., Zhou, H., Pang, T., & Lian, Z. (2019). *Symptomatic plant viroid infections in phytopathogenic fungi*. *Proceedings of the National Academy of Sciences*, *116*(26), 13042–13050.

Web sites list

[1] https://th.bing.com/th/id/OIP.1TwHiGC0j4Lp8a1Ay9ai8gHaH0?rs=1&pid=ImgDetMain **25.07.2024 18 :40**

[2] https://th.bing.com/th/id/OIP.QMxgGdIsMV-RTyX0ehrm7QAAAA?rs=1&pid=ImgDetMain

25.07.2024 18.47

[3] https://fr.wikipedia.org/wiki/Thalle#/media/Fichier:Ptilidium_pulcherrimum_leaf.jpeg **25.07.2024 18 :53**

[4] https://www.ipmimages.org/browse/taxthumb.cfm?class=339&aut=74577 **25.07.2024 18.57**

[5]

https://th.bing.com/th/id/OIP.edDYmTZRVmypYZmEltrKgHaHB?w=512&h=485&rs=1&pid=ImgDetMain **25.07.2024 19 :03**

[6]

https://th.bing.com/th/id/R.8ef61f466c320f01b7d1bc1e38448e70?rik=Y9ayA5AY%2f%2feAQQ&pid=ImgRaw&r=0 **15.09.2024 13 :11**

[7] https://th.bing.com/th/id/OIP.E_BzELZei85o62FZYuHdxQHaFq?rs=1&pid=ImgDetMain

25.07.2024 19 :10

[8] https://fr.wikipedia.org/wiki/Rhizopus_stolonifer#/media/Fichier:Sporocystophore.svg **25.07.2024 19 :15**

[9] https://live.staticflickr.com/2057/2293864343_2c04d954e4_b.jpg **25.07.2024 19 :22**

[10]

https://th.bing.com/th/id/OIP.OQ2QP8ZASVbI6ZlYo7KjAAHaFj?rs=1&pid=ImgDetMain **27.07.2024 18 :52**

[11]

https://s3.amazonaws.com/ai2-vision-textbookdataset/datase releases/rc2/val/question_images/fungi_reproduction_6911.png **b27.07.2024 18 :56**

[12]

https://cdn-sciaga.pullit.pl/cdn-content/FIrb6lNpSdPBSdVQ50bYIlPCziqr xICwCjoFxrOq2PN5dKm/typy-zarodnikow.png **27.07.2024 19 :08**

[13]

https://cdn-sciaga.pullit.pl/cdn-content/FIrb6lNpSdPBSdVQ50bYIlPCziqr-xICwCjoFxrOq2PN5dKm/typy-zarodnikow.png **27.07.2024 19 :11**

[14]

https://i.pinimg.com/originals/06/58/04/065804453608f06a05233ebf8be2cc12.jpg **27.07.2024 20:14**

[15]

https://s3-us-west-2.amazonaws.com/courses-images/wp-content/uploads/sites/1223/2017/01/26172307/Figure_24_02_04.png **16.08.2024 19 :48**

[16]

https://th.bing.com/th/id/R.e03ccc1bcf40a37f0c4adcdc9889d787?rik=c%2bz9zS3Lyd8l6Q&pid=ImgRaw&r=0 **16.08.2024 19 :50**

[17]

https://th.bing.com/th/id/R.798b3e232958fada959b87a35c3ffceb?rik=k0FoUrxCXNcmtQ&riu=http%3a%2f%2fephytia.inra.fr%2ffr%2fIC%2f6161%2fgeotrichum-tomate-DB-243-794&ehk=1X%2bQEWAvmRokHrpKu3ITs1MkGc%2bL49u0bvovZpsV9ME%3d&risl=&pid=ImgRaw&r=0 **16.08.2024 19 :56**

[18]

https://www.gardeningknowhow.com/wp-content/uploads/2021/01/leaf-roller-caterpillars.jpg

16.08.2024 20 :01

[19] https://plantdoctor.co.nz/assets/uploads/2016/05/32624427_l-123stock.jpg **16.08.2024 20 :06**

[20] https://th.bing.com/th/id/OIP.OBfpb-dQJp-i9maoDtiJJwHaER?rs=1&pid=ImgDetMain

18.08.2024 20 :09

[21] https://image1.slideserve.com/2061893/basidium-basidiospore-development-l.jpg

27.08.2024 12 :14

[22] https://i.ytimg.com/vi/kBlzl0FpeC8/maxresdefault.jpg **12 :19 27.08.2024**

[23] https://bugwoodcloud.org/images/1536x1024/5492511.jpg **27.08.2024 12 :23**

[24] https://bugwoodcloud.org/images/1536x1024/5465745.jpg **27.08.2024 12 :25**

[25]

https://www.lfl.bayern.de/mam/cms07/ips/bilder/fittosize__600_0_bfd41f9bc5a8fb8219c397d9fa803cc7_wurzelt%C3%B6terkrankheit.jpg **12 :30 27.08.2024**

