**Pigeon droppings as a *Cryptococcus* reservoir: A Review**

**Abstract**

*Cryptococcus neoformans* are an encapsulated yeast and causative agent of cryptococcosis in man and animals. *C. neoformans* has worldwide distribution and infects immunosuppressed individuals, especially those suffering from AIDS. *Cryptococcus neoformans* and *Cryptococcus gattii* are the two species of Cryptococcus that are typically linked to human illnesses. It has been identified for its association with bird guano accumulations, particularly pigeon excrement, and has been isolated from various natural sources. The major environmental sources of *Cryptococcus neoformans* are soil contaminated with pigeon droppings or eucalyptus trees and decaying woods forming hollows in living trees. Pigeon droppings are a suitable environment for the growth of fungi and bacteria. Pigeon guano is a common source for infection propagules of *Cryptococcus neoformans* and is postulated to play a central role in transmission from the environment to humans. Pigeon dropping consists of nitrogen, phosphorus, potassium as well as other minerals. These constituents provide an excellent sanctuary that supports the growth of various microorganisms. The review emphasizes that pigeon droppings are a significant reservoir and spread site for the *Cryptococcus neoformans* fungus.

**Keywords**: *Cryptococcus neoformans*, Cryptococcosis, Pigeon droppings, Epidemiology, Fungi, Public health.

**Introduction**

Fungus is a eukaryotic, heterophilic, and adaptable living group that can infect humans and animals **(Pal, 2007**). They include molds, yeasts, and dimorphic fungus. Approximately 600 of the five million common fungal species have been linked to several clinical conditions in both people and animals (**Pal, 2019**). Numerous sources, including soil, avian excrement, air, water, sewage, bat guano, fruits, vegetables, woodlands, grains, etc., are known to contain fungi (**Pal, 2007; Pal, 2017; Pal, 2019**). Both humans and animals, including birds, are susceptible to fungal diseases, which are a major source of illness and mortality. The environment is the primary source of fungal infections, which can affect anyone because fungi are natural saprobes (**Pal, 2007**). Pigeons are found throughout the world, although they originated in Africa. They are very adaptive and can withstand a wide variety of environmental factors (**Gouge *et al*., 2022).** Birds and their droppings can cause over 60 diseases, a majority of which are airborne and can be spread to humans simply by being close to them **(Grisin, 2017)**. Humans and animals may become infected after being exposed to airborne particles carrying spores from bird droppings **(Nyakudi, 2011)**. Avian droppings are known to contain a variety of pathogenic and opportunistic microorganisms. Bird droppings have been identified as a possible environmental source of yeasts that are harmful to humans. Pigeon guano, which is abundant in public areas, could especially be a potential carrier in the spread of pathogenic yeasts - into the environment and subsequently humans **(Chee & Lee, 2005)**.

Humans and animals get the infection from an environment in which fungus thrives abundantly **(Pal, 2007)**. Cryptococcus is an invasive fungus that causes cryptococcosis, a disease that affects people with weak immune systems, but is rare in healthy people. Two cryptococcus species are commonly associated with human infections: *Cryptococcus neoformans* and *Cryptococcus gattii* **(Lin *et al.,*2015)**. The risk of acquiring cryptococcal infection is higher for zookeepers, pet bird keepers, pigeon breeders, and those who clean ancient structures **(Pal, 2006)**.

**Cryptococcosis**

Cryptococcosis is an emerging, life-threatening, hidden fungal saprozoonosis of global importance. It is an acute, subacute, and chronic mycosis caused by the genus *Cryptococcus,* which consists of 37 species, of which *Cryptococcus neoformans* and *Cryptococcus gattii* are implicated in most cases. Cryptococcosis is a cosmopolitan infectious disease of humans and animals caused by an encapsulated basidiomycetous yeast-like fungus called *Cryptococcus neoformans* **(Pal, 1975)**. Worldwide, Cryptococcosis is a potentially fatal opportunistic fungal infection. Acquired Immuno Deficiency Syndrome (AIDS), Malignancy, sarcoidosis, Hodgkin's lymphoma, Diabetes mellitus, and Organ transplantation are the risk factors for cryptococcosis **(Chayakulkeeree *et al*., 2006)**. A fungal infection known as cryptococcosis is brought on by the encapsulated, basidiomycetous yeast *Cryptococcus neoformans*, which is among found in environments all over the world. It includes infections brought on by *C. neoformans var. neoformans and C. neoformans* *var. gattii*, two different forms of the fungus, While *C. neoformans var. gattii* primarily affects immunocompetent hosts. *C. neoformans var. neofromans* is frequently linked to infections in immunocompromised patients **(Chayakulkeeree *et al.,*2006)**.

