GENERAL CHARACTERISTICS OF FUNGI

Fungi (singular: fungus) are members of eukaryotic organisms that include microorganisms such as yeast, moulds and mushrooms.

1. Most fungi are saprophytic in nature, and thus feed on dead organic matter.
2. They are non-phototrophic eukaryotic microorganisms that are heterotrophic in nature.
3. They contain rigid cell walls that are made up of chitin unlike bacteria cell wall that contains cellulose.
4. They form characteristic structures called mycelium and hyphae.
5. They also form fruiting structures especially fungal spores. The spores of fungi are ubiquitous in the air, soil and dust, and they serve as source of contamination to both humans and animals.
6. The size of fungi ranges from 2.0- 1.0 µm (for moulds) and 5 – 10 µm (for yeasts).
7. Fungi have beneficial importance as they are usually used for the production of some antibiotics like penicillin and food such as bread. For example, yeasts are used in the food industry to produce beverages like bread, wine and beer.
8. They also cause a range of diseases in animals, plants and humans.

OVERVIEW OF FUNGAL INFECTIONS

The study of fungi is called mycology. Fungal infections are generally known as mycosis (plural: mycoses). Pathogenic fungi are eukaryotic organisms that cause infections or diseases in man, plants and animals. Most fungal infections usually arise from the inhalation of fungal spores from the environment. Fungal spores are suspended in the atmosphere, and they can be inhaled by susceptible human or animal hosts when the opportunity arises. However, the immune status of the exposed individual is critical to the containing or fighting of the infection once the fungal spores have been inhaled. If the host immune system has been compromised either via chemotherapy (as can be seen in cancer patients) or through the presence of an immune deficiency disease such as AIDS, the infected host stands the chances of being seriously affected by the invading fungus.

People at risk of acquiring fungal infections include:

- Individuals on high antibiotic therapy.
- Immunocompromised patients such as AIDS patients.
- Individuals under steroid treatments.
- Individuals under chemotherapy such as cancer patients.
- Diabetic patients.
- Young people.
- Elderly people.
- Everybody. Though everyone is at risk of acquiring or developing one fungal infection or the other, the above people are mostly at risk of developing fungal infection than the rest of the population (with intact immune system) because of an impediment or problem with their health status.

CLASSIFICATION OF MYCOSES

The classification of fungal infection is usually based on the part of the body or particular tissue or organ of the body that is mostly affected. Aside this, human mycoses can also be classified with consideration to the site of the infection, route of entry of the pathogen, and the type of virulence exhibited by the fungus. However, there are usually five (5) different human mycoses; and these main classes of fungal mycoses in humans include:
As shown in Figure 1 and Figure 2 below, fungal spores of pathogenic fungi have different portal or route of entry into the body; and these individual portals of entry depicts the passage way of the fungal spores into the host. They are very crucial in fungal pathogenesis because fungal organisms responsible for causing superficial mycoses may not cause systemic mycoses because they have different routes of entry into the host. The parts of the human body, organ or tissue mostly affected by pathogenic fungi include the lungs, skin, liver, spleen, kidney, hair and the nails including those of the fingers and toes.

Figure 1. Human tissue sites of deep mycoses in comparison to those of the superficial, cutaneous, and subcutaneous mycoses.
Superficial mycoses are fungal infections of the outer skin surface and the hair. This type of mycoses includes the following fungal infections (with their etiological agent in parenthesis): black piedra (*Piedraia hortae*), white piedra (*Trichosporon beigelii*), pityriasis versicolor (*Malassezia furfur*), and tinea nigra (*Phaeoannelomyces werneckii*). Pityriasis versicolor is a common superficial mycosis, which is characterized by hypopigmentation or hyperpigmentation of skin of the neck, shoulders, chest, and the back. Pityriasis versicolor involves only the superficial keratin layer of the skin. Black piedra is a superficial mycosis that is manifested by a small firm black nodule involving the hair shaft. White piedra is characterized by a soft, friable nodule of the distal ends of hair shafts. Tinea nigra usually presents as a brown to black silver nitrate-like stain on the palm of the hand or sole of the foot. Superficial mycoses are limited to the stratum corneum of the skin; and they generally do not elicit any form of inflammation.

Cutaneous mycoses are fungal infections that extend beneath the outer skin surface and into the epidermis layer of the skin. Fungal organisms that cause cutaneous mycoses are called dermatophytes. They cause nail diseases and diseases of the invasive hair. Infections caused by dermatophytes are restricted to the keratinized layers of the skin, hair, and nails; and these infections can also be called ringworm or tinea. Cutaneous mycoses may also be called dermatophytoses or dermatomycoses due to their causative agents. Dermatophytoses are caused by three main etiological agents or dermatophytes in the fungal genera: *Epidermophyton*, *Microsporum*, and *Trichophyton*. Dermatomycoses are cutaneous infections due to other fungi that exclude the dermatophytes (i.e. *Epidermophyton*, *Microsporum*, and *Trichophyton*), and the most common causative agent of dermatomycoses are Candida spp. known to cause candidiasis in humans. The dermatophytoses are characterized by an anatomic site-specificity according to genera. For example, *Epidermophyton floccosum* infects only the skin and nails, but
does not infect the hair shafts and follicles while *Microsporum* spp. infect the hair and the skin, but do not infect the nails. *Trichophyton* spp. infect the hair, skin, and the nails.

