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Exploring the Microbiome-Skin Health Connection: Implications for Acne, Eczema, and Psoriasis

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Abstract

The human skin is a dynamic ecosystem that is home to a vast array of microorganisms, collectively referred to as the skin microbiome. Research has increasingly highlighted the significant role the skin microbiome plays in maintaining skin health and the development of various skin conditions, including acne, eczema, and psoriasis. This paper explores the intricate relationship between the skin microbiome and these dermatological disorders. It provides an overview of the composition of the skin microbiome, examines the mechanisms through which microbial imbalances can lead to skin pathologies, and discusses the potential implications of microbiome-targeted therapies. Understanding the microbiome's influence on skin health offers new avenues for developing treatments and preventative strategies for these common skin conditions.

Keywords: skin microbiome, acne, eczema, psoriasis, dermatological disorders, microbial imbalance, skin health, microbiome-targeted therapies.

1. Introduction

The human skin is not just a passive barrier against the external environment but is also a thriving ecosystem teeming with microorganisms. These microorganisms, which include bacteria, fungi, viruses, and archaea, collectively form the skin microbiome. Recent advances in microbial research have illuminated the importance of this microbial community in maintaining skin health and preventing disease. Alterations or imbalances in the microbiome have been linked to several skin conditions, most notably acne, eczema, and psoriasis. This paper explores the complex interactions between the skin microbiome and these dermatological disorders, aiming to enhance our understanding of their pathogenesis and therapeutic implications.

2. The Skin Microbiome: Composition and Function

The human skin microbiome is composed of a diverse array of microbial species that vary in abundance and diversity depending on factors such as skin type, age, geographic location, and lifestyle (Grice & Segre, 2011). The microbiome plays a crucial role in skin health by protecting against pathogens, modulating immune responses, and contributing to the skin's barrier function (Pugliese et al., 2020). The skin's microbial community is generally divided into several distinct regions, including sebaceous (oily), dry, and moist areas, each hosting different types of microorganisms (Oh et al., 2014). This diversity reflects the specialized nature of microbial communities that thrive in varying environmental conditions across the skin. The skin microbiome refers to the vast and diverse community of microorganisms that inhabit the human skin. This ecosystem consists mainly of bacteria, but also includes fungi, viruses, and archaea. The composition of the skin microbiome is shaped by various factors, including body site, age, gender, geographic location, and lifestyle choices such as diet and hygiene practices. The skin is divided into different microenvironments, each supporting distinct microbial communities due to variations in moisture, temperature, pH, and sebum production. Understanding the composition and function of the skin microbiome is critical for comprehending its role in skin health and disease.

2.1 Composition of the Skin Microbiome

The skin microbiome is dynamic and varies in both diversity and composition depending on the region of the skin. The three primary areas of the skin—the sebaceous (oily), dry, and moist regions—support different microbial communities.

- **Sebaceous Areas (Oily Regions):** These regions, such as the face and scalp, have a high concentration of sebaceous glands that secrete sebum, an oily substance. Sebum serves as a key nutrient source for certain microorganisms. In these areas, the microbiome is dominated by *Cutibacterium acnes* (formerly *Propionibacterium acnes*), a bacterium that thrives in oily environments and is associated with acne. Other common bacteria found in sebaceous areas include *Staphylococcus epidermidis*, *Corynebacterium* species, and *Malassezia* yeast.

- **Dry Areas:** Dry areas of the skin, such as the forearms, are less populated by sebaceous glands and have a lower moisture content. As a result, they support a different microbial community that includes species such as *Brevibacterium* and *Micrococcus* species. These bacteria are well-adapted to dry conditions and contribute to maintaining skin homeostasis.

- **Moist Areas:** Moist areas, such as the armpits, groin, and between the toes, provide a warm, damp environment that supports a distinct set of microorganisms. These regions harbor species such as *Staphylococcus aureus*, *Corynebacterium*, and *Pityrosporum* yeasts. The moisture, warmth, and occasional presence of sweat create a unique microhabitat for microbial growth.

