NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: BIO 311

COURSE TITLE: MYCOLOGY

NATIONAL OPEN UNIVERSITY, LAGOS

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BIO 311: MYCOLOGY

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MODULE 1: GENERAL CLASSIFICATION OF FUNGI
UNIT 1:

1.0 Introductions

Living things are classified into 2 main groups which are plants and animals Living things are thus classified into Kingdoms: Plant Kingdom and animal Kingdom.

The plant Kingdom id further divided into two:

1. Flowering plants
2. Non – flowering plants

Fungi (Singular, fungi) are groups of eucaryotic organisms that are of great practical and scientific interest to biologist. Fungi have a diversity of morphological appearances depending on the species.

The classification of Fungi, like that of bacteria is designed mainly for practical application but also bear some relation to phylogenetic considerations.

2:0 OBJECTIVES

At the end of the unit, students should be able to:

- Explain the various basis of classification of fungi
- Differential the classes of Fungi
- Identify the advantages of the various criteria used in classification of fungi
- Identify the limitation of the various bases of fungal classification.

3:0 MAIN CONTENTS

3.1 GENERAL CHARACTERISTICS USED IN CLASSIFYING FUNGI

On the basis of distinctive characteristics the nomenclature of fungi, the nomenclature is binomial with a generic and specific name (e.g *Aspergillus flavus*). Species are collected in genera, genera in families (*Suffix* - *Aceae*), families in orders (*Suffix* - *ales*) and the orders in classes (*Suffix* - *Mycetes*). The division of *Mycota* or Fungi and moulds, include the true slime moulds (*Myxomycetes*), the lower fungi (*Phycomycetes*) and the higher fungi (*Eumycetes*).

Fungi have been classified in a number of ways. This earlier classification is other wise called primitive classification such criteria used are:

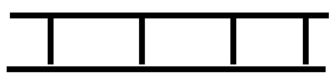
1. **HABITAT:** Primarily, the habitat has been used as a means of classification of fungi e.g aquatic, terrestrial or atmospheric fungi. A number of fungi of different characteristics may be found in the various habitats, therefore the use of habitat is not scientific and thus not authentic.

   In the atmosphere, propagoles of fungi, those terrestrial and those on trees can be disseminated into the atmosphere i.e conidia and spores, so the use of atmosphere is grossly inadequate.

2. **STRUCTURE:** The somatic structure or vegetative parts may be used as a means of classification.

3. **TYPES OF HYPHAE:** The aseptate hyphae (*Coenocytic*) has been used as a means of classification especially in the lower fungi placed in *Phycomycetes*. If the Hyphal is septate such a fungus belongs to the higher fungi and is thus classified on that basis. For example, fungi with ordinary septate hyphae belong to *Ascomycetes*. When the hyphae are divided into a number of clamp connections, the fungi belong to *Basidiomycetes*.

Classification on the basis of hyphae was a convenient method of classification in the 1940's – Note that fungi can either be unicellular or have hyphae



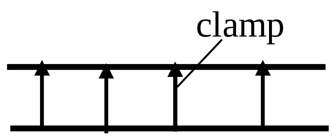


Fig 1: Lower fungi **Fig 2: Septum:** ***Ascomycetes*** ***Basidiomycetes***

4. **SPORES:** The types of spores used in/for reproduction were also used in classification.

   When the spores are motile with means of flagella, they are known as zoosporic while those with conidia are conidial.

5. Fungi with zoospore that have a single flagella are referred to as haplomastigmycotina and those with 2 flagella are diplomastigomycotina.

However, those without flagella are amastigomycotina and those in between the flagellate and non – flagellate are sub- mastigomycotina

In the amastigomycotina, some produces zygotes and are referred to as zygomycetes. Some fungi continues produce sac-like structures which serve as spores containers and are known as *Ascomycetes*. They produce spores within the sacs which are borne endogenously.

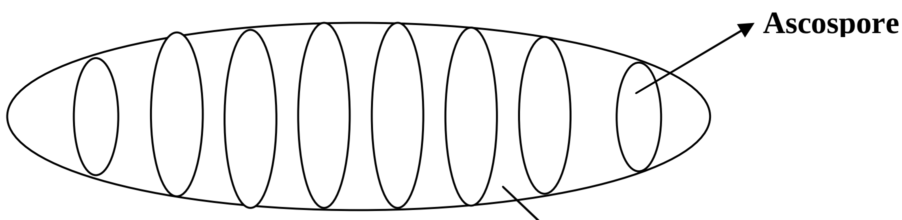


Figure: *Ascus* bearing ascospores

Spores produced by *Basdiomycetes* are borne exogenously, usually on the surface of the basidia

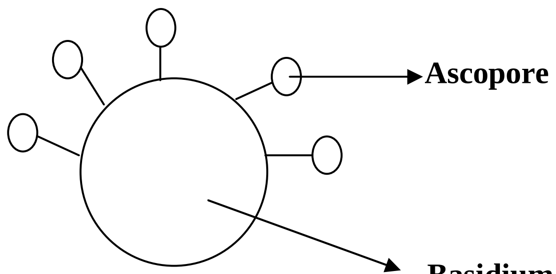


Figure: Basidium bearing basidiospores

It is very interesting to see how structures radiate round the different types of fungi

3.12 Taxonomy: Taxonomy of fungi follows the recommendations of the Committee on International Rules of Botanical Nomenclature (IRBN). According, the various taxa have endings as follows:

DIVISIONS:	*mycotina*
SUBDIVISIONS:	*mycotina*
CLASSES:	*mycetes*
SUB-CLASSES:	*mycetidae*
ORDER:	*ales*

FAMILIES: *aceae*

Genus and species have no standard endings

The organism is supposed to have 2 names, the first being the generic name which is always a noun, the first letter of which is usually Capital. The second name is the species name which is usually an adjective that must always begin with a small letter, underlined separately or must be in italics. An example is the fungus *Saccharomyces carlbergensis* which is a fungus that is capable of degrading carbohydrates and is used for growing cereals in the order *Endomycetales,* in sub- class Hemi – Ascomycetidae, in the class Ascomycestes and sub – division – Eumycotina. Another example is *Auricularia auricularia Judais* which is a fungus that looks like the ear.

CLASS: Basidiomycetes

SUB-CLASS: Heterobasidiocomycetidae

ORDER: Tremallales (Soft)

FAMILY: Auriccullaricae

NIGERIAN CLASSIFICATION

In the Nigeria system, fungi are classified using different parameters. The names of fungi vary from one ethnic group to the other. For example the Yoruba call it Ero or Olu, Hausas call mushrooms, Namagara, Urhobos call it Ihe while the Ibibios call it Ode.

A systematic nomenclature based on some characteristics also exist in Nigeria, some of such characteristics include:

i. **Habitat:** A good example is Olu-Ogan which is a fungus in termite hills. The scientific name of this fungus is *Termitomyces*

ii. **Shape:** An example is Eti-Ologbo which scientific name is *Auricularia auricularia judais*

iii. **Texture:** A good example is Olu-awo which is a leathery fungus which scientific name is *Lentinous sub-nodules*

iv. The size of the basidiocarp e.g wowo which means tiny, the scientific name of which is *Esattyrella atroumbonatum*

v. **Season:** The season in which the fungus is found is also used e.g Olu eji is found in the rainy season which scientific name is *Termitomyces robustus*

vi. **The flavour taste e.**g Ogiri agbe which means the farmers spice, which scientific name is *Volvarela esculentus*. It is usually on pods of oil palms. Another example is Takele which means adorns the muscle known scientifically as *Tormitomyces clypeatos*.

vii. **Life Span:** The life span of mushroom is also used as a criterion e.g Olu Olosunmeta which means mushroom that matures within 3 months, which scientific name is *Trichonema lobayesis.* Another example is Olu Oku which is a mushroom which grows repetitively called *Pleurototus tuberegium*.

ix. **Legendary status:** In this Nigerian classification the taxonomic characteristics used has to do with the legend of the area. A good example is Akufodewa meaning hunter would come to search for it. The legend is that the hunter died, was buried and a millipede was found at the spot. The scientific name is *Dictyophora or Phalus*

4.0 CONCLUSION

Several criteria are used in the classification of fungi. Some of these criteria include habitat, structure, types of hyphae, types of spores and flagella. Others include texture, season, flavor/taste, life span and legendary status.

5.0 SUMMARY

Classification of fungi is based on several criteria which makes it possible for the same fungus to be classified into several groups particularly due to dispersal of their spores by wind and water. Majority of these criteria are therefore of little or no scientific significance. The general criteria used universally and in the Nigerian classification thus need very critical evaluation so as to make the classification be of scientific significance particularly on evolutionary relationship and significance. The methods of classification studied above thus fall short of modern basis of classification.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe briefly the general characteristics used in classification of fungi

2. How are fungi named?
3. Critically examine Nigerian classification of fungi

7.0 REFERENCES/FURTHER READINGS

1. Alexopoulos, C.J., Mimis, C.W., Blackwell, M. 91996): Introductory mycology, 4th edition, New York, Wiley-Liss, Pp. 1-60.
2. Pelczar, M.J., Chan, E.C.S., Krieg, N.R. (2008): Microbiology Tata McGraw-Hill Pub. Comp. pp. 333-364.

MODULE 1

UNIT 2: MODERN CLASSIFICATION OF FUNGI

1.0 Introduction

A critical look of the earlier basis of classification vis-à-vis modern classification which takes into consideration evolutionary relationship. Fungi were broadly divided into two classes:

1. Lower fungi
2. Higher fungi

Fungi are classified on morphology and physiology into Acrasiomycetes (Cellular slime moulds), Myxomycetes (True slime moulds), Phycomycetes (Lower fungi), which consists of Chytriomycetes, Oonmycetes, Zygomycetes and Eumycetes (The Higher fungi) consisting of Ascomycetes and Basidiomycetes. There are 8 classes in the sub-division Eumycotina which vary from class A to I

The modern classification consists of 5 major divisions which are Mastigocotina, Amastigomycotina, Ascomycotina, Basidiomycotina and Deuteromycotina. Nigerian classification uses different parameters which are descriptive, shape habitat, texture, season, flavour as well as legendary status.