**Subcutaneous mycoses** are fungal infections of the subcutaneous layer of the skin. They involve the dermis, subcutaneous tissues, and muscles. The three types of subcutaneous mycoses are: chromoblastomycosis, mycetoma, and sporotrichosis. These mycoses are usually caused by a traumatic inoculation of the etiologic agent into the dermis or subcutaneous layer of the skin. They are usually difficult to treat, and may require surgical operation to resolve. **Chromoblastomycosis** is a subcutaneous mycosis characterized by verrucoid lesions of the skin; and there is no involvement of the bone, tendon, or muscle. The most common causes of chromoblastomycosis are *Fonsecaea pedrosoi*, *Fonsecaea compacta*, *Cladosporium carionii*, and *Phialophora verrucosa*. **Mycetoma** is a suppurative and granulomatous subcutaneous mycosis caused by dematiaceous (melanized) fungi such as *Pseudallescheria boydii* and *Nocardia brasiliensis*. Mycetoma destroys the bone, tendon, and skeletal muscle. Dematiaceous or dimorphic fungi are fungi that exhibit both yeast-like and mould-like features. **Sporotrichosis** is caused by *Sporothrix schenckii* and it involves the subcutaneous tissue at the point of traumatic inoculation. The infection usually spreads along cutaneous lymphatic channels of the extremity involved.

**Systemic mycoses** are fungal infections that are disseminated widely in the body. They can also be called deep mycoses. Unlike superficial mycoses, cutaneous mycoses and subcutaneous mycoses which are localized in a particular organ or tissue of the body, systemic (deep) mycoses are not localized in the body, and they are usually spread throughout the body via the blood stream. Systemic mycoses usually originate from the lungs after the inhalation of infective fungal spores, and it spreads to other parts or organs of the body from this site. The causative agents of systemic (deep) mycoses (with the disease they cause in parenthesis) include: *Histoplasma capsulatum* (histoplasmosis), *Blastomyces dermatitidis* (blastomycosis), and *Coccidioides immitis* (coccidioidomycosis). The pathogenic fungi that cause systemic mycoses are usually restricted to some geographical locations of the world – where the disease and/or causative agents are most endemic; and people who mostly suffer from these infections are those living in these endemic regions as well as people who visit these places. Most causative agents of systemic mycoses are dimorphic in nature, and this implies that they can assume both yeast-like and mould-like characteristics.

**Opportunistic mycoses** are fungal infections that happen in immunocompromised individuals, and they are caused by fungal organisms known as opportunistic fungi. Opportunistic fungi do not cause mycosis in people with intact immune system. The alteration of the normal body flora by antibiotics, presence of HIV/AIDS, exposure to chemotherapy and cancer are typical examples of immunocompromised conditions that can expose someone to acquiring an opportunistic mycosis. Examples of opportunistic mycoses (with their causative agents in parenthesis) include: candidiasis (*Candida* species), aspergillosis (*Aspergillus* species), zygomycosis (caused by moulds including *Rhizopus* and *Mucor* species) and cryptococcosis (*Cryptococcus* species).

**CONTROL, PREVENTION AND TREATMENT OF FUNGAL INFECTIONS**

Fungal infections can be controlled by ensuring a spore-free environment especially in working places, hospitals and even in our homes. People working in places where dust particles can be easily aerosolized such as road construction workers and farmers should ensure that they always wear protective face mask that will prevent the inhalation of fungal spores from dust particles that result from their job or activities. Fungal spores are found in the air and even in dust particles; and when they become aerosolized, infection can set in once these spores are inhaled by susceptible host. The prevention of fungal infection especially those involving systemic mycoses could be achieved by avoiding visits to endemic regions of the disease or taking necessary precautions when in such areas. Fungal infections can be treated with antifungal agents; and these agents are used topically or
systemically. However, most antifungal agents are topically applied on the surface of the skin since many of them have untoward effects greater than antibacterial drugs used to treat bacterial infections or diseases.

**GENERAL CHARACTERISTICS OF PROTOZOA**

Protozoa (singular: protozoan) are unicellular eukaryotic microorganisms that lack cell wall. They are motile and move by means of cilia, flagella and pseudopodia. They are single-celled organisms, and they can only be seen under a microscope. Their size varies from 5-200 µm, and they usually live in moist environments like soil, water and marshy environments. Protozoa are heterotrophic in nature, and thus depend on other organisms for their own food. Protozoa have varying importance in nature including those that are found in the stomach of animals and helps in their digestion, and plasmodium parasites which are the best known protozoa because they cause disease in humans. Typical examples of protozoa include amoeba, plasmodium and trypanosome parasites – which causes amoebiasis, plasmodiasis, and trypanosomiasis respectively.