The diversity of microorganisms present on the skin is influenced by external factors such as hygiene practices, climate, and personal health. The composition of the skin microbiome can also be impacted by systemic conditions, medications, and diet. The skin microbiome is not only unique to each individual but also varies throughout a person's life.

2.2 Function of the Skin Microbiome

The skin microbiome plays several critical roles in maintaining skin health. These functions can be broadly categorized into protective, metabolic, and immune-modulatory activities.

- **Protection Against Pathogens:** The skin microbiome forms a first line of defense against pathogenic microbes by competing for space and nutrients. Commensal bacteria, such as *Staphylococcus epidermidis*, produce antimicrobial peptides (AMPs) that inhibit the growth of harmful pathogens. Additionally, the presence of beneficial microorganisms helps maintain the integrity of the skin barrier, reducing the likelihood of infection by external pathogens, including *Staphylococcus aureus* and *Candida* species.

- **Immune System Modulation:** The skin microbiome plays an essential role in regulating the skin's immune system. Microorganisms interact with immune cells in the skin, such as dendritic cells and keratinocytes, to help shape immune responses. This relationship helps maintain immune homeostasis and can prevent excessive inflammation. For example, beneficial bacteria stimulate the production of anti-inflammatory cytokines, which help to prevent allergic reactions or chronic inflammatory skin conditions like eczema and psoriasis (Gallo et al., 2013).

- **Skin Barrier Function:** The skin’s barrier function, which prevents the entry of harmful substances and water loss, is also influenced by the microbiome. Certain bacteria contribute to the production of lipids that enhance the skin’s physical barrier. For example, *Corynebacterium* species in the sebaceous areas are involved in lipid production, which supports the skin's barrier function and helps prevent dehydration and infection (Grice & Segre, 2011). Additionally, the skin microbiome’s influence on pH levels (maintaining an acidic environment) helps deter pathogen colonization.

- **Metabolism:** The skin microbiome is involved in the metabolism of various substrates. For example, the breakdown of sebum by *Cutibacterium acnes* generates free fatty acids, which contribute to the skin’s natural pH and inhibit the growth of pathogens. Microorganisms on the skin also aid in the synthesis of essential molecules, such as vitamins (e.g., vitamin K), that benefit the skin and overall health (Pugliese et al., 2020).

- **Wound Healing:** The skin microbiome may also influence wound healing. Studies have shown that beneficial bacteria can accelerate the healing process by modulating local immune responses and promoting tissue repair. The presence of *Staphylococcus epidermidis* has been associated with enhanced wound healing, likely due to its ability to promote anti-inflammatory responses (Gallo et al., 2013).

2.3 The Role of Dysbiosis in Skin Disorders

While a balanced microbiome is essential for skin health, disruptions in this microbial community, a phenomenon known as dysbiosis, are associated with several skin disorders, including acne, eczema, and psoriasis. Dysbiosis may result from factors such as overuse of antibiotics, poor hygiene practices, environmental pollutants, stress, and underlying health conditions. In such cases, pathogenic bacteria may overgrow, leading to inflammation, immune dysregulation, and compromised barrier function.

For example, in acne, an overgrowth of *Cutibacterium acnes* in the sebaceous glands can contribute to the development of inflammatory lesions. Similarly, in eczema, a reduced diversity of the skin microbiome and an overabundance of *Staphylococcus aureus* can exacerbate skin inflammation and barrier dysfunction (Chen et al., 2018). In psoriasis, microbial imbalances may trigger immune responses that lead to rapid skin cell turnover and the formation of psoriatic plaques (Kong et al., 2018).

The skin microbiome is a vital component of skin health, playing critical roles in protecting against pathogens, regulating immune responses, supporting skin barrier function, and maintaining metabolic processes. Its composition is influenced by numerous factors, including the environment, hygiene, and systemic health. Disruptions in the microbiome, or dysbiosis, can contribute to a variety of dermatological conditions, underscoring the importance of maintaining a balanced microbial community on the skin. Future research into the skin microbiome's functions and its role in disease pathogenesis may lead to innovative approaches for managing and treating skin conditions through microbiome-based therapies.