2.0 OBJECTIVES

At the end of this unit, students should be able to:

- Differentiate the lower fungi from the higher fungi

- Differentiate the lower fungi from slime moulds
- Identify members of the various classes of fungi from A to I
- Describe the various appearance of fruiting bodies in fungi
- List the 6 divisions in the modern classification of fungi

3.0 MAIN CONTENT

3.1 AMPLIFICATION OF THE CLASSIFICATION OF FUNGI

In the primitive classification, the first class is the lower fungi which have their vegetative mycelia which are *coenocytic* or *aseptate*. A few are unicellular and vegetative mycelium ranges from simple rhizoid to somatic cell and to even extremely intricate *anaesomes* of *rhizomycellium*.

The higher group of lower fungi however has well-developed hyphal system, usually coenocytic and are only endowed with septa to cut off the reproductive structure.

The second class is the higher fungi with the vegetative mycelium usually septate. In this class, the mycelium becomes differentiated into fruiting bodies which are usually visible and conspicuous. Edible mushroom are extensions of mycelium. Two major groups are known and recognized in the higher fungi.

1. The Ascomycetes in which the characteristic spores in the perfect stages are endogenous. These spores are bound in sacs known as asci. The imperfect stages produce conidia which are extensions of aerial mycelium.
2. The Basidiomycetes in which the characteristic spores in the perfect stage is exogenous and are found in fruiting bodies called basidiocarp. The fruiting body of most basidiomycetes develops from a subterranean mycelium and grows outward to differentiate in pileus which houses the gills or lamella from where basidia develop. However, some higher fungi can be unicellular e.g Yeast. In times of regular nomenclature, the lower fungi fall into class Phycomcetes, whereas the higher fungi are comprised of the Ascomycetes and Basidiamycetes.

   These terms where conveniently used fungi past but of recent new terms are used. Fungi are now placed in a division known as mycota. There are several subdivisions, one of which is Myxomycotina which is a sub-division that comprises the slime moulds. The vegetative structure known as plasmodium is a multinucleate mass of cytoplasm unbounded by rigid walls, which flow in amoeboid fashion over the surface of the substrate, ingesting smaller microorganism and fragments of decaying plant material. Some slime moulds are plasmodial in shape and form aerial hyphae.

The sub-division Eumycotina consists of the true fungi which are mainly filamentous. There are eight (8) classes that are recognized which are numbered A to I class

Class A: Chytridiomycetes. This class contains fungi that have a single posterior whip-like flagellum.

Class B: Oomycetes: Fungi in this class have zoospores that have two (2) flagella.

The anterior flagellum is whip-lash like while the other is tinsel shaped.

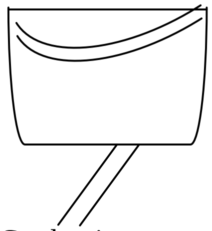
Class C: Plasmodiophoromycetes: In this class the motile cells have two (2) anterior whiplash-like flagella.

Class D: The **Zygomycetess:** Fungi in this class have coencytic hyphae, septate at the point of reproduction and the sexual reproductive form which it derives its name from is by fusion of two (2) gametangia.

Class E: Trichomyces: Fungi in this class are filamentous which are found in the guts or cuticle of arthropods.

Class F: Ascomycetes: Fungi in this class have septate hyphae. The imperfect stages develop conidia and the perfect stage produces ascospores. The nature of fruiting body can be extremely varied but the characteristic feature is the development of ascospore. The mycelium varies but in some cases no mycelium is produced e.g in yeast. In a number of them, there are fruiting bodies which are saucer – shaped and are generally called apothecium, where the ascocarp/fruiting body occurs as a flat surface or hollow saucer. The ascocarp differentiates into an upper part containing the asci and the lower part made up of pseudoparenchyma cell.

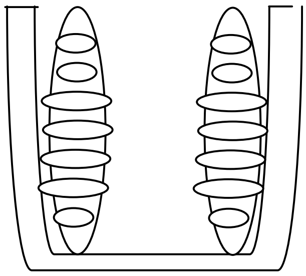
In some others, the fruiting body is like a wine glass which holds the fruiting body in position and serves for conduction of nutrients.



Cookenia

In the third category, the fruiting body has been differentiated into a sporogenous body, the stalk and the subterranean hyphae.

In the fourth category, the fruiting body is like a flask which encloses the asci



Flask-Shape ascocarp

This flask –shape ascocarp may or may not have an ostiole (hole). It may have a neck which ends in an opening and the nature of the fruiting body can be used in classifying fungi in this class.

Class G: Basidiomycetes: The characteristic feature of this is the possession of basidia. The fruiting body is highly specialized. In this group are the edible mushroom, the bracket fungi, the puffballs, the parasitic rusts and smuts which are devastating to grasses and trees

Class H: Deuteromycetes: This is a combination of the class ascomycetes and basidiomycetes which sexual or perfect stages have not yet been discovered. The imperfect stage is characterized and given the same type of name as ascomycetes. However, when the perfect stage is discovered, they either fall into ascomycetes or basidiomycetes and the appropriate name is then given. When the perfect stage is discovered the name assigned to the perfect stage becomes the recognized name.

Class I: Lichens: In this class, a situation arises in which there is a symbiotic association between algae or cyanobacteria with ascomycetes or basidiomycetes. Lichens are composite organisms composed of fungi and algae, each contributing to the benefit of the other or both. The algae synthesize carbohydrates and vitamins by photosynthesis and obtain other nutrients (water and minerals and moist sheller) from the fungi while the fungi depend on the algae for organic carbon.

3.11 MODERN CLASSIFICATION

In the modern classification fungi are classified into six (6) major divisions which include the:

1 Mastigomycotina which consists chytridiomycetes and Oomycetes

2. Amstigomycotina which has Zygotes. The two classes above were regarded as phymycetes i.e the lower fungi

3. Ascomycotina consists of Hemi-ascomycetidae
Plenomycetidae and other classes like Pyrenomycetes and Discomycetes

4. Basidiomycotina which has two (2) orders which are the (A) Aphylophrales (Bracket fungi) and (B) Agaricales.
The two divisions Ascomycotina and Basidiomycotina are regarded as higher fungi.

5. Deuteromycotina formerly called Deuteromycetes are called fungi imperfect.

6. The Lichens.

3.1.1 HIGHER FUNGI

Subdivision 3: Ascomycotina

Class 1: Hemiascomycetes

Order 1: Ascomycetales

Order 2: Taphrinales

Class 2: Pyrenomycetes

Order 1: Erysiphales **–** e.g. *Erysiphe gramminis*

Order 2: Shaeriales

Order 3: Hypocreales

Class 3: Loculoascomycetes

Order 1: Myriangiales

Order 2: Dothiodiales

Order 3: Pleosporales

Subdivision 4: Basidiomycotina

Class 1: Hemibasidiomycetes

Order 1: Ustilaginales e.g. *Ustilago* spp.

Order 2: Uredinales

Class 2: Hymenomycetes

Order 1: Exobasidales

Order 2: Agaricales e.g. *Agaricus* spp, *Pleurotus* spp.

Order 3: Tulasnellales

Order 4: Aphyllophorales

Subdivision 5: Deuteromycotina (fungi imperfecti)

Class 1: Coelomycetes

Order 1: Melanconiales

Class 2: Hyphomycetes

Order 1: Hyphales e.g. *Alternaria cercospora* spp.

Class 3: Agonomycetes

Order: Agonomycetales e.g. *Rhizoctoma* spp.

4.0 CONCLUSION

In the amplified classification, the hyphal system was used to differentiate fungi into 2 groups: 1) lower fungi which have coenocytic or aseptate hyphae from the 2) higher fungi with vegetative mycelium which is usually septate. There are nine classes while the modern classification of fungi has 6 major divisions.

5.0 SUMMARY

Two major groups of higher fungi are known which include the Ascomycetes and the Basidiomycetes. In the sub-division, Eumycotina, there are 8 recognized classes which are number A to I. They include: Chytridiomycetes, Oomycetes, Plasmodiophoromycetes, Zygomycetes, Trichomycetes, Ascomycetes, Basidiomycetes, Deuteromycetes and Lichens. In the modern classification, however, fungi are grouped into 6 major divisions which include: 1) Mastigomycotina, 2) Amastigomycotina, 3)Ascomycotina, 4) Basidiomycotina, 5) Deuteromycotina and 6) The Lichens on the basis of their evolutionary advancement and status.

6.0 TUTOR-MARKED ASSIGNMENT

1. Differentiate Ascomycetes from Basidiomycetes
2. Describe concisely the fruiting bodies of Ascomycetes and Basidiomycetes
3. Of what significance are the Deuteromycetes in the classification of fungi?

7.0 REFERENCES/FURTHER READING

Moore-Landecker, E. (1982): The fundamentals of fungi. 2nd ed. Prentice-Hall, Englewood, Cliff, New Jersey, Pp. 15-25.

Ingraham, J.L., Ingraham, C.A., Prentiss, H. (1995): Microbiology Wadsworth Pub. Comp., New York, Pp. 275-284.

MODULE 2

CHARACTERISTICS, STRUCTURE AND CLASSIFICATION OF MAJOR FUNGAL GROUPS

UNIT 1:

1.0 INTRODUCTION

Fungi are ubiquitous and very diverse with characteristics, and structure and are thus classified into several classes. The classes of interest are Chytridiomycetes, Oomycetes, Abscomycetes and Basidiomycetes. The orders of scientific interest would also be listed in this unit. The characteristic spores of each class would also be elucidated.

