Aves

Mycoses of *Aves* (birds)

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Birds are a diverse class of warm-blooded, egg-laying vertebrates characterized by feathers, beaks without teeth, and a high metabolic rate. This class includes more than 11,000 species, ranging from small songbirds to large flightless birds such as ostriches and emus. Birds are found across almost all habitats on Earth, from polar regions to tropical forests, deserts, and oceans.

Modern birds are classified into around 40 orders, with *Passeriformes* representing the largest order. Some bird species, such as the domestic chicken (*Gallus gallus domesticus*) and domestic pigeon (*Columba livia*), have been widely domesticated and adapted to human environments. Other species, like penguins (e.g. *Megadyptes antipodes* and *Spheniscus mendiculus*) or the California condor (*Gymnogyps californianus*) are rare or endangered, highlighting the conservation challenges faced by certain avian groups.

Birds first appeared during the Jurassic Period, evolving from theropod dinosaurs, with *Archaeopteryx* representing one of the earliest known avian ancestors. Since then, birds have radiated into a wide range of ecological niches. They display a variety of ecological strategies,

including migratory, arboreal, aquatic, and flightless forms. Many species exhibit complex social behaviors, including flocking, cooperative breeding, and elaborate mating displays.

Birds are highly susceptible to fungal infections. A combination of anatomical and physiological characteristics facilitate infection and hinder fungal clearance. Anatomically, birds lack an epiglottis − a structure present in mammals that serves as a mechanical barrier preventing the entry of exogenous particles into the respiratory tract. They also do not possess a diaphragm, eliminating the cough reflex, which is a critical defense mechanism against respiratory pathogens. In addition, their trachea lacks pseudostratified ciliated epithelium, which normally assists in clearing inhaled particles, making the removal of fungal spores more difficult. Besides all of these predisposing factors, a unique feature of avian anatomy is highlighted: the presence of air sacs, structures with high oxygen content but limited vascularization, which provide an ideal environment for fungal growth. These air sacs can even support the development of reproductive fungal structures, frequently observed in histopathology of birds with aspergillosis, contributing to the progression of the disease.

Major mycoses

Aspergillosis

Aspergillosis is a significant disease reported across various types of poultry production, affecting broilers, turkeys, geese, ducks, pigeons, rheas, and ostriches. Young birds are particularly vulnerable to infection. In these production systems, outbreaks of aspergillosis are commonly observed, with mortality rates ranging widely from 4.5% to as high as 90% (Arné *et al*., 2011). Environmental conditions, such as poor moisture control, accumulation of organic material, and the use of bedding materials rich in organic matter are important risk factors contributing to the development of aspergillosis in domestic birds (Zafra *et al.*, 2008).

From an ecological perspective, aspergillosis represents a significant concern due to its high mortality rates in wild birds kept in captivity, such as those in zoos and rehabilitation centers (Arné *et al.*, 2021; Melo *et al.*, 2019). Among penguins undergoing rehabilitation, the proportionate mortality attributed to aspergillosis can reach approximately 50% (Silva Filho *et al.*, 2015). Furthermore, cases of aspergillosis have been documented among free-ranging bird populations, highlighting its relevance beyond captivity and its impact on wildlife conservation (Melo *et al.*, 2020ab, 2023). Environmental conditions and host immunological status play a crucial role in predisposing birds to infection (Beernaert *et al.*, 2010).

The clinical manifestations of aspergillosis in birds are generally nonspecific. In many cases, affected birds may remain asymptomatic or exhibit only mild signs − such as lethargy, anorexia, or mild respiratory distress − until the disease has reached an advanced stage. By the time clinical signs become apparent, the fungal infection has often disseminated or caused

significant damage, particularly within the respiratory system. Dyspnea is frequently noticeable in severe cases (Tell *et al*., 2019; Souto *et al.*, 2025).