The encapsulated yeast of the genus *Cryptococcus* is the cause of the systemic mycosis known as cryptococcosis. Cryptococcus has a wide range of distribution. It is typically found in the waste surrounding pigeon nests, decaying wood, and soil polluted with pigeon or chicken droppings. Although pigeons are not afflicted, *C. neoformans* grow to high concentrations in their faeces. *Cryptococcus neoformans* and *Cryptococcus gatii* are the two most prevalent species. The infection enters the body primarily through the lungs. Clinical signs and symptoms include systemic spread and silent lung colonization. Meningoencephalitis is the primary clinical sign **(Tristano, 2010; Negroni, 2012)**. Cryptococcosis is most likely caused by inhaling the fungus, which causes a major focus in the lungs. Following hematogenous diffusion from the lungs, the CNS and skin are the two most prevalent sites of infection **(Chayakulkeeree *et al*., 2006)**. Human cryptococcosis and *Cryptococcus* infection are typically caused by inhaling environmental yeasts or spores of *Cryptococcus neoformans* and *Cryptococcus gattii. Cryptococcus neoformans* is the only known pathogenic species among the cryptococcal species **(Maziarz *et al*., 2016; May *et al*., 2016)**.

***Cryptococcus neoformans***

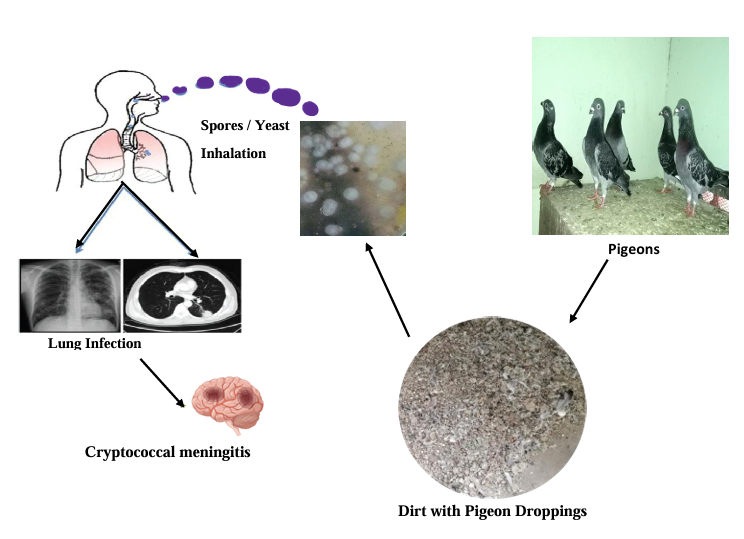
Generally single-budding, *Cryptococcus neoformans* is a spherical, yeast-like organism that ranges in size from 4 to 20µ in tissues and cultures. It is not dimorphic. Its primary feature is a thick, mucinous capsule, which is a pattern specific to pathogenic fungi but isn't always present in all strains and is often only observed in a small number of organisms. On existing culture media, it grows quickly at 37°C and room temperature **(Baker *et al*.,1971)**. One significant environmental source of *C. neoformans* is avian guano. This bacterium may also mate and create infectious spores in pigeon droppings, where it thrives. Other bird droppings or cloacal swabs have occasionally been found to include both *C. neoformans* and *C. gattii* **(Hagen *et al*., 2015)**. Systemic cryptococcosis in immunocompromised patients is primarily caused by *Cryptococcus neoformans* sensu stricto (formerly known as *C. neoformans variant grubii*). It is closely linked to bird droppings, particularly those of pigeons **(Anna Rovid Spickler, 2013)**.

*C. neoformans* typically find its environmental reservoir in bird droppings, especially those of pigeons. But it has also been discovered in decomposing trees, wood and plant matter, soil, and waterways all of which are typically contaminated with bird droppings **(Refai *et al*.,1989; Abo *et al*., 2006; Abou *et al*., 2011; Saleh *et al*., 2011; Rafei *et al*., 2014; EI-Hariri *et al*., 2015; EI-Hariri *et al*., 2016)**. *Cryptococcus neoformans var. neoformans* is found globally and has been related to pigeons and other bird droppings, in addition to soils contaminated with these droppings **(Speed& Dunt, 1995)**. F.Sanfelice identified *Cryptococcus* from peach juice samples for the first time in 1894**(Sanfelice, 1894)**. *Cryptococcus neoformans* is primarily found in soil polluted by pigeon droppings, while *Cryptococcus gattii* is primarily found in eucalyptus trees and rotting tree hollows **(Callejas *et al*., 1998; Chakrabarti *et al*., 1997; Lazera *et al*.,1998; Mahmoud, 1999)**. Two species, *C. neoformans* and *C. gattii* **(Kwon-Chung, *et al*.,2002; Kwon-Chung, *et al*., 2006)** with serotypes A, D, and AD for the former and B and C for the latter, comprise the species complex, according to the current taxonomy.