A parasite is an organism that lives on or in a host organism and gets its food from or at the expense of its host. Parasitic infections cause a tremendous burden of disease in both the tropics and subtropics as well as in temperate countries. Of all parasitic diseases, malaria is reported to cause the most deaths globally. Malaria according to the center for disease control and prevention (CDC) kills approximately 660,000 people annually, and most of these people are young children in sub-Saharan Africa (e.g. Nigeria).

There are three main classes of parasites that can cause disease in humans:

1. Protozoa
2. Helminths
3. Ectoparasites

Protozoa as aforementioned are microscopic in nature. They are one-celled or single-celled organisms that can be free-living or parasitic in nature. Free-living - because some protozoa do not cause disease, and parasitic - because some protozoa can cause disease in their human or animal host. The transmission of protozoa that live in a human's intestine to another susceptible human host typically occurs through a fecal-oral route (for example, contaminated food or water or person-to-person contact). Protozoa that live in the blood or tissue of humans are transmitted to other humans by an arthropod vector (for example, through the bite of a mosquito as can be seen in the case of malaria – in which a mosquito passes on the *Plasmodium* parasite to a susceptible human host via a bite or when taking a blood meal from the host).

**CLASSIFICATION OF PROTOZOA INFECTIOUS TO HUMANS**

The protozoa that are infectious to humans (i.e. that cause disease in man) are classified into four (4) groups as follows:

1. **Sporozoa.** The sporozoan are mostly blood-borne parasites e.g. *Plasmodium* species and *Cryptosporidium* species
2. **Sarcodina.** These are called the amebas e.g. *Entamoeba*
3. **Ciliophora.** These are called the ciliates e.g. *Balantidium*
4. **Mastigophora.** These are called the flagellates e.g. *Leishmania* species and *Giardia*

Helminths are large, multicellular organisms that are generally visible to the naked eye in their adult stages. They can be either free-living or parasitic in nature. In their adult form, helminths cannot multiply in humans. There are three main groups of helminths that are human parasites, and they include:
1. **Flatworms** (platyhelminths). These include the trematodes (flukes) and cestodes (tapeworms).
2. **Acanthocephalins** (Thorny-headed worms). The adult forms of the acanthocephala reside in the gastrointestinal tract.
3. **Roundworms** (nematodes). The adult forms of nematodes can reside in the gastrointestinal tract, blood, lymphatic system or subcutaneous tissues. Alternatively, the immature (larval) states can cause disease through their infection of various body tissues.

**Ectoparasites** are parasites that live outside the body of their host. Parasites that live within the body of their host (i.e. inside the body of their host) are called **endoparasites**. Examples of endoparasites are the protozoa and helminths discussed above. The term ectoparasites can broadly include blood-sucking arthropods such as mosquitoes (because they are dependent on a blood meal from a human host for their survival). Examples of ectoparasites include ticks, fleas, lice, and mites that attach or burrow into the skin of their hosts. Arthropods are important in causing diseases but they are more important as vectors, or transmitters, of many different pathogens that also cause disease in man.

**SOME EXAMPLES OF PARASITIC DISEASES**

1. **Amoebiasis**: This disease is caused by the sarcodina group of protozoa especially *Entamoeba histolytica*. Amoebiasis is transmitted through contact with infected feces. Food and water contaminated by feces is the most common route of transmission, but oral contact with fecal matter can also cause infection. Common symptoms of amoebiasis include loose stools with varying amounts of blood and an inflamed colon.
2. **Giardiasis**: This disease is caused by *Giardia lamblia*. It is transmitted through oral contact of feces as the parasite is found in fecal matter. If hands are not properly washed after using the bathroom or changing a diaper, it is easy to come into contact with this parasite. Drinking water which has been contaminated by this parasite or even ingesting contaminated swimming water can cause giardiasis. Symptoms include mucous stools, diarrhea, nausea, abdominal pain and upset stomach.
3. **African sleeping sickness**: African sleeping sickness is a disease caused by *Trypanosoma* species that is carried by tsetse fly. It is transmitted to humans through tsetse fly bites. Symptoms of this disease include confusion, seizures, insomnia, personality changes, weight loss, slurred speech and trouble talking or walking.
4. **Leishmaniasis**: This disease is caused by the *Leishmania* parasite. These parasites are found mainly in southern Europe, the tropics and subtropics. It is transmitted through the bite of a sand fly, which carries the parasite. Symptoms include weight loss, organ enlargement, fever and extremely high or low blood levels.
5. **Toxoplasmosis**: Toxoplasmosis is caused by *Toxoplasma gondii*. Many of the people infected by this disease do not have any symptoms. Other symptoms include body aches, fatigue, fever, sore throat and swollen lymph nodes.
6. **Malaria**: Malaria is a very common disease in some countries and is spread through mosquito bites of mosquitoes that have been infected by one of the many different malaria-causing parasites in the genus *Plasmodium*. Malaria symptoms include headache, aches and fever.
7. **Trichomoniasis**: This disease is caused by the protozoan parasite *Trichomonas vaginalis*. This disease is most commonly transmitted sexually. Symptoms of this disease differ per gender. In woman, vaginitis may occur which will cause white discharge. Men may experience a burning sensation while urinating.