In birds, aspergillosis is most often diagnosed *post-mortem*. Gross lesions observed during necropsy commonly consist of white to yellow granulomas located in the lung parenchyma and/or on the air sac membranes (Fig. 1). In more severe cases, the infection may spread to other organs, including the heart, liver, kidneys, and spleen (Fig. 2). The presence of fungal colonies in the air sacs (Fig. 3), often accompanied by moderate to abundant conidial production (Fig. 4), has been commonly described in several avian species (Cacciuttolo *et al.*, 2009; Hauck *et al.,* 2020; Pal, 2003; Souto *et al*., 2025; Xavier *et al*., 2011). *Aspergillus* species from section *Fumigati* are recognized as the most frequent causative agents of aspergillosis in birds, highlighting *A. fumigatus sensu stricto* as the main species (Beernaert *et al*., 2010; Sabino *et al*., 2019). However, other *Aspergillus* have also been implicated in cases of avian aspergillosis. Pulmonary infection due to *A. flavus* has been reported in ducks (Copetti *et al*., 2015) and turkeys (Hadrich *et al.,* 2013), and Xavier *et al*. (2011) reported a mixed infection with *A. fumigatus* and *A. flavus* in a penguin. *Aspergillus terreus* has been reported from pigeons (Pal, 1992), and parrots (Lagneau & Houtain, 2001). *Aspergillus nidulans* has been reported from ducklings (Deka & Rao, 1988). Isabelle *et al*. (2020) reported sinusitis due to *A. viridinutans* in a parrot. An investigation in Australia allowed the collection of 30 *Aspergillus* isolates from affected birds from zoos, pet birds and poultry. The species *A. fumigatus* was predominant (*n* = 26 isolates) but other species were also detected: *A. restrictus* (*n* = 1), *A. flavus* (*n* = 2), and *A. nidulans* (1) (Talbot *et al.*, 2018).

Candidiasis

Candidiasis is a fungal infection that primarily affects the upper gastrointestinal tract of birds, especially the oropharynx, esophagus, and crop. It is characterized by white to greyish mucosal lesions, often accompanied by epithelial thickening (hyperkeratosis). Although considered relatively uncommon in veterinary medicine, candidiasis remains an important differential diagnosis, particularly in birds that fail to respond to antibiotic therapy (Seyedmousavi *et al*., 2018).

Clinical signs are non-specific and can vary widely. Affected birds may present with stunted growth, lethargy, ruffled feathers, anorexia, dullness, greenish diarrhea, whitish oral plaques, regurgitation, and weight loss (Talazadeh *et al.*, 2022). Histopathological examination of the affected mucosa typically confirms tissue invasion by fungal pseudohyphae (Fig. 6). *Candida albicans* is the most frequently implicated species, though others such as *Candida (Nakaseomyces) glabrata*, *C. parapsilosis*, *C. tropicalis*, and *Pichia kudriavzevii* (*Candida krusei*). Disease typically arises when local or systemic conditions promote fungal overgrowth (Seyedmousavi *et al.*, 2018), and is not related to a specific genotype of fungal species, as recently showed in studies including isolates from environment, animals and humans (Rhimi *et*

al., 2025; Domán *et al.*, 2021).

Young birds are especially vulnerable due to their immature immune systems. Additional predisposing factors include prolonged antibiotic use, immunosuppressive states, and concurrent infections. Clinical cases have been reported in various avian species, including pigeons, chickens, turkeys, geese, pheasants, parrots, quails, and guinea fowl. In urban environments, *C. albicans* has been frequently isolated from pigeon droppings, suggesting that birds and their excreta may act as environmental reservoirs for *Candida* spp. including the multidrug-resistant species *C. auris* (Nemeth *et al.*, 2016; Casadevall *et al.*, 2019; Talazadeh *et al.*, 2022).