Two types of *Cryptococcus neoformans* are currently known to exist: Serotypes A **(Franzot, *et al*., 1999)** and D are *C. neoformans variety grubii* and *C. neoformans variety neoformans*, respectively **(Kwon-Chung, *et al*., 2011)**. Based on capsular agglutination reactions, *C. neoformans* was first divided into four serotypes (A to D). The molecular study, however, has lately led to the classification of *C. gatti* (formerly known as *C. neoformans* serotypes B and C) as a separate species. Furthermore, two variants of *C. neoformans* have been identified: *C. neoformans var. grubii* (serotype A) and *C. neoformans* *var. neoformans* (serotype D). *C. neoformans* VNI, VNII, VNIII, and VNIV are the major molecular types into which the two species have been separated. *Cryptococcus neoformans* can be divided into four serotypes according to their polysaccharide capsule; serotype A and D are designated as variety *neoformans,* and serotypes B and C are categorized as variety *gattii* **(Meyer, *et al*., 1999; Ellis, *et al*.,2000; Sorrel, *et al*.,1996)**.

*Cryptococcus neoformans* is primarily associated with nests and soil that contain avian droppings, particularly those of pigeons **(Chee & Lee, 2005)**. It is an encapsulated, round-to-oval-shaped yeast that reproduces via budding. Its surrounding polysaccharide capsule, when grown in a lab, ranges in size from 1 to more than 30 µm **(Kwon-Chung, *et al*., 1992)**. *Cryptococcus neoformans* has been isolated from a variety of natural sources and is most generally associated with pigeon (order Columbiformes) droppings, but less frequently with the droppings of other birds, such as the order Psittaciformes and Passeriformes **(Caicedo, *et al*., 2000; Filiu, *et al*.,2002)**. The primary saprobic reservoir of *C. neoformans* is pigeon droppings. It is important to mention that *C. neoformans* can survive for roughly 20 years in dry, ancient pigeon droppings **(Pal, 2007)**. Pigeon droppings have been identified as a primary source of *Cryptococcus neoformans* and other diseases in various countries (**Dickx V, *et al*., 2010; Liu Z, *et al*., 2012; Rad FS, 2013**).

**Figure 1**: Diagrammatic view of Pigeon droppings as a reservoir of *Cryptococcal* infection.



**Pigeon droppings**

Pigeons are popular domestic birds and are often regarded as symbols of peace. Pigeon keeping is a primordial human interest. The Asian subcontinent has been known to be the pioneer of fancy pigeon farming from ancient times. Pigeons acclimatize quickly to a range of environments. Pigeons are common birds that may be found in almost every city and rural throughout the world. Pigeons live among humans as a source of food, hobby, and experimental purposes **(Sari *et al*., 2008)**. Pigeons belong to the Columbidae family, which is distinguished by sturdy bodies, short necks, small heads, and thick, heavy plumage **(Gifford, 1941)**. Approximately 800 domesticated pigeon breeds include messenger, flying/sporting, racing, fancy, and utility pigeons **(https://en.wikipedia.org/wiki/List\_of\_pigeon)**. Pigeons are the source of various diseases that are transmitted to humans, primarily through contact with dried bird droppings, feather dust, and mites **(Kozdrun *et al*.,2015; Coudert *et al*., 2015)**. A recent rise in the number of pigeons has caused public health concerns. Pigeons spread harmful parasites, germs, fungi, and viruses that can harm both people and animals. Numerous literary works have examined how birds contribute to the spread of certain microorganisms. A lot of harmful germs, such as *Salmonella, Cryptococcus,* and *Chlamydia* species, may be found in pigeons **(Haag-Wackernagel *et al*., 2004)**.

Pigeons have a rather high body temperature (approximately 400C), and yeasts cannot grow there. However, their dried excreta include low molecular weight nitrogenous compounds, that create favorable conditions for fungal growth **(Naz, 2017)**. Certain microorganisms that have been isolated from pigeon droppings are known to be harmful to immunodeficient people, while infections from these organisms are also reported in immunodeficient individuals **(Hamasha *et al*., 2004)**. Of all bird species, the pigeon has been most closely associated with *C. neoformans.* Some experimental work has documented that the alimentary tract of pigeons may be colonized by *C. neoformans* and that viable organisms are excreted in guano for many weeks **(Littman *et al*., 1965 & 1968)**. Other findings suggest that pigeon droppings might enrich the soil and help the already-existing *C. neoformans* grow because guano probably contains a variety of chemical compounds, like creatinine, that encourage this organism's growth **(Denton *et al*., 1968)**.