2.0 OBJECTIVES

At the end of this unit, students should be able to:

- List the major fungal classes of interest
- Describe the structural features of each class
- Describe the different types of spores produced by each group
- List the various orders in each class of fungi
- Describe reproduction in the major classes of fungi

3.0 MAIN CONTENT

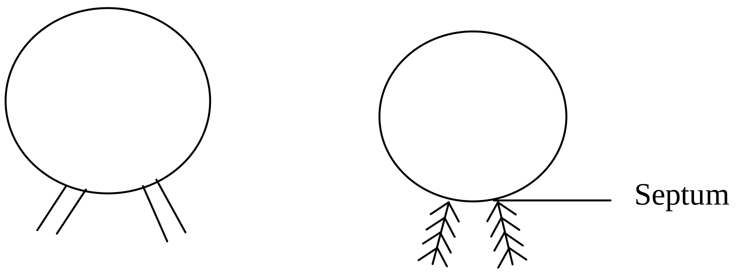
3.1 Class Chytridiomycetes

The lowest fungi ever studied are the chytrids of the family Chytridiaceae and order Chytridiales. These are fungi that produce motile spores called zoospores (planogametes). The zoospores have a single posterior whip-lash like flagellum. The coenocytic thallus is made up of simple hyphae and the thallus is well developed. The conjugating zoospores soon develop/convert into a resting sporangium.

HABITAT: They are prevalently aquatic but some are found in soil, while a good number are parasitic in the tissue of angiosperms. They can be collected and cultivated easily using baits like fruits, pollen grain, boiled grass blades, egg albumen, cellophane, nectars of flowers, petals, insect excuvia, dead insects etc. Colonies are often inside or outside the bait.

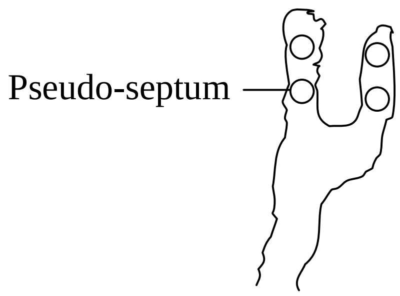
SOMATIC STRUCTURES OF CHYTRIDS

In every primitive chytrids, the somatic structures are unicellular and holocarpic in fungi with holocarpic somatic structures, the same somatic structure serves for both vegetable and reproductive purposes. Such fungi do not have respectable mycellium. In slightly higher ones, there are few rhizoids for anchorage and nutrition. The sporogenous part of the thallus is separated from the rest by a septum.



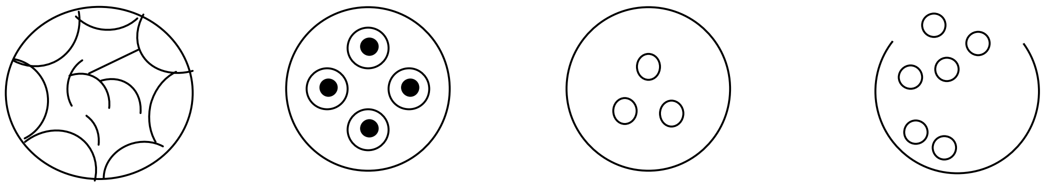
- On the evolutionary trend of chytrids the somatic structures range from simple holocarpic to eucarpic. It also ranges from simple cell to simple rhizoids, to complex rhyziods and extensive rhizomycellium. The mode of reproduction ranges from isogamous, ansogamous, gamentagial copulation to somatogamy as in *N. ramosa*.

Some higher chytrids have branches of rhizomycellium and there are some with well developed hyphae with pseudo-septa.



Asexual reproduction in chytrids

This is by means of sporangia. The sporangium is initially filled with densely fluid in form of protoplasm followed by cleavage. The protoplasm becomes separated and surrounds the nucleus.



ASEXUAL REPRODUCTION IN CHYTRIDS

The zoospores can be released in a number of ways;

1. If the chytrid is inoperculate, the zoosporangium breaks.
2. If it is operculate, the operculum opens and the chytrids escape from the operculum.

The zoospores thus liberated would swim for a little while and encyst, loose their flagellum and secretes a cell wall round themselves. After some time, the zoospores geminate as their ancestors.

SEXUAL REPRODUCTION IN CHYTIDS

Sexual reproduction in chytrids is more complex and can take any of the following forms:

1. **Planogametic copulation:** Two swimming gametes conjugate and form a zygote. When the two swimming gametes are equal in size, the copulation is said to be isogamous. Quite often the gametes may be unequal thus called planogametes. The conjugation of two unequal gametes leads to the formation of a motile gamete which later looses the flagella and becomes resting. It is then called anisogamous. The non-motile gamete is usually the female, larger and sedentary while the motile gamete is the male. The non-motile female gametes are known as oogonia and the males are the antheridia.
2. **Gamentagial copulation:** The body of the gamentagial of two gametes fuses to form a zygote. The entire protoplasm of 1 gamentaguim fuses with another. The two fuse together after which cleavage occurs and spores are formed.
1. **Somatogamy:** The gametes pass from the rhizoid form to form a zygote which forms a resting gamete (spore) which later germinate and later release spores. Fungi in the class

Chytridiomycetes are classified into 4 orders which include; 1) Chytridiales, 2) Blastodiales, 3) Monoble pharidiales and 4) Harpochytridiales

3.2 CLASS OOMYCETES

Examples include *Saprolegnia ferax* and *S. parasitica*.

Fungi in this class are distinguished by the presence of two flagella i.e they are biflagellate. They have motile cells with two literally inserted flagella, one tinsel and anteriorly directed; the other whiplash and posteriorly directed. In the primary zoospore, one flagellum is tinsel while the other is whip-lash like at their anterior portion while the secondary zoospore is kidney-shaped with two flagella.

There are 4 different orders in the class Oomycetes which are; 1) Saproleginiales, 2) Legenidiales, 3) Leptomitales and 4) Peronosporales.

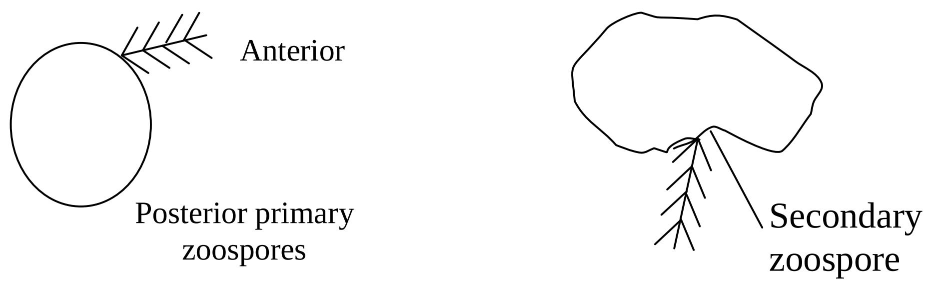


Fig. Zoospores of class Oomycetes

The first and fourth orders are important. Generally, Oomycetes were called water moulds until in **1925** when **Harvey** isolated some Saprolegiales from the soil, so the modification of the definition hence the term is no more applicable in the lower fungi.

Fungi in the order Saprolegniales are found in water and have also been from moist or dry soil. Majority are saprophytic while some are parasitic. Saprolegnial parasites are known to be cause of diseases of fishes and its egg thereby capable of affecting adult fish and fingerlings, egg hatcheries, lobsters, crabs and a number of aquatic animals. Examples of such include; *Achlya* spp and *Saprolegnia* spp.

Another genus *Phanomyces* which contain several parastitic species which cause several parasitic diseases of serious economic losses like peas, legumes, sugar beeds, rice, maize especially those that grow in submerged areas . Saprolegniales are widely distributed worldwide and are very easy to grow and cultivate.

Structurally, they posses extensive mycellium usually filamentous, coenocytic, no crosswalls or septa except in regions which limits the reproductive structures from vegetative structures.

Asexual reproduction, takes place by either production of zoospores or gemmae. In the process of development of the sporangia, the apical portion of the filament is cut off by a septum after the tip has been filled with dense protoplasm.

Initially, there are long coenocytic hyphae and by reproduction, we have separation of the hyphae. When this occurs, the densely fluid filled cytoplasmic portion cleaves and separates regions where there are nuclei surrounded by cytoplasm which is the beginning of sporogenesis. The nuclei present differentiate into zoospores. An opening develops at the tip of the sporangium and pear-shaped, primary zoospores escape into the surrounding aqueous environment. They swim for sometime (usually from a minute to over an hour), then withdraw their flagella and encyst. This cyst, after a period of rest (2 to 3 hours, depending on the species), geminates to release a further bean-shaped secondary zoospore. The secondary zoospore may swim vigorously for several hours before encysting again. This encysted spore now germinates by sending a germ tube that develops into a hypha, forming a new colony. When conditions are favourable for sexual reproduction, the somatic hyphae give rise to oogonia and antheridia.

3.3 CLASS ZYGOMYCETES

Examples are *Mucor racemosus, M. rouxii* and *Rhizopus stolonifer*.

Mucor: Members of the genus occur abundantly in soil and manure and on fruits, vegetables and starchy foods. Common species are *M.* *racemosus* and *M.* *rouxii*. Morphologically, the mycelia are usually white or gray and are non-septate. Sporangiophores may be branched. The columellae (sterile structures in sporangium) are round, cylindrical or oval. Spores are black or brown and are smooth in appearance. Zygospores are produced when plus and minus strains of the organism are both present. The plus and minus strains are so called because there is no morphological differentiation between the male and the female strains even though there is physiological heterothallism. Zygospores are also formed in growth on artificial media in the laboratory. No stolons or rhizoids are produced. In the absence of a fermentable carbon source in a medium consisting of yeast extract and peptone supplemented with potassium acetate, *Mucor* may grow in a yeast-like form instead of a filamentous form.

3.4 CLASS ASCOMYCETES

All fission yeasts belong to the genus *Schizosaccharomyces*. They reproduce by transverse division as well as by ascospores. The best known species is *S. octosporus*, which has been isolated from currants and honey. Its cells are globase to cylindrical, uninucleate and haploid. *S. pombe* is the fermenting yeast of some of beer (e.g. African millet beer) isolated from sugar molasses and from grape juice. *S. vertisatilis*, isolated from grape juice grows like yeast but it can also form a true mycelium.