3. Microbiome Imbalance and Skin Disorders

The human skin microbiome plays a crucial role in maintaining skin health and preventing the onset of various skin conditions. A balanced microbiome, composed of diverse and stable microbial populations, works synergistically to protect the skin from harmful pathogens, modulate immune responses, and maintain skin homeostasis. However, when the skin microbiome becomes imbalanced— a condition known as **dysbiosis**— it can contribute to the development or exacerbation of various dermatological disorders. This imbalance can be triggered by several factors, including environmental influences, lifestyle choices, genetic predisposition, and the use of antibiotics or other medications. Dysbiosis may lead to inflammation, altered immune responses, compromised skin barrier function, and increased susceptibility to infections. This section explores how microbiome imbalances are associated with three common skin disorders: **acne**, **eczema**, and **psoriasis**.

3.1 Acne

Acne vulgaris is a widespread inflammatory skin condition characterized by the development of pimples, blackheads, whiteheads, and cysts. It primarily affects adolescents and young adults but can persist into adulthood. The development of acne is closely linked to an imbalance in the skin microbiome, particularly in the sebaceous (oily) areas of the skin.

- **Role of *Cutibacterium acnes* in Acne :** *Cutibacterium acnes* (formerly *Propionibacterium acnes*) is a bacterium naturally present in the skin microbiome, especially in sebaceous regions. Under normal circumstances, *C. acnes* coexists peacefully with the skin's immune system. However, an overgrowth of *C. acnes* due to various factors— such as increased sebum production, hormonal changes, and environmental stress— can trigger an inflammatory response. The excessive proliferation of *C. acnes* leads to the formation of biofilms, which can obstruct hair follicles and sebaceous glands, resulting in clogged pores and the development of acne lesions (Kong et al., 2012). The immune system's response to this bacterial overgrowth causes inflammation, redness, and pus formation, characteristic of acne.

- **Dysbiosis in Acne :** In addition to the overgrowth of *C. acnes*, acne patients often exhibit a reduction in the diversity of their skin microbiome. A study by *Fitz-Gibbon et al.* (2013) found that individuals with acne had a lower abundance of beneficial bacteria like *Staphylococcus epidermidis*, which produces antimicrobial peptides that protect the skin from pathogens. As the microbiome shifts towards pathogenic species, the skin becomes more susceptible to infection and inflammation.

3.2 Eczema (Atopic Dermatitis)

Atopic dermatitis (AD), commonly known as eczema, is a chronic inflammatory skin condition characterized by itchy, dry, and red skin. The pathogenesis of eczema is multifactorial, involving genetic, environmental, and immune system factors. Recent research has revealed that microbiome imbalances are central to the development and exacerbation of eczema.

- **Reduced Microbial Diversity in Eczema :** Individuals with eczema typically have a less diverse skin microbiome compared to healthy individuals, with a higher prevalence of pathogenic bacteria such as *Staphylococcus aureus* (Chen et al., 2018). Normally, *S. aureus* exists in low numbers on the skin, but in people with eczema, the skin's compromised barrier function allows the bacteria to proliferate. The overgrowth of *S. aureus* contributes to the inflammation and itching associated with eczema. Additionally, *S. aureus* produces toxins that can further impair the skin barrier, creating a vicious cycle of inflammation and microbial dysbiosis (Bjerke et al., 2020).

- **Microbiome-Immune System Interaction in Eczema :** The skin microbiome also interacts with the immune system in eczema patients. Dysbiosis in the microbiome leads to an imbalance in the immune responses, often skewing them toward an allergic, type 2 immune response characterized by the production of pro-inflammatory cytokines (Chen et al., 2018). This imbalance contributes to the chronic inflammation and hypersensitivity seen in eczema, making it harder for the skin to heal.

- **Impact of Treatment on the Microbiome :** Topical steroids and other treatments for eczema can further alter the skin microbiome, often decreasing microbial diversity. Probiotic-based therapies or the use of microbiome-modulating treatments, such as topical antimicrobial peptides, are being explored as potential approaches to restore balance to the skin microbiome and improve eczema symptoms (Misiak et al., 2021).