Pigeon guano is a common source of infectious propagules of *C. neoformans* and is thought to serve a critical role in transmission from the environment to humans **(Casadevall *et al*., 1998; Ensley *et al*., 1979; Gallo *et al*., 1789; Haag-Wackernagel *et al*., 2004; Hotzel *et* *al*., 1998; Khan *et al*., 1978; Khosravi *et al*., 1997;Lopez-Martinew *et al*.,1996; Schonheyder *et al*., 1982; Sriburee *et al*., 2004; Stenderup *et al*., 1989; Swinne-Desgain, 1976; Swinne *et al*., 1989; Yamamoto *et al*., 1995; Yilmaz *et al*., 1989)**.Pigeon droppings are becoming a significant environmental threat, as pigeon populations increase. Furthermore, pigeon excreta are a major public health problem because they are sources and carriers of opportunistic and pathogenic microorganisms such as fungi, bacteria, and viruses **(Abulreesh *et al*., 2019; Santos *et al*., 2020)**. Pigeon excrement is a significant problem for property owners and historical and archaeological buildings in various countries **(Razani *et al*., 2018)**. Pigeon droppings contain nitrogen, phosphorous, potassium, and other minerals. The constituents produce an ideal environment that promotes the growth of numerous microorganisms **(Nyakudi, 2011)**. Pigeon droppings are the primary saprobic reservoir of *C. neoformans*. It is vital to note that *C.neoformans* can survive for two decades in ancient and dry pigeon excreta that have been shielded from the ultraviolet rays of the sun **(Pal, 2007)**. 1g of dry pigeon droppings may contain 50 million viable cells of *C.neoformans* **(Pal *et al*., 2011)**. The uric acid in pigeon droppings also aids in the formation of a polysaccharide capsule, which resists phagocytosis and increases the pathogenicity of the organisms. This virulence factor has the potential to negatively impact a host's immune response during infection **(Lee *et al*., 2011)**.

**Conclusion**

In conclusion, *Cryptococcus neoformans* is a pathogenic yeast commonly associated with environmental sources, particularly pigeon droppings. This microorganism thrives in the warm, moist environments created by bird feces, and it can pose a serious health risk to humans, especially those with weakened immune systems, such as individuals with HIV/AIDS. When people come into contact with contaminated pigeon droppings or inhale the fungal spores present in the droppings, they can become infected, leading to diseases like cryptococcosis. This infection primarily affects the lungs but can spread to the brain, causing meningitis in severe cases. As such, proper handling and cleanup of pigeon droppings, particularly in areas of high exposure, is crucial to prevent the transmission of *Cryptococcus neoformans* and protect public health. Further research and awareness about the risks associated with pigeon droppings and fungal infections are essential to minimize these threats.

**Ethical consideration**

Pigeons were not disturbed, caught, or hurt. Therefore, ethical approval was not necessary.

**Acknowledgments**

I want to express my deepest gratitude to all those who contributed to the completion of this review paper on *Cryptococcus neoformans* from pigeon droppings. Special thanks are extended to the researchers whose previous work laid the foundation for this review, providing invaluable insights into the ecology, pathogenicity, and epidemiology of *C. neoformans*. Finally, I would like to express my gratitude to the research guide who supported me throughout the research and writing process.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

**Bibliography**

Abo El-Yazeed H, Ezz-Eldin N, Tawakkol W, El-Hariri M, Kotb M, *et al.*, (2006) Isolation and identification of *Cryptococcus neoformans* from bird droppings, with special reference to newly formulated differential media based on development of brown colonies. *Journal of Egyption Veterinary Medical Association .*66: 165-179.

Abou-Elmagd, Sh. Hosam Kotb, Khaled Abdalla and Mohamed Refai (2011). Prevalence of *Candida albicans* and *Cryptococcus neoformans* in Animals from Quena Governorate with Special Reference to RAPD-PCR Patterns] *Journal of American Science* .7(12): 20-31]. (ISSN: 1545-1003).

Bongomin F, Gago S, Oladele RO, *et al.,* (2017).Global and multi-motional prevalence of fungal diseases-estimate precision. *Journal of Fungi* (Basel). 3(4):57.