In the genus *Saccharomyces*, there are about fifty species. The best known is *S. cerevisiae* strains of which are used in the fermentation of beer and wine and in baking. It is found in nature on ripe fruits. Grapewine are often made by spontaneous fermentation by yeast growing on the surface of the fruit. *S. cerevisiae* is therefore of great economic importance. Its cells are elliptical, measuring about 6 to 8 by 5µm. They multiply asexually by budding. When a bud is formed on a cell, a raised scar remains. As many as 23 buds scars have been seen on a single cell. During budding, the nucleus divides by constriction and a part of it enters the bud along with other organelles. Under appropriate conditions, *S. cerevisiae* forms asci. The cytoplasm of the cell differentiates into 4 thick-wall spherical spores, although the number of spores can be fewer. The cells forms which asci develop are diploid and the nuclear divisions which preceded spore formation are meiotic. It may be noted that many strains of the yeast are heterothallic, and the ascospores are of two mating types. Mating type is controlled specifically by a single gene which exists in two allelic states a and α, and segregation at reduction division preceding ascospore formation gives rise to two a and two α ascopsores. Fusion normally occurs only between cells of differing mating types by a process termed legitimate copulation. Such fusions result in diploid cells which form asci containing viable ascospores. Studies on yeast genetics revealed that by means of hybridization (crossing of different yeasts), it is possible to develop strains of yeasts (hybrids) with desirable characteristics from two genetically different strains.

3.5 CLASS BASIDIOMYCETES

In the genus, *Agaricus*, the best known species is *Agaricus compestris*, the field mushroom and *A. bisporus* the cultivated mushroom. The young gill is coloured pink due to cytoplasmic pigment in the spores. The gills later turn a purplish brown because of the deposition of dark pigments in the spore wall. Most of the larger species of *Agaricus* are edible.

Of the approximately 12,000 species of Basidiomycetes, none was implicated in human diseases until recent times. The perfect stage of *Cryptococcus neoformans* was discovered in 1975. It is now called *Filobasidiella neoformans*. It is an important basidiomycetous pathogen of humans, causing cryptococcosis, a generalized (systemic) mycotic infection involving the bloodstream as well as the lungs, central nervous system and other organs.

TABLE: PROPERTIES OF MAJOR GROUP OF FUNGI

Class:	**Distinguishing characters/Examples**
The Lower Fungi:	Mycelia (if present) are coenocytic and lack septa
Chytridiocetes:	Water moulds with uniflagellated sporangiospores and gametes *Allomyces* (seen as fuzzy growth in tropical ponds and streams).
Oomycetes	Water moulds with biflagellate sporangiospores and male gametes, non-motile female gametes and sexual spores. Example is Saprolegnia (seen as fuzzy growth on fish in the stream).
Zygomycetes	Terrestrial fungi with non-motile sporangiospores and zygospores. Several genera parasitize weakened human patients. Example is *Rhizopus* (Black bread mould)
The higher fungi	Mycellia (if present) are septate: All species are terrestrial; conidia and gametes (if present) are non-motile
Ascomycetes	Ascospores formed in sacs (ascus), Some parasitic on plants or animals. Example is *Peziza* (an orange cup fungus, seen on soil in damp wood).
Basidiomycetes	Basidiospores formed on a club-shaped basidium; some are parasitic on plants or animals.

	Example is *Amanita* (Red or white mushrooms seen in forests
Deuteromycetes: (fungi imperfecti)	Higher fungi that lack sexual spores, some are parasitic on plants animals. Example is *Penicillium* (blue or green mould seen on fruit; used to make penicillin).
Yeast	Unicellular, oval cells mostly as Ascomycetes and Deuteromycetes but some Basidiomycetes and Zygomycetes; some parasitic on plants animals. Example is *Saccharomyces cerevisiae* (yeast used baking, brewing and wine making) (Ingraham *et al.,* 1995).

4.0 CONCLUSION

The characteristic features of fungi of several classes and genera are discussed. Examples of such classes include Chytridiomycetes, Oomycetes, Zygomycetes, Ascomycetes and Basidiomycetes.

5.0 SUMMARY

Chytrids produce motile spores, most of which are saprophytic while some reside in the rumen of herbivores. Fungi in the class Oomycetes are distinguished by the presence of two flagella i.e. they are biflagellate. Members of the class Zygomycetes produce zygospores. The class Ascomycetes contains the sac fungi because these fungi form a sac-shaped reproductive structure called ascus. In the class Basidiomycetes, the spores are borne on the surface of the Basidia.

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly describe the somatic structure of chytrids
2. Describe the morphology of a named member of class Zygomycetes
3. How does budding occur in yeasts?

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MODULE 3: REPRODUCTION IN FUNGI

UNIT 1: ASEXUAL REPRODUCTION IN FUNGI

UNIT 1: ASEXUAL REPRODUCTION IN FUNGI

CONTENT

1.0 INTRODUCTION

Fungi reproduce naturally by a variety of means. Reproduction in fungi occurs by spore formation. Spores are formed from the aerial mycelium in a great variety of ways, depending on the species. Mycelia can either be vegetative or reproductive. Some hyphae of the vegetative mycelium penetrate into the medium in order to obtain nutrients; soluble nutrients are absorbed through the walls, while insoluble nutrients are first digested externally by secreted enzymes. Reproductive mycelia are responsible for spore production and usually extend from the medium into the air.

Fungal spores can be asexual or sexual. Asexual spores are formed by aerial mycelium of one organism. When these spores germinate, they become organisms that are genetically identical to the parent. Sexual spores result from the fusion of nuclei fro two opposite mating strains of the same species of fungus organism that grow from sexual spores will have genetic characteristics of both parental stains.

2.0 OBJECTIVES

At the end of this unit readers should be able to:

- Explain different types of reproduction in fungi
- The role of the mycelium in reproduction of fungi
- The different types of asexual spores
- How asexual reproduction occurs in fungi

3.0 Main Contents

3.1 Different types of asexual spores in fungi

Asexual spores are produced by an individual fungus through mitosis and subsequent cell division; there is no fusion of the nuclei of cells. Asexual reproduction (Also called somatic or vegetative reproduction) does not involve the union of nuclei, se cells or sex organs. It may be accomplished by:

1. Fission of somatic cells yielding two similar daughter cells
2. Budding of somatic cells or spores, each bud being a small outgrowth of present cell developing into a new individual
3. Fragmentation or disjointing of the hyphal cells, each fragment becoming a new organisms; or
4. Spore formation.

Several forms of asexual spores are produced by fungi, Asexual spores, whose function is to disseminate the species are produced in large numbers. Examples of such spores include:

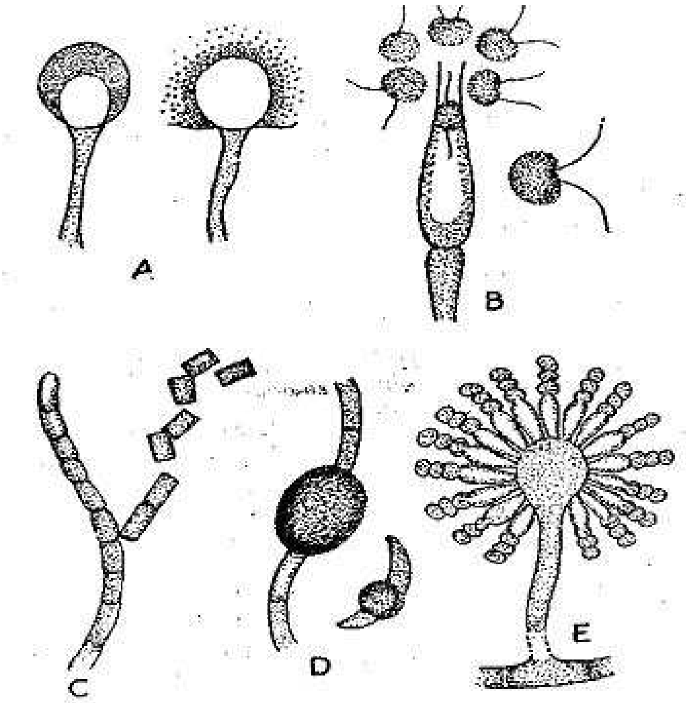
i. Sporangiospores**:** These single-celled spores are formed within sacs called sporangia (Singular, sporangium) at the end of special hyphae e.g. Rhizopus. Aphanospores are non-motile sporangiospores, their motility is due to the presence of flagella).

ii. Conidiospore**:** This is a unicellular or multicellular spore that is not enclosed in a sac. Conidiospores are produced in a chain at the end of a conidiophore. Small, single-celled conidia are called microconidia while large, multicellular conidia are called macroconidia. Conidia are formed at the tip or side of a hypha. e.g *Penicillin*.

iii. Oidia (Singular, Oidium) or Arthrospores. These single-celled spores are formed by disjointing of hyphal cells or by fragmentation of a septate hypha into single, slightly thickened cells. One species that produces such spores is *Coccidiodes immitis*.

iv. Chlamydospores**:** These are thick-walled spores formed as segments within a hypha. Chlamydospores are highly resistant to adverse conditions and are formed from cells of the vegetative hyphae e.g. *Candida albicans.*

v. Blastospores**:** These are spores formed by budding. These spores often come off the parent cell (e.g. yeast).



Diagrammatic representation of asexual spores

a. Sporangiospores are formed within a sporangium (spore sacs)

b. Blastospores are formed from buds of the parent cell.

c. Fragmentation of hyphae results in the formation of arthrospores

d. Chlamydospores are thick-walled cells within the hyphae

e. Conidiospores are arranged in chains at the end of a conidiophore

CONCLUSION

Fungi reproduce asexually by spores which include sporangiospores, conidiospores, arthrospores, chlamydiospores and blastospores.

5.0 SUMMARY

Asexual reproduction in fungi is usually with the aid of spores. Asexual reproduction in fungi does not involve the union of nuclei of sex cells or gametes or sex organs. The asexual spores are produced in very large numbers to enhance the dissemination of species in either of the different kinds of asexual spores such as sporangiospores, conidiospores oidia, chlamydospores, and blastospores.