Less common mycoses

Cryptococcosis

Cryptococcosis is predominantly caused by *Cryptococcus neoformans* and *C. gattii*. This mycosis is considered rare in birds; available evidence suggests that initial colonization usually occurs in the respiratory tract, with potential for subsequent systemic dissemination (Siqueira *et al.*, 2022). The upper respiratory tract may be particularly susceptible to fungal establishment due to its relatively low temperature, which favors fungal growth (Dahlhausen, 2006). Outbreaks of cryptococcosis have been reported in psittacine, pigeons and kiwis, sometimes resulting in systemic infection and death (Malik *et al.*, 2003; Marietto-Gonçalves *et al.*, 2025; Raso *et al.*, 2004). Maccolini *et al.* (2017) described of a case of disseminated *Cryptococcus gattii* VGIIa infection in a cockatoo. Silva *et al.* (2021) described a cryptoccoma due to *C. bacillisporus* in a parrot.

Despite the low incidence of clinical disease, many birds, especially pigeons and parrots, can act as asymptomatic carriers, shedding *Cryptococcus* yeast cells into the environment through their droppings (Abulreesh *et al.*, 2019; Anacona *et al.*, 2018; Ghaderi *et al.* 2019; Gumasta *et al.*, 2019; Malekifard *et al.* 2023; Lugarini *et al.*, 2008; Velasco, 2000). These excreta may represent a significant source of environmental contamination and pose a public health risk, particularly to immunocompromised individuals in urban settings (Siqueira *et al.*, 2022). Cafarchia *et al.* (2006) isolated *C. neoformans* was from three cloacae samples from falcons (*Falco tinnunculus*) and a howl (*Buteo buteo*), as well as from samples collected at the aviaries in which these animals were kept.

Histoplasmosis

Birds are generally not susceptible to histoplasmosis, possibly due to their elevated body temperatures. However, they can act as asymptomatic carriers, and their droppings enrich soil nitrogen levels, creating favorable conditions for fungal proliferation. Rare or isolated cases of infection by *Histoplasma capsulatum* have been reported in birds (Quist *et al.,* 2011). Migratory birds probably play a significant role in the geographic dissemination of the fungus, transporting it across regions during seasonal movements (Moreira *et al.*, 2022).

Mucormycosis

Avian mucormycoses are usually severe and fatal, but infrequently reported. The presence of some comorbidities and immunosuppression could contribute to the fatal outcome. Reports of systemic mucormycosis causing pneumonia and air sacculitis are described in love birds (*Agapornis fischeri* and *A. roseicollis*), caused by *Mucor* spp. (Mitchell *et al.*, 1986; Galosi *et al.*, 2022; Garijo *et al.*, 2024). Lesions were minimal, limited to pulmonary congestion and parenchymal consolidation. Histopathology revealed disseminated infection with extensive hepatic necrosis, pyogranulomatous inflammation, vascular invasion with thrombosis, and granulomatous lesions in lungs, spleen, kidneys, and air sacs.

Miscellanous hyalohyphomycoses

Hyalohyphomycosis broadly refers to infections characterized by the presence of colorless, septate fungal hyphae within affected tissues. Consequently, the fungi associated with this condition are highly heterogeneous. Opportunistic fungi of the genus *Penicillium* can act as significant pathogenic agents in exotic birds, especially under conditions of stress or immunosuppression. Fatal cases of infection by *Penicillium griseofulvum* in a group of captive toucanets were reported by Aho *et al*. (1990). Furthermore, Lanteri *et al.* (2011) described a case of *Penicillium chrysogenum* infection in a Congo African grey parrot. Tunç *et al.* (2022) reported the first fatal case of invasive infection by *Scopulariopsis brevicaulis* in canaries, highlighting its ability to affect internal organs and cause systemic disease in birds. McCowan *et al*. (2014) reported the occurrence of mycotic keratitis caused by *Scedosporium apiospermum* in layer pullets (Fig. 7). Laclaire *et al.* (1974) described a case of pulmonary and air sac infection due to *Paecilomyces variotii* in pigeons. Odening *et al*. (1998) reported infections due to *Emmonsia crescens* in zoo parrots.

