

# The Role of Fungi in Biodeterioration of Cultural Heritage: New Insights for Their Control

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## Introduction

Fungi are nature's major decomposers, and they play an essential role in biogeochemical cycles. Thanks to their wide enzyme repository, they can break down organic matter and hard-to-degrade biopolymers such as lignin, cellulose, and chitin. They also produce several inorganic and organic metabolites, organic acids, and chelating agents of fundamental importance in geological processes, leading to chemical transformations at local and global scales [1]. Though frequently overlooked, fungi are ubiquitous and can be found even in environments that are not so suitable for life due to their ability to metabolize xenobiotics [1]. Therefore, it is not surprising that fungi are considered the most detrimental threat to both indoor and outdoor artefacts of historical and/or artistic value; their presence can lead to physical, chemical, and aesthetical damages [2,3].

Cultural heritage conservation refers to the measures, protocols, and methods taken to extend the life of artefacts, monuments, and sites. Biological deterioration of historical and artistic artefacts has gained significant attention in recent decades, evidencing how limited our knowledge of biodeteriogens is when we consider the wide range of heritage materials used and the environments in which they are kept. In conservation practices, precise and reliable identification of biodeteriogens is useful; however, further research is needed to assess their ecological requirements and metabolic profiles. Indeed, the environmental conditions favoring various taxonomic groups, and their limited lives, are essential in assessing the risk for artefacts and designing indirect (preventive) and direct (biocide treatments) control methods.

In this Special Issue, we present seven study cases and two reviews addressing the deterioration of different materials, such as stone, textiles, wood, and scientific instruments, exposed to outdoor, confined, or semi-confined environments.

From the UNESCO heritage sites of Cuma, Ercolano, Nola, Oplonti, and Pompei, Petrarretti and colleagues [4] performed a deep sampling on frescoes, marble, mortars, plaster, and tuff to assess the biodiversity of the culturable fungal fraction. In addition to isolating fungal strains with detrimental potential, the authors suggest the importance of collecting detrimental fungi for future research on cultural heritage.

The study performed by Isola and colleagues focused on a selection of black meristematic fungal strains belonging to the Culture Collection of Fungi from Extreme Environments (CCFEE, Viterbo, Italy). All strains were isolated from marble monuments of the Bonaria Cemetery (Cagliari, Italy) and, using plate assays, the main ecological and metabolic traits and tolerance to traditional biocides were assessed [5]. The preservation of traditional Romanian clothes was the focus of the Ilies study group [6]. In detail, different essential oils were applied to different materials comprising coats (e.g., wool, cotton, leather) to control the detrimental fungal species. Other artefacts from museums include optical lenses



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studied by Ngo and co-workers [7]. This study evidenced the surface corrosion produced by fungi, here favored by the high humidity which is typical of North Vietnam's climate.

The study performed by Jurado and colleagues is of interest, instead, for the conservation of show caves [8]. In this study, the microclimatological and aerobiological monitoring gave insight into the seasonal dynamics of airborne fungi in the Nerja cave (Spain).

Barboux and colleagues [9] proposed an alternative instrumental method (FTIR) for detecting *Serpula lacrymans*; this method could be especially useful for protecting wooden structures from the dry rot fungi which are prevalent in indoor environments, especially in the holarctic regions. The study performed by Chlebicki and colleagues was devoted to testing the in vitro inhibitory effect exerted by bioactive ions exposed to galvanic systems with changing electrode distance [10].

This Special Issue also presents two reviews. The study performed by Zucconi and colleagues addressing wall paintings accounts for 60 years of fungal biodeterioration reports [11]. An exhaustive list of identified fungi was produced. However, the technical and methodological improvements that occurred within that period evidenced some limitations in the fungal identification (mainly morphological) and culturing protocols, posing the basis for future improvements.

De Leo and colleague reviewed 109 papers published within the last 30 years to critically summarize the current knowledge on black fungi associated with the biodeterioration of stone monuments with a look at control methods and future perspectives [12].

This Special Issue offers an insight into the vast world of fungal deteriogens. More research is necessary in this field; however, with the incoming improvements in instrumental technologies, molecular diagnoses, and sustainable control methods, the research prospects in this field are exciting.

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### Short Biography of Authors

**Prof. Filomena De Leo** graduated in Biological Sciences, specialized in “Applied Microbiology” and Post graduated Degree (PhD) in Microbial Biotechnologies. Currently is Associate Professor of Microbiology at the Department of Chemical, Biological, Pharmaceutical and Environmental Sciences of the University of Messina, Italy: professor of “General Microbiology”, degree Course CdL in “Biotechnology”, and professor of “Nutrimicrobiomic” degree Course CdLM in “Biology of Health, Applied Technologies and Nutrition”. She is a member of the Council of PhD in “Applied Biology and Experimental Medicine” of the University of Messina, Italy. She is member of the Reference Scientific Community of the “Stazione Zoologica Anton Dohrn” Naples, Italy (<http://www.szn.it/index.php/it/chi-siamo/comunita-scientifica-di-riferimento>, accessed on 7 October 2022). She is member of the University Research Center for the study of extreme environments and extremophiles (CUR AEE) and she is member of the National Consortium for Marine Sciences (CoNISMa). Her main interest is the study of biodiversity, ecology and genetic diversity of bacterial and fungal population involved in the biodeterioration of Cultural Heritage (especially stone monuments) and more recently in the diversity of halophilic microorganisms in deep sea environments. One special task is the taxonomy of black fungi that are among the most harmful microorganisms causing biodeterioration of stone monuments. She described two new fungal species and four new bacterial species isolated from monuments. She has participated in numerous National and International research projects both as Scientific Responsible and as a member of the Research Unit. Prof Filomena De Leo published 51 articles in Journals, 16 monographs (or book chapter), 19 Proceedings of International Congress and 54 Poster and oral communication. The publications are visible on “Researchgate” link [https://www.researchgate.net/profile/Filomena\\_De\\_Leo](https://www.researchgate.net/profile/Filomena_De_Leo), accessed on 7 October 2022.

**Prof. Daniela Isola** is a contract Professor of Botany Applied to Cultural Heritage at the University of Tuscia. She graduated in Biological Sciences at the University of Cagliari and received postgraduate specializations in Neuropharmacology and Environmental Hygiene (University of Cagliari), and Bioinformatics (La Sapienza University of Rome). She obtained PhD in Biological and Biochemical Evolution at the University of Tuscia. Since then, she has focused on fungi from extreme environments and “black fungi”. Her main interests are the biodeterioration of cultural heritage and biodegradation of aromatic hydrocarbons. Particular attention has been paid to the identification, diversity, phylogeny, metabolic skills of the involved organisms, and low-impact methods to control biodeterioration. She is the author of 4 genera and 11 fungal species, more than a thousand of sequences deposited in GenBank (covering bacteria, fungi, viruses and higher plants) and about 40 scientific papers with an H-index of 22.