6.0 TUTOR MARKED ASSIGNMENT

1. List the different types of asexual spores in fungi
2. How is asexual reproduction accomplished by fungi?

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MODULE 3

UNIT 2: SEXUAL REPRODUCTION IN FUNGI

CONTENT:

1.0 INTRODUCTION

Sexual reproduction in fungi is carried out by fusion of the compatible nuclei of two parent cells. A fungal sexual spore results from sexual reproduction consisting of three phases:

1. A haploid nucleus of a donour cell (+) penetrates the cytoplasm of a recipient cell (-)
2. The (+) and (-) nuclei fuse to form a diploid zygote nucleus
3. By meiosis, the diploid nucleus gives rise to haploid nuclei (sexual spores), some of which may be genetic recombinants. There are various methods of sexual reproduction, some of which include gametic copulation, gamete-gametangial copulation, gametangial copulation etc.

2.0 OBJECTIVES

At the end of this unit, students should be able to:

- Explain the process of sexual reproduction in fungi
- Describe the different types of spores involved in sexual reproduction of fungi
- Understand the various methods of sexual reproduction in fungi
- Explain the significance of sexual spores in sexual reproduction of fungi

3.0 MAIN CONTENT

The process of sexual reproduction begins with the joining of two cells and fusion of their protoplast called plasmogamy, thus enabling the two haploid nuclei of two mating types to fuse together called karyogamy to form a diploid nucleus (2n). This is followed by meiosis, which again reduces the number of chromosomes to the haploid number (n).

The sex organelles of fungi, if they are present, are called gametangia (singular, gametangium). They may form differentiated sex cell (gametes) or may contain instead one or more gamete nuclei. If the male and female gametangia are morphologically different, the male and female gametangia are called the antheridium (plural, antheridia) and the female gametangium is called oogonium (plural, oogonia) respectively.

The various methods of sexual reproduction (by which compatible nuclei are brought together in plasmogamy), may be summarized as follows:

1. **Gamete copulation:** Fusion of naked gametes, one or both of which is/are motile.
2. **Gamete-gametangial copulation**: Two gametangia come into contact but do not fuse. The male nucleus migrates through a pore or fertilization tube into the female gametangium.
3. **Gametangial copulation:** Two gametangia or their protoplasts fuse and gives rise to a zygote that develops into a resting spore.
4. **Somatic copulation:** Fusion of somatic or vegetative cells
5. **Spermatization:** Union of a special male structure called spermatium (plural, spermatia) with a female receptive structure. The spermatium empties its contents into the latter during plasmogamy.

Sexual spores, which are produced by the fusion of two nuclei occur less frequently, later and in smaller numbers than do asexual spores. There are several types of asexual spores; they are often produced only under special circumstances. Some examples of sexual fungal spores are:

1. **Ascospores:** These are single-celled spores which are produced in a sac called an ascus (plural asci). There are usually two to eight ascospores in each ascus. They are often produced by the phylum Ascomycota.
2. **Basidiospores:** These are single-celled spores that are borne on a club-shaped structure called a basidium (plural basidia). There are usually four basidiospores per basidium. Basidiospores are produced only by the phylum Basidiomycota.

3. **Zygospores:** These are large, thick-walled spores formed when the tips of two sexually compatible hyphae or gametangia, of certain fungi fuse together e.g *Mucor hiemalis.*

4. **Oospores:** These are formed within a special structure, the oogonium. Fertilization of the eggs or oospheres by male gametes formed in an antheridium gives rise to oospores. There are one or more oospheres in each oogonium.

Asexual and sexual spores may be surrounded by highly organized protective structure called fruiting bodies. Asexual fruiting bodies have names such as acervulus and pycrudium. Sexual fruiting bodies have names such as perithecium and apothecium.

Although a single fungus may produce asexual and sexual spores by several methods at different times and under different conditions. The spores are sufficiently constant in their structures and in the methods by which they are produced to be used in identification and classification.

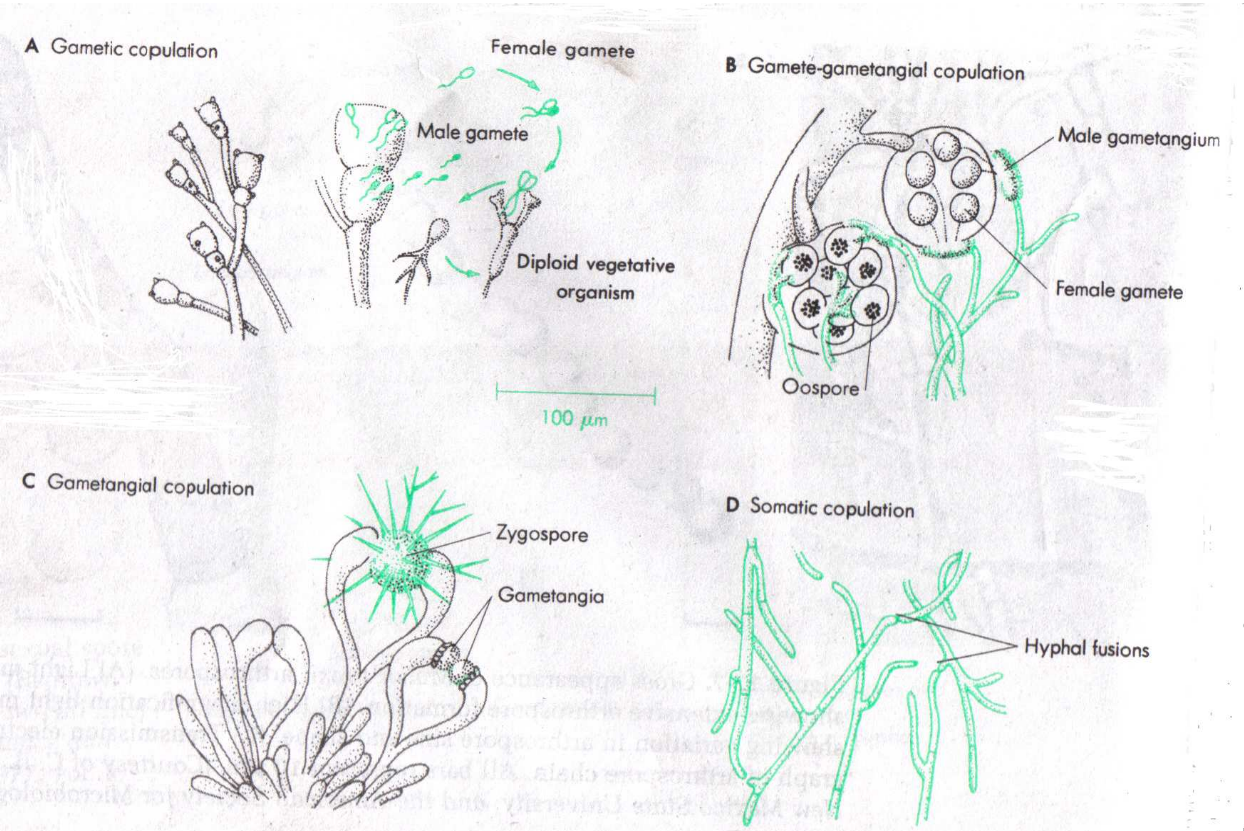

Figure 17-8. Some sexual mechanisms in fungi. (A) Gametic copulation: the fusion in pairs of sexual cells or gametes, formed in specialized sporangia-like gametangia (BJ gamete-gametangial copulation: the fusion of a differentiated gamete of one sex with a gametangium of the other sex; (C) gametangial copulation: the direct fusion of gametangia without differentiation of gametes; (D) somatic copulation: the sexual fusion of Undifferentiated vegetative cells; (EJ spermatization: spermatia uniting with receptive hyphae of the opposite (compatible) strain. (A-D: Pelczar*, et. al.*, 2008).

4.0 CONCLUSION

Sexual reproduction in fungi occurs by fusion of the compatible nuclei of two parent cells. The two haploid through the joining two cells and fusion of their protoplasts enable the two haploid nuclei of the two mating types to fuse together resulting in a diploid nucleus.

This is immediately followed by meiosis which then reduces the numbers of chromosomes to the haploid number. The sex organelles of fungi are the gametangia which form sex gametes, which when different form anteridium and oogonia.

5.0 SUMMARY

The various methods of sexual reproduction include gametic copulation, gamegatanial copulation gametangial copulation, somatic copulation and spermatization**.**

Several forms of sexual spores are involved in the fusion of two nuclei, examples of which are: Ascospores, basidiopores zygospores and oospores.

The highly organized structure in fungi the fruiting bodies are often surrounded both sexual and asexual spores.

6.0 TUTOR MARKED ASSIGNMENT

1. List the various phases in sexual reproduction in fungi that produce sexual spores.
2. What is a fruiting body and what are its functions
3. What is a gametangium
4. Briefly described spermatization

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MODULE 4: MYCOLOGY

BIO 311

UNIT 1 FUNGAL DISEASES IN MAN

1.0 INTRODUCTION

Fungi cause diseases known as mycosis both in man and in animals. Most fungi are moulds, but there are a number of pathogenic yeasts and many are dimorphic. Dimorphic fungi usually assume the mould form when growing as saprophytes in nature, and as yeast form when causing infection.

Some fungi are able to establish infection in all exposed individuals while others are opportunistic which cause diseases only in immunosuppressed individuals or host. Fungi cause three types of diseases, namely;

(a) Superficial mycosis

(b) Subcutaneous mycosis and

(c) Systemic (deep) mycosis

2.0 OBJECTIVES

At the end of this unit, the learner will be able to;

(a) Know the meaning of and causes of mycosis
(b) Differentiate between superficial and subcutaneous mycoses
(c) Know the different organisms involved in superficial mycoses
(d) Know the different organisms involved in subcutaneous mycoses
(e) Understand the pathogenesis of different fungal diseases
(f) Know the drug of choice for the different diseases

3.1 SUPERFICIAL MYCOSES

This is also known as dermatomycoses. They are diseases of the skin, hair, nail and mucous membranes and are the most common of all fungi infections and have a worldwide distribution. Superficial mycoses include ringworm.