Macrorhabdus infection

Avian *Macrorhabdus* infection is a disease that affects both wild and captive birds, including psittacines, passerines, poultry, and various other species, worldwide (Borrelli *et al.*, 2015; Đuričić, 2025). It is caused by *Macrorhabdus ornithogaster*, an opportunistic yeast that colonizes the gastric mucosa of many avian species. The fungus is as yet unculturable. The species is responsible for wasting disease in birds (Dorrestein *et al*., 1980; Pennycott *et al*., 1998; Gerlach, 2001). It is found in domestic and wild birds in the isthmus between the glandular and grinding stomach. Due to malfunctioning uptake of nutrients, the birds finally die of starvation. It may be present in gastric tissue (Filippich & Hendrikz, 1998; Mutlu *et al.*, 1997; Schulze & Heidrich, 2001; Martins *et al*., 2006). The disease typically presents as a chronic condition, with nonspecific clinical signs such as emaciation, anorexia, depression, cachexia, and ultimately death. In some cases, gastrointestinal symptoms may occur, including regurgitation or attempts to vomit, watery diarrhea, and weight loss despite a maintained appetite. Diagnosis and treatment remain challenging for avian veterinarians due to multiple factors (Baron *et al*., 2023; Đuričić, 2025).

Phaeohyphomycosis

Highly melanized ('dematiaceous') fungi usually appear sporadically in wild birds kept in captivity, although outbreaks have occasionally occurred in poultry (Seyedmousavi *et al.*, 2013). *Verruconis gallopava,* a species capable of growing at temperatures up to 50°C, naturally thrives in warm environments such as thermal soils and hot springs and can produce subcutaneous and systemic disease in birds, even with normal immune function. *Verruconis gallopava* shows marked neurotropism, having caused epidemic encephalitis in turkeys and chickens (Blalock *et al.*, 1973; Randall *et al*., 1981). Cerebral phaeohyphomycosis has also been observed in grey-winged trumpeters (*Psophia crepitans*) and quail chicks (*Coturnix coturnix japonica*). A captive snowy owl chick (*Nyctea scandiaca*) developed acute neurological signs and fatal brain invasion with melanized, septate hyphae (Shane *et al*., 1985; Karesh *et al*., 1987; Salkin *et al*., 1990). In addition, a case of mycetoma caused by *Curvularia geniculata* with pulmonary and central nervous system involvement has been described in an Eclectus parrot (*Eclectus roratus roratus*; Clark *et al*., 1986). *Hormonema dematioides* is an opportunistic plant pathogen causing needle necrosis of conifers (Talgø *et al*., 2010), but a cutaneous phaeohyphomycosis was ascribed to this species by Coldiron *et al.* (1990). Kent *et al*. (1998) reported human fungemia after exposure to birds.

Superficial mycosis

Lophophyton gallinae is a zoophilic dermatophyte causing dermatophytosis in chickens and associated avian species mainly on the comb and wattles (Fig. 8AB; Fonseca & Mendoza, 1984;

Droual *et al*., 1991; Bradley *et al*., 1993; Ferreira *et al.*, 2015; Yamaguchi, 2019; Thongkham *et al*., 2022). Human infections are uncommon (Torres & Georg, 1956) and possibly transmitted from infected chickens (Murata *et al.*, 2013; Miyasato *et al.*, 2011).

Out of the 19 species currently described within the genus *Malassezia*, three seem to be specifically associated the skin of birds: *M. psittaci* and *M. brasiliensis* (Cabañes *et al*., 2016) in parrots and *M. gallinae* (Zhao *et al*., 2024) in chickens. Pathology could not be established for these avian-related *Malassezia* species. The non lipid-dependent species *M. pachydermatis* has been detected in many warm-blooded vertebrates including birds (Guillot & Bond, 1999*).* Overgrowth of *Malassezia* yeasts may be responsible for cutaneous lesions (Fig. 9). Queseda *et al*. (2007) reported a *Mucor ramosissimus* infection associated with feather loss in canaries (*Serinus canarius*).

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