Buchan BW (2013). Ledeboer NA. Advances in identification of clinical yeast isolates by use of matrix-assisted laser desorption ionization-time of flight mass spectrometry. *J Clin Microbiol*. 51:1359-66.

Callejas A, Ordonez N, Rodriguez MC, Castaneda E (1998). First isolation of *Cryptococcus neoformans var. gattii,* serotype c, from the environment in Colombia. *Medical Mycology*. 36: 341–344.

Casadevall, A., and J. R. Perfect (1998). *Cryptococcus neoformans*. *ASM Press*, Washington, DC.

Chakrabarti A, Jatana M, Kumar P, Chatha L, Kaushal A, Padhye AA (1997). Isolation of *Cryptococcus neoformans var. gattii* from eucalyptus camaldulensis in India. *Journal of Clinical Microbiology*. 35: 3340 –3342.

Chayakulkeeree M, Perfect JR. Cryptococcosis. *Infect Dis Clin North Am* (2006). 20: 507-44. Denton JF, Di Salvo AF.

Chee HY, Lee KB (2005) Isolation of *Cryptococcus neoformans var. grubii* (serotype A) from pigeon droppings in Seoul, Korea. *Journal of Microbialogy*. 43:469-72.

Dawn H. Gouge, Clifton Mc Reynolds, & Tim W. Stick (2022). Managing Pigeons. The Univerty of Arizona Cooperative Extension. extension.arizona.edu/pubs/az2001-2002.pdf.

Del Poeta M, Casadevall A (2011). Ten challenges on Cryptococcus and Cryptococcosis. *Mycopathologia*, 173:303-310.

Dickx V, Beeckman DS, Dossche L, Tavernier P, Vanrompay D (2010). Chlamydophila psittaci in homing and feral pigeons and zoonotic transmission. *Journal of Medical Microbiology* 2010; 59: 1348-53.

Dawn H. Gouge, Clifton Mc Reynolds, & Tim W. Stick (2022). Managing Pigeons. The Univerty of Arizona Cooperative Extension. extension.arizona.edu/pubs/az2001-2002.pdf.

El-Hariri M, D. Hamza, R. Elhelw, and M. Refai (2015). “Lovebirds and cockatiels risk reservoir of *Cryptococcus neoformans*, a potential hazard to human health,” *Journal of Veterinary Science & Medical Diagnosis*, vol. 4, no. 4.

El-Hariri M, Dalia Hamza, Rehab Elhelw, and Mohamed Refai (2016). “Eucalyptus Tree: A Potential Source of *Cryptococcus neoformans* in Egyptian Environment,” *International Jornal of Microbiology*, Article ID 4080725, 5 pages, 2016. doi:10.1155/2016/4080725.

Ellis D, Marriott D, Hajjeh RA, Warnock D, Meyer W, Barton R (2000). Epidemiology: surveillance of fungal infections. *Medical Mycology* 38: 173–182.

Ensley, P. K., C. E. Davis, M. P. Anderson, and K. C. Fletcher (1979). Cryptococcosis in a male Beccari’s crowned pigeon. *Journal of American Veterinary Medical. Association*. 175:992–994.

Franzot SP, Salkin IF, Casadevall A (1999). *Cryptococcus neoformans var. Grubii*: Separate varietal status for *Cryptococcus neoformans* serotype a isolate. *Journal of Clinical Microbiol*ogy. 37: 838–840.

Franzot, S.P. I.F. Salkin, A (1999). Casadevall. *Cryptococcus neoformans var. grubii*: separate varietal status for *Cryptococcus neoformans* serotype A isolates *J. Clin. Microbiol*., 37 (3) pp. 838–8407.

Gallo, M. G., P. Cabeli, and V. Vidotto (1789). Presence of pathogenic yeasts in the feces of the semi-domesticated pigeon (*Columba livia*, Gmelin , urban type) from the city of Turin. *Parasitologia* 31:207–212.

Grisin,T.,C ., Bories, P. M., Loseau, Bouchemal, K (2017). Cyclodextrin- mediated self -associating chitosan micro- platelets act as a drug booster ahainst *Candida glabrata* mucosal infection in immunocompetent mice. *Int. J. Pharm*. 19: 381-389.

Haag- Wackernagel, D S.a. (2012). *The feral Pigeon* [ online]. Basal: University of Basal. Available:[https://anatomie.unibas.ch/IntegrativeBiology/haag/Culture-History Pigeon/feral-pigeon-haag.html](https://anatomie.unibas.ch/IntegrativeBiology/haag/Culture-History%20%20%20%20%20%20%20%20%20%20%20%20%20%20Pigeon/feral-pigeon-haag.html) .