3.1.1 RINGWORM

Ringworm infections are common diseases of the stratum corneum of the skin, hair and nail; they are also referred to as dermatophytosis or tinea, a name which is qualified by the site affected, e.g. Tinea capitis involves the scalp, Tinea pedis involves the feet, Tinea cruris involves the groin and Tinea corporis involves other areas.

The infections are caused by about 20 species of dermatophyte fungi which are grouped into three genera, *Microsporum*, *Trichophyton* and *Epidermophyton*.

Ringworm infections are spread by direct or indirect contact with an infected individual or animal.

Indirect transfer may occur via the floors of swimming pools and showers or on brushes, combs, towels and animal grooming tools. Some abnormalities of the epidermis, such as slight peeling or minor trauma, are probably necessary for the establishment of infection. The infective particle is usually a fragment of keratin containing viable fungus.

Scalp ringworm is predominantly a disease of children, and foot ringworm a disease of adults, particularly adult males.

The hyphae grow into newly differentiated keratin as it is formed, keeping pace with the keratin growth. In tissue, fungi take the form of branching hyphae, which may essentially break up into athroconidia, particularly in infected hair.

Ringworm lesions vary considerably according to the site of the infection and species of fungus involved. Sometimes there is only dry scaling or hyperkeratosis. But more commonly there is irritation, erythema, oedema and some vesiculation. More inflammatory lesions with weeping vesicles, pustules and ulceration are usually caused by zoophidic species of dermatophyte.

In skin infection of the body, face and scalp, spreading annular lesions with a raised, inflammatopry border are produced. Lesion in groins, tend to spread outwards from the flexures. In foot ringworm, infection is often confined to the toe clefts, but it can spread to the sole. Infected nails become discoloured, thickened, raised and friable.

In scalp infection, the fungus invades the hair shaft and then the hyphae break up with chains of arthroconidia. The pattern of hair invasion affects the clinical appearance of the lesion. In endothrix infection, the hair breaks off at or just below the mouth of the follicle, which then becomes plugged with dirt and seburn to give what is known as black dot ringworm, but in extothrix infection, the hair usually breaks off 2-3 mm above the mouth of the follicle resulting in favus. Fungal growth with the favus is minimal and the hair remains intact but intense fungal growth within and around the hair follicle produces a waxy, honeycomb-like crust on the scalp.

Tropical agents such as Whitfield's ointment and tolnafotate are used for the treatment of most dermatophyte infections of skin but these have been largely superceded by terbinafine and azole compounds.

Oral griseofulvin is useful for scalp, skin and fingernail infections except for toe-nail infection. Terbinafine and itraconazole are now used for all forms of ringworm infection since they give much better cure rates with shorter periods of treatment and lower relapse rates.

Control of the spread of ringworm is through improved living conditions and standard of hygiene.

3.1.2 Superficial candidiasis

Candida albicans accounts for 80-90% of superficial *Candida* infection, which involves the mucous membrane of the mouth and vagina (thrush), the skin or nails. Other species such as *C. tropicalis*, *C. krusei* and *C. parapsilosis* may also be involved.

C. albicans forms about 20% of the normal flora of the mouth, gastro-intestinal tract, vagina and skin. The carriage rate tends to increase with age, and is higher in the vagina during pregnancy. Yeast overgrowth and infection occur when the normal microbial flora of the body is altered or when the host resistance to infection is lowered by disease.

Mucosal infections are the commonest form of superficial candidiasis. They are characterized by the development of discrete white patches on the mucosal surface which, may develop to form a curd-like pseudomembrane.

In the mouth or oral candidiasis white flecks appear on the buccal mucosa and the hard palate, the surrounding mucosa is red and sore and the infection may spread to the tongue. Infection occurs most frequently in infancy and old age, or in severely immune-compromised individual/patients, including those with AIDS.

In vaginal candidiasis, typical white lesions on the epithelial surface of the vulva, vagina and cervix are accompanied by itching, soreness and a non-homogenous white discharge. Sometimes the mucosa simply appears inflamed and friable. The peri-vulval skin may become sore and small satellite pustules may appear around the perineum and natal cleft. Vaginal candidiasis is common, especially during pregnancy; most women will have at least one episode during their lifetime and some suffer recurrent attack.

Other site of infection is the skin and nail. Skin infection occurs at moist sites such as the axillae, groins, perineum, sub-mammary folds and toe clefts. In infants, *Candida* species are frequently involved in napkin dermatitis.

Infection of the finger webs, nail folds and nails is an occupational disease of housewives, nurses and barmaids, who frequently immerse their hands in water.

Superficial infections occasionally occur on the penis after intercourse with females with vaginal thrush. The yeast may also affect the outer ear.

In the treatment of superficial candidiasis, the predisposing factor has to be taken into consideration in addition to the use of nystatin and amphotericin B. Azoles are more effective. In oval candidiasis, nystatin, amphotericin B and miconazole can be used in gel or lozenge form. The application of an azole derivative or with oral therapy with fluconazole or itraconazole for 1 day can be used to treat vaginal candidiasis successfully.

Treatment of chronic paronychia involves a combination of antifungal therapy, nail care and avoidance of prolonged exposure to water. Patients should dry their hands carefully after washing. Regular application of an azole lotion or an azole given orally is appropriate, but it may take several months to cure the condition; antifungal creams or ointment are less effective.

3.1.3 Tinea nigra

This is an asymptomatic skin disease caused by a black mould *Exophida werneckii*, characterized by pigmented macules of variable size, usually on the palms and soles. The disease is not contagious but is contracted by contact with the fungus in the soil.

Treatment is with the use of keratolytic agents such as Whitfield's ointment.

3.2 SUBCUTANEOUS MYCOSES

This is a disease of the skin, subcutaneous tissues and bone. They result from the infection of saprophytic fungus that grows in the soil, on living or decaying plant tissues, into the wounds, where it grows and spreads along lymphatic channels, producing subcutaneous nodules that sometimes drain to the skin.

Subcutaneous mycoses include mycetoma, chromomycosis and sporotrichosis.

3.2.1 Mycetoma

Mycetoma is a chronic, granulomatous infection of the skin, subcutaneous tissues, fascia and bone of the foot or the hand. It is caused by a member of the actinomycetes (actinomycetoma) or moulds (eumycetoma). Infection occurs when the organism is introduced into the subcutaneous tissue through thorns or sphisters from soil or vegetable source. Hence, the disease is most common in male agricultural workers, who acquire minor skin injuries.

Within host tissues, the organisms develop to form compacted colonies (grains), 0.5-2 mm in diameter, whose colour depends on the organism responsible; for example, *Madurella* grains are black and *Actinomadura pelletieri* grains are red.

Localized swollen lesions, which develop multiple draining sinuses, are usually found on the limbs, although infection occurs on other parts of the body.

The prognosis varies according to the causal agent, so it is important that its identity is established.

Actinomycetoma responds well to rifanipicin in combination with sulphonamide or cotrimoxazole. In eumycetoma, chemotherapy is ineffective, and radical surgery is usually necessary.

3.2.2 Chromomycosis

This disease, also known as chromoblastomycosis, is a chronic, localized disease of the skin and subcutaneous tissues. It is characterized by crusted, warty lesion in the limb. It is a tropical disease.

The causative agents include *Fonsecaea pedrosoi*, *F. compacta*, *Phialophora vernicosa*, *Cladosporium carrianii.*

Itraconazole, either alone or in combination with flucytosine is used for treatment. Early, solitary lesions may be excised.

3.2.3 Sporotrichosis

Sporotrichosis is a chronic, pyogenic granulomatous infection of the skin and subcutaneous tissues which may remain localized or show lymphatic spread. It is caused by *Sporothrix schenckii*, a saprophyte in nature.

S. schenkii is a dimorphic fungus. In nature and in culture at 25-30%, it develops as a mould with thin septate hyphae; spore-bearing hyphae carry clusters of oval spores. The yeast phase is formed in the tissue and in culture at 37˚C, and is composed of spherical cells.

Sporotrichosis most frequently presents as a modular, ulcerating disease of the skin and subcutaneous tissues. Typically, the primary lesion is on the hand with secondary lesion extending up the arm. The primary lesion may remain localized or disseminate to involve the bones, joints, lungs and in rare cases, the central nervous system. Disseminated disease usually occurs in debilitated or immunosuppressed individuals.

Treatment with potassium iodide or itraconazole is effective for the cutaneous form. In disseminated disease, intravenous amphotericin B is required.

4.0 CONCLUSION

Fungi such as the systemic pathogens *Histoplasma capsulatum* and *Coccioides immitis* are able to establish infection in all exposed individuals while others such as *Candida* and *Aspergillus* species, are opportunistic which ordinarily cause disease only in a compromised host. In some mycoses, the form and severity of the infection depend on the degree of exposure to the fungus, the site and the methods of entry the body, and the level of immunity of the host. Allergic disease of the airways may result from the inhalation of the fungal spores.

5.0 SUMMARY

Fungal infections or diseases are known as mycoses. Most of the fungi are dimorphic in nature. In other words, they grow as moulds in the soil or in culture and as yeast in human tissues. Infection occurs as a result of the inhalation of the spores of the fungi through the lungs. The infection may be localized or disseminated to other organs or tissues in the body. Allergic reactions may also occur as a result of the inhalation of fungal spores.

Fungus causes three types of diseases namely;

(a) Superficial mycoses
(b) Subcutaneous mycoses
(c) Systemic or deep mycoses

The incidence of all the mycoses is related directly to factors which affect the degree of exposure to the causal fungi e.g. living condition, occupation and leisure activities.

Superficial and subcutaneous mycoses often produce characteristic lesions which strongly suggest a fungal aetiology but they may also closely resemble and be confused with other diseases.

