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Editorial

From Head to Toe: Mapping Fungi across Human Skin

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Introduction

The human microbiota refers to the complex aggregate of fungi, bacteria and archaea, found on the surface of the skin, within saliva and oral mucosa, the conjunctiva, the gastrointestinal. When microbial genomes are accounted for, the term mirobiome is deployed. In recent years the first in-depth analysis, using sophisticated DNA sequencing, of the human microbiome has taken place through the U.S. National Institutes of Health led Human Microbiome Project [1]. This required sophisticated analysis and representative sampling, given that a single square centimeter of human skin can contain up to one billion microorganisms.

The collected of data from the Human Microbiome Project has enabled microbiologists to develop an ecological map of the human body, both inside and outside. Many of the findings have extended, or even turned upside down, what was previously known about the relationship between humans and microorganisms. One of the most interesting areas related to fungi, especially in advancing our understanding about fungal types, locations and numbers and how this affects health and disease [2]. With this fungal and bacteria diversity do not correlate; some parts of the body have a greater prevalence of bacteria (such as the arms) whereas fungi are found in closer association with feet. This article reviews some of the more recent literature.

Exploration of human commensurable skin-fungi

A variety of bacteria and fungi are found on the typical 2 square meters that represent the surface of the skin, and within the deeper layers, of a typical adult. These can be considered as 'residential' (that is ordinarily found) or 'transient' (carried for a period of time by the host.) The resident microorganism types vary in relation to skin type on the human body; between men and women; and to the geographical region in which people live.

While there has been considerable analysis of the 19 phyla of bacteria, information relating to the eukaryotic mycoflora that reside on the skin has been slower to emerge. Nonetheless, there have been a number of recent observations of interest.

The first observation is that many locations across the skin contain considerable populations of fungi. Prime locations, as reported by Findley and colleagues [3], were inside the ear canal and behind the ear, within the eyebrows, at the back of the head; with feet: on the heel, toenails, between the toes; and with the rest of the body notable locations were the forearm, back, groin, nostrils, chest, palm, and the elbow.

The second observation is that several different species are found, and these vary according to different niches. Focusing on one ecological niche, a study by Oyeka found that the region between toes, taken from a sample of 100 people, discovered 14 genera of fungi. In terms of the individual species recovered, a relatively high number were observed (an average of 40 species.) Examples of this species richness included [4]:

a. Yeasts, such as *Candida albicans, Rhodotorularubra, Torulopsis* and *Trichosporoncutaneum.*
b. Dermatophytes, including *Microsporumgypseum*, and *Trichophytonrubrum*.

c. Opportunistic fungi: *Rhizopusstolonifer, Trichosporoncutaneum, Fusarium, Scopulariopsis brevicaulis, Curvularia, Alternaria alternata, Paecilomyces, Aspergillus flavus* and *Penicillium species*

While the toe area has shown a large number of different species, the greatest varieties of fungi are to be found on the heel (approximately 80 different species.) The second most populous area is with the toes, where toe nails recover around 80 different species. Even within different genera, differences occur. For example, the external ear canal and the base of the foot are colonized by specific *Malassezia* microbiota

With the genitals, where early investigations had suggested that *Candida albicans* was the most commonly isolated yeasts. However, an investigation of 83 patients by Bentubo., *et al*. [5] showed more variety, with high recoveries of *Candida parapsilosis, Rhodotorulamucilaginos, Rhodotorulaglutinis, Candida tropicalis* and *Trichosporoninkin [5].*

Considering species more generally, Findley's work identified isolates using two phylogenetic markers: 18S rRNA cloning (to characterize genera) and pyrosequencing of the internal transcribed spacer regions (to narrow-down for species identification.) Common genera were *Malassezia, Candida, Chrysosporium, Cryptococcus, Aspergillus, Cladosporium, Epicoccum, Leptosphaerulina, Penicillium, Phoma, Malassezia,* and *Rhodotorula.* The genus recovered most often was *Malassezia. Malassezia* organisms are associated with both health skin and with individuals suffering with psoriatic lesions. How these lipophilic yeasts play a role in infection is part of a complex process and one that reinforces the significance of characterizing fungal skin flora [6].

Significance of mycological skin analysis

The importance of the investigative work into the human skin fungi helps medical researchers understand more fully the connections between the composition of skin-fungi and certain pathologies [7]. Here the intricate interactions between fungi and immune cells on the skin surface is of importance; often this mutualistic relationship is beneficial, at other times dysbiosis can lead to the manifestation of diseases especially when there is a breakdown of the mutualistic relationship.

Changes to fungal diversity can be associated with several health conditions, including atopic dermatitis, psoriasis, acne vulgaris and chronic wounds [8]. Diversity can alter through the over-use of antibiotics, where a decline in bacterial numbers can lead to a rise in fungal populations occupying the same space.

Moreover, research has indicted that patients who have a primary immunodeficiency are host to more populous fungal communities than healthy people. Here it is suggested that the weaknesses in the immune system allow higher numbers of fungi to survive, and, in turn these weaknesses can lead some ordinarily non-harmful species to become pathogenic [9]. Such opportunistic fungi include species of *Aspergillus* and *Candida*. Investigations into this area also present opportunities. For example, in developing a new understanding for immunological research and developing immune-based therapeutic approaches for people who are infected with pathogenic fungi [10].

The findings are also important for the production of medicines. Periodically pharmaceutical product recalls arise due to fungal contamination of medicinal products [11]. Contamination can arise from faulty clean air systems, improper cleaning and disinfection, and from people not following correct aseptic techniques. With people, understanding the relationship between people and contamination can lead to improvements in gowning and various hygiene practices, such as glove changing and glove sanitization [12].

Conclusion

This article has presented some of the recent research into the diversity and complexity of fungi found on the surface of human skin. As well as demonstrating the variations based on different ecological niches and the species richness, the article has shown how understanding the etiology of many fungal and immune-related diseasesis important for diagnosing and treatingvarious diseases. A further important consideration relates to the safe manufacture of pharmaceutical products. While studies to date have been interesting, there remains a dearth of studies into the fungi of the skin and it would be immensely useful to see more research directed into this field.

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