Haag-Wackernagel, D., and H. Moch. (2004). Health hazards posed by feral pigeons. *J. Infect.* 48:307–313.

Hagen F, Khayhan K, Theelen B, Kolecka A, Polacheck I, Sionov E, Falk R, Parnmen S, Lumbsch HT, Boekhout T(2015). Recognition of seven species in the *Cryptococcus gattii/ Cryptococcus neoformans* species complex. *Fungal Genetics and Biology* 2015;78: 16–48. <https://doi.org/10.1016/j.fgb>. 02. 009.

Hamasha, A. M. S., Yildiran, S.T., Gonlum, A., Saracli, M.A. & Doganci, L. (2004).*Cryptococcus neoformans* varieties from material under the canopies of eucalyptus trees and pigeon dropping sample from major cities in Jordan. *Mycopathologia*, 158: 195-199.

Hotzel, H., P. Kielstein, R. Blaschke-Hellmessen, J. Wendisch, and W. Bar (1998). Phenotypic and genotypic differentiation of several human and avian isolates of *Cryptococcus neoformans. Mycoses* 41:389–396.

<http://www.cfsph.iastate.edu/>

<http://www.infectiousdisease.dhh.louisiana.gov/>

Khan, Z. U., M. Pal, H. S. Randhawa, and R. S. Sandhu (1978). Carriage of *Cryptococcus neoformans* in the crops of pigeons. *Journal of Medical. Microbiology*. 11:215– 218.

Khosravi, A. R (1997). Isolation of *Cryptococcus neoformans* from pigeon (*Columbia* *livia*) droppings in northern Iran. *Mycopathologia* 139:93–95.

Kwon-Chung K.J., A.Varma. (2006). Do major species concepts support one, two or more species within Cryptococcus neoformans? FEMS *Yeast Res.,* 6 (4), pp. 574–587.

Kwon-Chung K.J., T. Boekhout, B.L. Wickes, J.W. Fell (2011). Systematics of the genus Cryptococcus and its type species *C. neoformans*. J. Heitman, T.R. Kozel, K.J. Kwon-Chung, J.R. Perfect, A. Casadevall (Eds.), Cryptococcus: From Human Pathogen to Model Yeast, *ASM Press*, pp. 3–16 (Chapter 1).

Kwon-Chung K.J., T. Boekhout, J.W. Fell, M. Diaz. (2002). Proposal to conserve the name Cryptococcus gattii against C. hondurianus and C European Journal of Academic Essays 4(8): 202-223, 2017 215 *bacillisporus (Basidiomycota, Hymenomycetes, Tremellomycetidae) Taxon,* 51 (4) , pp. 804–806.

Kwon-Chung KJ, Kozel TR, Edman JC, *et al*. (1992). Recent advances in biology and immunology of *Cryptococcus neoformans*. *Journal of Medical and Veterinary Mycology*; 30:133-42.

Kwon-Chung KJ, Varma A (2006). Do major species concepts support one, two or more species within *Cryptococcus neoformans*? FEMS *Yeast Res*. 6: 574–587.

Lazera MS, Cavalcanti MA, Trilles L, Nishikawa MM, Wanke B. *Cryptococcus neoformans var. gattii*—evidence for a natural habitat related to decaying wood in a pottery tree hollow. *Medical Mycol*ogy1998; 36:119–122.

Lee, I. R., M., Chow, E.W., Morrow, C.A., Djordjevic, J.T.& Fraser, J. A (2011). Nitrogen metabolite repression of metabolism and virulence in the human fungal pathogen *Cryptococcus neoformans*. *Genetics*, 188: 309-323.

Lee, WD; Fong, JJ; Eimes, JA and Lim, YM (2017). Diversity and abundance of human- pathogenic fungi associated with pigeon faeces in urban environments. *Molecular.Ecology*.26: 4574-4585.

Lee,IR,Yang,L.,Sebetso,G.,Allen,R.,Doan,T.H.N.,Blundell,R.,Lui,E.Y.L.,Morrow,C.A & Fraser, J.A (2013). Characterization of the Complete Uric Acid Degradation Pathway in the Fungal Pathogen *Cryptococcus neoformans, PLoS* One, 8: 1-13.

Levitz SM (1991). The ecology of *Cryptococcus neoformans* and the epidemiology of cryptococcosis. *Reviews of Infectious Disease*. 13:1163-9.

Lin, Z., et al., (2015). Environmental Uncertainty, Diversification and Cost of Capital. *The Accounting Research*, 36-43.

Littman ML, Borok R, Dalton (1965). TJ. Experimental avian cryptococcosis. *American Journal of Epidemiology*. 82: 197–207.