There are relatively few therapeutically useful antifungal agents, most of which are only for topical use, and relatively few can be administered systematically. Some, such as itraconazole and terbinafine are usually administered orally; others like amphotericin B and niconazole are given parenterally because of poor absorption from the gastrointestinal tract while flucytosine and fluconazole are available for oral or parenteral administration.

Antifungal prophylaxis may be used for the prevention of opportunistic infection.

6.0 TUTOR-MARKED ASSIGNMENT

1. What do you understand by the word “mycosis”?
2. Briefly describe superficial mycoses
3. Write short note on;
    a. Ringworm infection
    b. Superficial coccidioides
    c. Aspergillosis
4. Briefly describe the diseases;
    a. Mycetoma
    b. Sporotrichosis

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MODULE 4

UNITS 2: FUNGI DISEASES IN MAN (CONTINUED): SYSTEMIC (DEEP) MYCOSES

1.0 INTRODUCTION

SYSTEMIC (DEEP) MYCOSES

Systemic mycoses or deep-seated fungal infection are usually acquired by inhaling the spores of free living fungi present as dimorphic fungi the diseases include coccidiomycosis, blastomycosis, histoplasmosis, and cryptococcosis.

Several systemic mycosis also occur in patients compromised by disease or drug treatment. These opportunistic mycoses include systemic candidiasis, aspergillosis and zygomycosis.

2.0 OBJECTIVES

At the end of this unit, the learner will be able to:

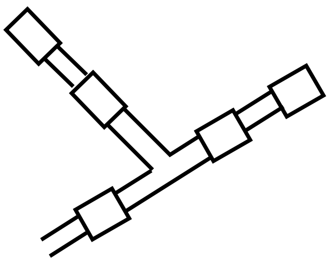
1. Know the meaning of systemic mycoses

2. Know the different diseases caused by fungi
3. Differentiate between mould and yeast
4. Know the drug of choice for the different fungi diseases

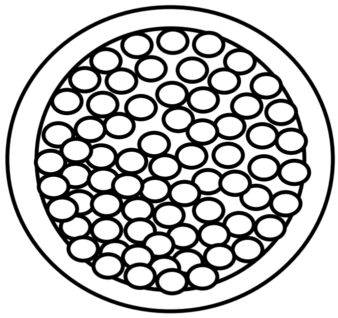
3.0 MAIN CONTENT

3.1 Coccidiomycosis

This is primarily an infection caused by *Coccidiodis immitis,* a dimorphic fungus found in the soil of semi-arid areas especially in South-Western States, California and Mexico. In the soil and on moist culture media, *C. immitis* grows as a mould, forming barrel-shaped arthrospores at the tip of hyphae, which is easily dispersed in wind currents. However, in humans, it grows as yeast, forming thick-walled spherules filled with endospores. See diagram below.



C. immitis in culture and soil



Thick-walled spherules in human being (lungs)

The disease is acquired by inhaling arthrospores usually contained in dust. Primarily pulmonary coccidiomycosis develops after an incubation period of 7 to 28 days. Skin rashes may develop with the diseases. Endospores.

Endospores are released by rupture of the spherule walls and develop to form new spherule in adjacent tissue, or following dissemination, in other organs of the body.

C. immitis usually cause an asymptomatic or self-limiting pulmonary illness, but a progressive and sometimes fatal secondary disease occasionally develops.

Treatment is by the use of intravenous amphotericin B and concomitant intrathecal therapy is required in the meningeal form. Ketoconazole and itraconazole are also useful.

3.2 Blastomycosis

Blastomycosis is a chronic infection of the lungs which may spread to the skin and bones. It is caused by *Blastomyces dermatitidis*, a dimorphic fungus which grows as a mould with a septate mycelium on culture, but as a budding yeast in human tissues. Infection results from inhalation of spores, especially in cool, wet climate condition.

Primary lung disease is usually relatively mild, but within a few weeks the disease may disseminate to other tissues.

In disseminated infection the chronic pulmonary disease persists, and abscesses and granulomatous lesions are found in most organs and body tissues including bone. Chronic cutaneous lesions occur in about 80% of patients with pulmonary infection; the characteristic secondary skin lesions are typically raised with a well-demarcated edge. It is from these skin lesions that the diagnosis is most often made.

Intravenous amphotericin B is the drug of choice in the treatment of all forms of serious blastomycosis. Hydroxystilbamidine is used in localized disease. Oral ketoconazole or itraconazole are also effective in less serious extra-central nervous system blastomycosis.

3.3 Histoplasmosis

The causative agent of this disease is *Histoplasma capsulatum* , a fungus which grows in culture as a mould and as an intracellular yeast in animal tissues. The fungus is an intracellular parasite found in soil enriched with the droppings of birds and bats, and infection results from the inhalation of the spores.

Histoplasmosis is an asymptomatic or relatively mild, self-limiting pulmonary infection, although chronic or acute disseminated disease may also occur.

A chronic form of histoplasmosis occurs mainly in adults; large cavities develop from primary lesions in the lung or by reactivation of old lesions. Occasionally the acute form of the disease may spread to infect the reticulo-endothelial system and disseminate to other organs of the body. Disseminated infection occurs most often in old age and infancy, or in individuals with impaired immune response.

Treatment is by the use of intravenous amphotericin B for disseminated histoplasmosis in immunocompromised patients. Ketoconazole and itraconazole give good results in less ill cases.

3.4 Cryptococcosis

Cryptococcosis is carried by *Cryptococcus neoformans,* a fungus that is commonly found in the excreta of wild and domesticated bird throughout the world. The birds themselves are not infected. Cryptococcosis occurs frequently as a disease of the central nervous system, although the primary site of infection is the lung. It occurs sporadically throughout the world but it is now seen most often in patients with Acquired Immune Deficiency Syndrome (AIDS). Lesions of the skin, mucosa, viscera and bones may also occur. In its disseminated form, the disease may resemble tuberculosis.

Infection follows inhalation of the cells of the organisms into the lungs, resulting in a mild self-limiting pulmonary infection in symptomatic infection. Lesions may take the form of small discrete nodules which may heal with a residual scar or may become enlarged, encapsulated and chronic. The meningeal form can occur in immunosuppressed individuals. Chronic meningitis or meningo-encephalitis develop insidiously with headaches and low-grade pyrexia, followed by changes in mental state, anorexia, visual disturbances and eventually coma. The outcome is always fatal unless it is treated. Most cryptococcal infections are now seen with individuals with AIDS, 3–20% of whom develop cryptococcosis.

Treatment is by the use of intravenous ampholericin B in combination with flucytosine. Intrathecal amphotericin B may also be used in severe meningeal disease. Patients with AIDS commonly relapse after the initial course of therapy, and may react badly to the drug. Fluconazole can be used for treatment and also as a maintenance therapy to control cryptococcosis in AIDS patients.

3.5 Systemic Candidiasis

The main causative agent of systemic candidiasis is *Candida albicans.* Other organisms involved are *C. tropicalis, C. glabrata,* and *C. hisitaniae.* The disease results following overgrowth of these commensal yeasts in association with serious abnormality of the host. The abnormality may be as result of immunosuppressed patients, patients treated with antibiotics or steroids or in patients after organ transplant or heart surgery.

The disease may be localized or widely disseminated and associated with a septicaemia (candidaemia).

Common sites of Involvement in disseminated systemic candidiasis include the kidney, liver, spleen, brain and gastro-intestinal tract. The symptom is the presence of white candidal lesions within the eye (Candida endophythalmitis). Candida endocarditis usually follows surgery for valve replacement, but also occurs in drug addicts and occasionally in patients on immunosuppressive therapy. Infection of the kidney is usually blood-borne. Bladder infections are usually associated with the presence of an indwelling urinary catheter and the infection often clears when the catheter is removed.

Intravenous amphotericin B in combination with flucytosine is the treatment of choice for most form of systemic candidiasis. Flucytosin is not used on its own due to problem of resistance. Fluconazole, ketoconazole and itraconazole have also been used successfully.

3.6 Aspergillosis

This is caused by *Aspergillus* spp, notably among them are *Aspergillus fumigatus, A. niger, A. flavus, A. terreus and A. nidulans.* Inhalation of the spores of these organisms may lead to the development of different types of diseases depending on the location and types of organisms.

Aspergilloma*:* This is also referred to as fungus ball. The fungus colonizes pre-existing (often tuberculous) cavities in the lungs and form a compact ball of mycelium, eventually surrounded by a dense fibrous wall. Patients are either asymptomatic or have only a moderate cough and sputum production. Occasionally, haemophysis may occur. Surgical resection is most often used to treat this condition.

Allergic aspergillosis: This usually occur in atopic individuals with elevated IgE level. Asthma with cosinophilia is a more chronic form. The fungus grows in the airways to produce plugs of fungal mycelia which may block off segment of living tissues. Allergic alveolitis follows particularly in heavy and repeated exposure to a large number of spores. Breathlessness, fever and malaise appear some hours after exposure, and repeated attacks result in progressive lung damage.

Invasive Aspergillosis: This is often caused by *Aspergillus fumigatus*, and occurs mostly in severely immunocompromised individuals with serious underlying illness. The lung is the sole site of infection from which it spreads into tissues as blood vessels causing thrombosis. Septic emboli may spread the infection in other organs, especially the kidneys, heart and brain. Invasive aspergillosis has a poor prognosis and is often diagnosed post mortem.

Treatments of allergic forms of aspergillosis are with the use of corticosteroids. Aspergilloma is treated by surgical incision or sometimes with antifungal agents. In invasive aspergillosis, the treatment of choice is intravenous amphotoricin B.

3.7 Zygomycosis

Zygomycosis is a relatively rare, opportunistic infection caused by saprophytic moulds of the species of Rhizopus, Mucor and Absidia. The disease is also known as mucormycosis or phycomycosis.