[26]

https://1.bp.blogspot.com/bcUe8RfWS4/XoVqoSuiX4I/AAAAAAAACTE/8TKhKSvBw_sE9wLGvJZbzE-xHQUFyG0aQCLcBGAsYHQ/s1600/Wheat%2Brust%2B1.jpg

27.08.2024 12 :44

[27]

https://biocyclopedia.com/index/introduction_to_botany/images_phyco/18-7.gif **27.08.2024 12 :50**

[28]

https://www.planetnatural.com/wp-content/uploads/2022/03/downy-mildew-on-leaves-300x300.jpg **11.09.2024 18 :52**

[29]

https://www.growerexperts.com/wp-content/uploads/2021/11/tobacco-rattle-virus-in-potatoes-1536x1197.jpg **11.09.2024 19 :02**

[30] https://th.bing.com/th/id/OIP.KVMMin1yn2bN9K_N3vQzIgHaFj?rs=1&pid=ImgDetMain

11.09.2024 19 :05

[31]
https://th.bing.com/th/id/R.2b0036276209efa307aec5c072504d99?rik=mhcqT8hKffAzQQ&pid=ImgRaw&r=0 **19.09.2024 13 :09**

[32]
https://th.bing.com/th/id/R.0f2d85e6ab0b2e782fde591b85465ebf?rik=9mVWOnHFkeLY%2fw&pid=ImgRaw&r=0 **12.08.2024 18 :40**

[33]

https://th.bing.com/th/id/OIP.Lcj0RQJX4qsPxm1vw3WswHaH7?rs=1&pid=ImgDetMain **12.08.2024 18 :45**

[34]
https://th.bing.com/th/id/R.caa2397cd274fa927a0f6202844de458?rik=TzPDCx2G8qeRHg&riu=http%3a%2f%2fwww.agrimaroc.ma%2fwp-content%2fuploads%2fchancre-tomate-2.jpg&ehk=OnPGe2EDXF9q6K2naV6LUqWmb380GgiNSqF1y4UhhEA%3d&risl=&pid=ImgRaw&r=0
12.08.2024 02 :23

[35] https://canal9.ch/wp-content/uploads/INF-FEU-BACTERIEN-20190808.jpg **12.08.2024 19:10**

[36] https://image.slideserve.com/382375/slide3-l.jpg **12.08.2024 19:18**

[37]

https://www.complete-gardening.com/wp-content/uploads/2021/06/malattie-olivo_NG3.jpg **12.08.2024 19 :37**

[38]

https://www.nexles.com/article/wp-content/uploads/2020/05/tomate-solanum-lycopersicum-tache-bact%C3%A9rienne.jpg **12.08.2024 19 :42**

[39]
https://www.researchgate.net/profile/Paul_Taylor41/publication/23301599/figure/download/fig1/AS:340924606500865@1458294168534/Anthracnose-symptoms-on-chilli-fruits.png

12.08.2024 19 :50

[40] https://www.avenir-agricole **12.08.2024 19 :54**

[41]
https://th.bing.com/th/id/OIP.55nHHO_EEmq_FAZjR7tRVgHaFI?w=1536&h=1065&rs=1&pid=ImgDetMain
12.08.2024 20 :01

[42]

https://images.collegedunia.com/public/image/I1_fc78028fb539a5d08963848b018ff0fe.png **14.08.2024 22 :56**

[43] https://image3.slideserve.com/6126920/virus-symmetry-l.jpg **14.08.2024 23 :02**

[44] https://o.quizlet.com/-qPn4WSKNlQlw4IwnJx6Sw.jpg **14.08.2024 23 :08**

[45]

https://4.bp.blogspot.com/-htLJQT5-too/XwoVHC5A4RI/AAAAAAAAcjA/BPKSd7FpsNQkJM6m4WAmKX1MgEmA3J2DACLcBGAsYHQ/s640/coronavirus%2Blife%2Bcycle.png **14.08.2024 23 :19**

[46] https://bugwoodcloud.org/images/768x512/0660082.jpg **14.08.2024 23 :47**

[47

https://cdn.mos.cms.futurecdn.net/KdAYEMGnLTBoxH42qFGvQm.jpg& https://th.bing.com/th/id/OIP.3OcoQnTE0HNImTgIukQusgHaHP?rs=1&pid=ImgDetMain **14.08.2024 23 :55**

[48]

https://th.bing.com/th/id/OIP.k74XxwWwDAiiJLIctxs8YAHaFj?rs=1&pid=ImgDetMain

16.08.2024 18 :53

[49] https://www.gardenworldimages.com/ImageThumbs/BEV1512/3/BEV1512_PARSNIP_YELLOW_FLECK_VIRUS_ON_LEAF.jpg

16.08.2024 18 :58

[50] https://bugwoodcloud.org/images/768x512/5265067.jpg **16.08.2024 19 :02**

[51]

https://bugwoodcloud.org/images/1536x1024/5361005.jpg& https://th.bing.com/th/id/OIP.BGwEeefl_Os9taalGRo3HgHaFu?pid=ImgDet&w=474&h=366&rs=1 **16.08.2024 19 :27**

[52] https://cdn.activityboard.jp/KR00401208/pictures/l00001F08F/P000131E63.jpg?v=1&size=pict640_480 **14.08.2024 23 :40**