Littman ML, Borok R (1968). Relation of the pigeon to cryptococcosis: natural carrier state, heat resistance and survival of *Cryptococcus neoformans*. *Mycopathol Mycol Appl* .35: 329–345.

Lopez-Martinez, R., J. L. Soto-Hernandez, L. Ostrosky-Zeichner, L. R. Castanon-Olivares, V. Angeles-Morales, and J. Sotelo (1996). *Cryptococcus neoformans* *var. gattii* among patients with cryptococcal meningitis in Mexico. First observations. *Mycopathologia* 134:61–64.

Liu Z, Ma L, Zhong Y, Wang X, Xie S (2012). Isolation, identification and significance of Cryptococcus neoformans and Candida albicans from faecal specimen of pigeon. Inf Technol Agric Eng 134: 507-12.

Mahmoud YA (1999). First environmental isolation of *Cryptococcus neoformans var. neoformans and var. gatti* from the Gharbia Governorate, Egypt. *Mycopathologia* ; 148: 83–86.

Martins MoA, Brighente KB, Matos TA, Vidal JE, Hipólito DD, Pereira-Chioccola VL (2015). Molecular diagnosis of *Cryptococcal meningitis* in cerebrospinal fluid: Comparison of primer sets for *Cryptococcus neoformans and Cryptococcus gattii* species complex. Braz J Infect Dis. 19: 62-7.

May, R.C.; Stone, N.R.H.; Wiesner, D.L.; Bicanic, T.; Nielsen, K (2016). Cryptococcus: From environmental saprophyte to global pathogen. *Nature Reviews Microbiol*ogy. 14, 106–117. [CrossRef]

Maziarz, E.K(2016). Perfect, J.R. Cryptococcosis. *Infectious Disease Clinical North America*. 30, 179–206. [CrossRef]

Meyer W, Marszewska K, Amirmostofian M, Igreja RP, Hardtke C, Methling K, Viviani MA, Chindamporn A, Sukroongreung S, John MA, et al; (1999). Molecular typing of global isolates of *Cryptococcus neoformans var. neoformans* by polymerase chain reaction fingerprinting and randomly amplified polymorphic DNA: a pilot study to standardize techniques on which to base a detailed epidemiological survey. Electrophoresis. 20: 1790 –1799.

Millar, B. C., XU, J. & Moore,J.E (2007).Molecular Diagnostics of Medically Important Bacterial Infections. *Current Issues in Molecular Biology*, 9: 2-30.

Negroni R. Cryptococcosis. Clin Dermatol (2012). 30: 599-609. 21. Tanner DC, Weinstein MP, Fedorciw B, Joho KL, Thorpe JJ, Reller L. Comparison of commercial kits for detection of cryptococcal antigen. *Journal of Clinical Microbiol*ogy 1994; 32: 1680-4.

Nyakundi, W. O. & Mwangi, W (2011). Isolation and characterization of pathogenic bacteria and fungi from *Leptotilos crumeniferus* (Marabou Stock) dropping. *Journal of Applied Technology in Environmental Sanitation*, 193-106.

Pal M (2019). “Contribution of Prof. Dr. Mahendra Pal in Veterinary and Medical Mycology”. *Open Access Journal of Mycology and Mycological Sciences* 2.2 (2019): 000110.

Pal M (2019). “Emerging role of saprobic fungi in human and animal health”. *Journal of Mycological Research* 53. 3: 1-2.

Pal M (2007). “Veterinary and Medical Mycology”. First Edition. *Indian Council of* *Agricultural Research*, New Delhi, India.

Pal M (2006). Dave P. Cryptococcosis: A global fungal zoonosis. *Intas Polivet*. 6: 412-420.

Pal M (2017). Morbidity and mortality due to fungal infections. *Journal of Applied Biochemistry and Microbiology.* 1(2):1–3.

Pal M (2011). Tesfaye S, Dave P. Cryptococcosis: a major life- threatening mycosis of immune compromised patient. *Indian Journal of Social Natural Science*. 1: 19-28.

Pal M (2007). Veterinary and medical mycology (1st Ed). *Indian council of agricultural research*, Delhi, India.

Pal M (2007). Zoonoses. *Satyam Publishers*.

Pal M (2017). “Prevalence of *Cryptococcus neoformans* in excreta, wood and air of an aviary”. *EC Microbiology* 13.1: 30-34.

R. D (1971). Baker et al., The Pathologic Anatomy of Mycoses © *Springer* Verlag, Berlin-Heidelberg.

Rad FS (2013). Isolation of Cryptococcus neoformans from pigeon excreta in Qazvin*. Life Science J*ournal 10: 214-9.