The best known form of the disease is rhinocerebral zygmycosis, a rapidly fulminating infection which is associated with either acute diabetes mellitus or with debilitating disease such as leukaemia or lymphoma. There is extensive cellulitis with rapid tissue destruction; most commonly spreading from the nasal mucosa to the turbinate bone, paranasal sinuses, orbit and brain. Rhinocerebral zygomycosis is rapidly fatal if untreated. Most diagnoses are made at necropsy.

Pulmonary and disseminated infection can occur in severely immuno-compromised individuals.

Treatment depends on early diagnosis of the infection so as to allow for prompt therapy with intravenous amphotericin B and aggressive surgical intervention.

4.0 Conclusion

Systemic mycoses are part of the diseases caused by fungi. They are known as deep-seated infections, occurring in the lungs as the first point of contact of the organisms in man or animals. They are then localized or disseminated to other tissues or organs of the body. Some of the diseases are self limiting, while others may be fatal if not treated.

Treatment of most of the diseases is by the use of intravenous amphotericin B**,** itraconazole or/and ketoconazole**.**

5.0 Summary

Systemic mycoses result from the inhalation of the spores of fungi such as those from the species of Coccidiodes, blastomycetes, histoplasma etc into the lungs. Most of these organisms are dimorphic in nature; they grow as moulds on the soil or vegetation plants or in culture, and as yeast in animal tissues.

The disease may be localized in the lungs or disseminated to other tissues or organs in the body.

6.0 Tutor-Marked assignment

1. What do you understand by the word "systemic mycoses?"
2. Briefly describe the disease "Aspergillosis"

7:0 References/Further Readings

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MODULE 4

UNIT 3: BENEFICIAL/IMPORTANCE OF FUNGI

1.0 INTRODUCTION

Traditionally, the role of yeast from the technical and industrial standpoint cannot be over emphasized. Although many genera and species of yeast exist in nature and many of them are used industrially; most important are the strains of *Saccharomyces cerevisiae*. They are used in the manufacture of wine and beer, and in the leavening of bread.

The use of yeast as a leavening agent for bread originated in Egypt about 6,000 years ago, and spread slowly to the rest of the western world. The discovery that alcohol can be distilled and so concentrated originated either in China or the Arab world.

2.0 OBJECTIVES

At the end of this unit, the learner will be able to

1. Know the process involved in the making of different type of wine and the organisms involved.
2. Know the process of beer making and the organisms involved.
3. Know the process of bread making and the organisms involved.
4. Know the meaning and definition of saccharification and leavening of bread.
5. Know the different products from fungi such as the different antibiotics and specific organisms involved.

3.0 MAIN CONTENT

3.1 WINE PRODUCTION

Wine production involved the fermentation of the soluble sugars (Glucose and fructose) of the juices of grapes into ethyl alcohol and CO_2. After the grapes are harvested, they are crushed to produce a raw juice or must, a highly acidic liquid containing 10 – 25% sugar by weight in any parts of the world, the mixed yeast flora on the grapes serves as the inoculums for the fermentation that convert the must into wine. In such a natural fermentation, a complex succession of changes in the yeast population occurs, in the later stages, the true wine yeast *Saccharomyces cerevisiae* var. ellipsoids predominates.

In California, the must is first treated with sulphur dioxide (SO_2) to eliminate the natural yeast flora; it is then inoculated with the desired strain of wine yeast. Must from both red and white wine grapes (*Vitis vinifera*) is white and results in a white wine. Since the colour of red grapes is in the skin, red wines are made by fermentation in the presence of the skin, the alcohol developed during fermentation extract the colour into the wine. Following fermentation the new wine must be classified, stabilized and aged to produce a satisfactory final product. These processes require months, and for high quality red wine, even years.

Although the high alcohol content and low pH (3.0) of wines make them unfavourable substrates for growth of most organisms, they are subject to microbial spoilage, especially when they are exposed to air film-forming yeast and acetic acid bacteria grow at the expense of the alcohol, converting it to acetic acid, this sourcing the wine in the absence of air, lactic acid bacteria grows at the expense of residual sugar and impart a “mousy” taste is the wine. Wine yeast can grow in sweet wines even after boosting, making the wine become cloudy and less attractive.

Wine spoilage can be prevent either by chemical additives such as sulphur dioxide (SO_2) or by sterilization through filtration.

3.2 BEER PRODUCTION

Beers are manufactured from grains, such as barley, corn and rice; which contain no fermentable sugars. The starch of the grams are first hydrolyzed in the fermentable sugars, maltose and glucose before fermentation by yeast the process of hydrolyzing the starch is maltose and glucose is called saccharification. Different grains have different saccharification processes.

In the case of barley, starch hydrolyzing enzymes (amylase) of the grain itself is used. Barley seeds contain little or no amylase, but upon germination large amount of amylase are formed. Hence barley is dampened, allowed germinate, and is then dried and stored for subsequent use. Such dried, germinated barley called malt, is dark in colour as a result of exposure to increased temperatures during drying. The starch of barley remains largely unaffected by the malting process, the first step in beer making is the grinding of malt and its suspension in water is allow hydrolysis of the starch. If a lighter beer is desired, unmalted barley or source other cereal grain is added to the saccharifying mixture. After saccharification has reached the desired stage, the mixture is boiled to stop further enzymatic changes and it is then filtered. Hops are added to the filtrate (wort) and contribute a soluble resin, which impacts the characteristics bitter flavour of beer and which also acts as a preservative against the growth of bacteria. After filtration the hopped wort is ready for fermentation. Special stains of yeast (*Saccharomyces cerevisiae*) are used as inoculum to commence the fermentation process which usually takes a period of 5 to 10 days at low temperature.

During the course of time, special strains of *S. cerevisiae* with desirable properties have been selected known as brewer's yeast. Strains of brewer's yeast fall into two groups known as top and bottom yeast. Top yeast so called because during fermentation they are swept to the top of the vat by the rapid evolution of CO_2. They are vigorous fermenters acting best at relatively high temperature (20%), and are used for making heavy beers of high alcoholic content such as English ales. In contrast, the bottom yeasts are so called because the slower rate of CO_2 evolution allows them to settle to the bottom of the vat during fermentation. They are slow fermenters, act best at low temperature (12% to 15%), and produce highly low alcoholic content beers like those made in the United States.

The diseases of beer occur most commonly following fermentation either during maturation or following bottling. One agent is a wild yeast *Saccharomyces pasteurcarius* which impacts a disagreeable bitterness to beer. Spoilage of beer can be prevented by the use of pure yeast strains as starters and pasteurization of the final product.

3.3 BREAD PRODUCTION

The yeast used in bread production belongs to the species *Saccharomyces cerevisiae*. Until the nineteenth century, yeast for bread making were obtained directly from the nearest brewery, but today the production of compressed yeast called baker's yeast is dried under controlled condition that maintain viability of the yeast cells, a treatment that facilitates shipment and storage is used.

An alcoholic fermentation by yeast is an essential step in the production of raised breads; this process is known as the leavening of bread.

During bread production, moisturized flour is mixed with yeast and allows to stand in a warm place for several hours. Flour itself contains almost no free sugar to serve as a substrate for fermentation, but there are some starch splitting enzymes present that produces sufficient sugar fermentation. In the highly refined flours these enzymes have been destroyed, and sugar must be added to the dough, the sugar is rapidly fermented by yeast the CO_2 produced is entrapped in the dough causing it to rise; a process known as leavening while the alcohol produced is driven off during the baking process.

3.4 FUNGI AS A SOURCE OF PROTEIN

Microorganisms because of their rapid growth, high protein content and ability to utilize organic substrates of slow cost are potentially valuable sources of animal food. Yeasts are the principal organisms that have been used and the generic name for the microbial product is single cell protein. The proposed use of single cell protein is as a supplement for animal feed to replace the other major supplements, soya beans and fish meal.

3.5 THE DISCOVERY OF ANTIBIOTICS

The first chemotherapeutically effective antibiotic was discovered in 1929 by Alexander Fleming, a British bacteriologist. He noticed that among a pile of petri dishes on his bench one that had been streaked with a culture of *Staphylococcus aureus* was also contaminated by a single colony of mould. Moreover, the colonies immediately surrounding the mould were transparent and appeared to be undergoing lysis. He reasoned that the mould was excreting into the medium a chemical that caused the surrounding colonies to lyse. He isolated the mould, which proved to be a species of penicilium, and stabilized that that culture filtrates contained an antibacterial substance which he called penicillin.

Penicillin rather than being a single substance, proved to be a class of compounds. These include penicillin G, penicillin F, Penicillin V, ampicillin and oxacillin.

Since 1945, thousand of different antibiotics produced by fungi, *Actinomycetes* have been isolated and characterized, for example, streptomycin obtained from *Streptomyces griseus* which is effective against many Gram-positive and Gram-negative and *Mycobacterium tuberculosis* was discovered by A. Schatz and S. Waksman. Tetracycline was produced from *S. aurefaciens* chloramphenicol from *S. venezuelae*, erythromcin from *S. erythreus* and cephalosporin from *Cephalosporium* spp.

CONCLUSION

Fungi have been found to be very useful to mankind and its importance cannot be over emphasized. Fungi has been involved in the fermentation of soluble sugars such as glucose and fructose into ethanol during wine production, they are also involved in the production of beer and leavening of bread. What would have been the fate of most patient or war victims in a world without antibiotics? Most of the antibiotics today are products of fungi.

SUMMARY

Microbial processes have been used by humans since prehistoric times in the preparation of food, drinks and other chemical. This process became controlled and perfected in the middle of the nineteenth century. The outstanding examples of traditional microbial processes are those used in the production of beer and wine and in the leavening of bread. The rise of microbiology which revealed the nature of these traditional processes led not only to the great improvements of many of them, but also to the development of entirely new industries based on the use of microorganisms that had previously not been exploited by humans.

TUTOR-MARKED ASSIGNMENT

1. Briefly describe the terms
    (a) Saccharification
    (b) Leavening of bread
    (c) Formation of malt
2. Describe the processes involved in beer production, using either "barley" or "rice"
3. List ten (10) products of fungi and the specific organisms involved in each of the product.

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