Refai M, Taha M, Selim SA, Elshabourii F, Yousseff HH (1983). Iolation of *Cryptococcus neoformans, Candida albicans* and other yeasts from pigeon droppings in Egypt. *Sabouraudia* 21: 163-165.

Refai, M. K., M El-Hariri, R Alarousy (2014). Monograph on Cryptococcus and cryptococcosis. <http://scholar.cu.edu.eg/?q=hanem/book/>

Saleh, H., Amgad A. Moawad, Mahmoud ElHariri, Mohamed K. Refai (2011). Prevalence of Yeasts in Human, Animals and soil sample in El-Fayoum Governorate in Egypt. *Int, J. Microbiol*. 2 (3): 233-239.

Sandelice F (1894). Contributo alla morphologia dei blastomiceti che sviluppano nei succhi di alcuni frutti, Ann Igien. 4;436-495.

Sanfelice F (1894). Contributo alle morfologia e biologia dei blastomiceti che si sviluppano nei succhi di alcuni frutti. *Ann Isto Igiene R Univ Roma*. 4: 463–495.

Schonheyder, H., and A. Stenderup (1982). Isolation of *Cryptococcus neoformans* from pigeon manure on two media inducing pigment formation. *Sabouraudia* 20:193–197.

Sorrell TC, Chen SC, Ruma P, Meyer W, Pfeiffer TJ, Ellis DH, Brownlee A G (1996). Concordance of clinical and environmental isolates of *Cryptococcus neoformans var. gattii* by random amplification of polymorphic DNA analysis and PCR fingerprinting. *Journal of Clinical Microbiology*. 34 :1253–1260.

Speed B, Dunt D (1995). Clinical and host differences between infections with the two varieties of *Cryptococcus neoformans. Clinical Infectious Dis*eases. 21:28-34.

Sriburee, P., S. Khayhan, C. Khamwan, S. Panjaisee, and P. Tharavichitkul (2004). Serotype and PCR-fingerprints of clinical and environmental isolates of *Cryptococcus neoformans* in Chiang Mai, Thailand. *Mycopathologia* 158: 25–31.

Stenderup, J., K. Flensted, C. Jorgensen, A. H. Sorensen, N. C. Hansen, and H. C. Siersted (1989). Occurrence of the yeast, *Cryptococcus (Cr) neoformans*, in pigeon droppings. *Ugeskr. Laeger* 151:2974–2975.

Swinne-Desgain, D (1976). *Cryptococcus neoformans* in the crops of pigeons following its experimental administration. *Sabouraudia* 14:313–317.

The prevalence of Cryptococcus neoformans in various natural habitats. *Sabouraudia* 1968; 6: 213–217

Tristano AG (2010). *Cryptococcal meningitis* and systemic lupus erythematosus: a case report and review. *Revista Chilena de Infectologia.*  27: 155-9

Yamamoto, Y., S. Kohno, T. Noda, H. Kakeya, K. Yanagihara, H. Ohno, K. Ogawa, S. Kawamura, T. Ohtsubo, K. Tomono, *et al*. (1995). Isolation of *Cryptococcus neoformans* from environments (pigeon excreta) in Nagasaki. *Kansenshogaku Zasshi* 69:642–645.

Yilmaz, A., G. Goral, S. Helvaci, K. Kilicturgay, F. Gokirmak, O. Tore, and S. Gedikoglu (1989). Distribution of *Cryptococcus neoformans* in pigeon feces. *Mikrobiyol*. Bul. 23:121–126.

[Yuan Zhang](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3AYuan%20Zhang)., [Nan Li](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3ANan%20Li) **.,**[Yuxuan Zhang](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3AYuxuan%20Zhang).,[Huiping Li](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3AHuiping%20Li).,[Xueyuan Chen](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3AXueyuan%20Chen) **.,**[Shanmei Wang](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3AShanmei%20Wang).,[Xia Zhang](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3AXia%20Zhang).,[Rongxuan Zhang](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3ARongxuan%20Zhang).,[Jinfu Xu](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3AJinfu%20Xu) **.,**[Jingyun Shi](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3AJingyun%20Shi) **.,**[Rex C. Yung](https://publications.ersnet.org/search?query=&f%5B0%5D=author%3ARex%20C.%20Yung) (2012) Clinical analysis of 76 patients pathologically diagnosed with pulmonary cryptococcosis**.** *European Respiratory Journal* .40(5): 1191-1200; DOI: <https://doi.org/10.1183/09031936.00168011>