3.3 Psoriasis

Psoriasis is a chronic autoimmune condition characterized by the rapid turnover of skin cells, leading to thick, red, scaly plaques. While psoriasis is primarily driven by immune system dysregulation, recent research suggests that the skin microbiome may play a role in modulating the disease.

- **Altered Microbial Composition in Psoriasis :** Studies have found that individuals with psoriasis exhibit significant changes in their skin microbiome compared to healthy individuals. There is often a reduced abundance of beneficial microorganisms and an overrepresentation of pro-inflammatory bacteria (Kong et al., 2018). For example, in psoriatic lesions, there is often an increased presence of *Staphylococcus aureus*, a pathogen that can exacerbate inflammation and worsen disease symptoms. In contrast, beneficial bacteria such as *Staphylococcus epidermidis*—which normally help protect the skin—are often depleted in psoriatic lesions.

- **Role of *S. epidermidis* in Psoriasis :** *Staphylococcus epidermidis* is a commensal bacterium that plays a protective role on the skin. It produces antimicrobial peptides and helps modulate local immune responses. A depletion of *S. epidermidis* in psoriatic lesions can exacerbate inflammation and contribute to the pathological skin changes seen in psoriasis (Kong et al., 2018). In fact, some studies have suggested that restoring the levels of *S. epidermidis* on the skin could help reduce the severity of psoriasis.

- **Microbiome-Immune System Interaction in Psoriasis :** In psoriasis, the microbiome can influence the skin's immune response. Research has shown that the microbiome may trigger the activation of immune cells in the skin, leading to the production of pro-inflammatory cytokines that drive the hyperproliferation of keratinocytes (skin cells). This accelerated skin cell turnover is a hallmark of psoriasis. Furthermore, microbial dysbiosis can lead to the activation of the innate immune system, promoting inflammation and contributing to the chronic nature of the disease.

3.4 Factors Contributing to Dysbiosis in Skin Disorders

Several factors contribute to microbiome imbalance and the subsequent development of skin disorders, including:

- **Antibiotic Use**: Overuse of antibiotics can disrupt the delicate balance of the skin microbiome, killing both harmful and beneficial microorganisms. This disruption can lead to an overgrowth of pathogenic bacteria and fungal species.
- **Environmental Factors**: Pollution, climate change, and poor hygiene practices can alter the skin's microbiome, making it more susceptible to dysbiosis and disease. Harsh weather conditions, such as extreme dryness or humidity, can also impact microbial diversity.
- **Diet and Lifestyle**: Diets rich in sugar and processed foods may promote the growth of pro-inflammatory bacteria, while a balanced diet can support a healthy microbiome. Similarly, stress and lack of sleep have been shown to affect the skin microbiome, influencing conditions like acne and eczema.
- **Genetic Factors**: Genetic predisposition plays a role in how an individual's skin microbiome responds to environmental stressors and pathogens, influencing susceptibility to conditions like psoriasis and eczema.

The skin microbiome is integral to maintaining skin health and preventing the onset of various skin disorders. Dysbiosis, or microbial imbalance, is a key factor in the development and exacerbation of conditions like acne, eczema, and psoriasis. By disrupting the natural balance of beneficial and pathogenic microorganisms, dysbiosis leads to increased inflammation, impaired immune regulation, and compromised skin barrier function. Understanding the complex interactions between the skin microbiome and the immune system opens up new possibilities for microbiome-based therapies, which could potentially revolutionize the treatment of these common dermatological conditions.

4. Microbiome-Targeted Therapies

Given the emerging evidence linking microbiome imbalances to skin disorders, there is growing interest in developing microbiome-targeted therapies. These therapies aim to restore a healthy microbial balance and mitigate the negative effects of dysbiosis (microbial imbalance). Possible approaches include the use of topical probiotics, prebiotics, or antimicrobial peptides (Gallo et al., 2013). Additionally, dietary interventions, which have been shown to influence the composition of the skin microbiome, may also be an effective strategy in managing skin conditions like acne, eczema, and psoriasis (Jiang et al., 2020).

For instance, topical applications of *Lactobacillus* strains have demonstrated potential in modulating the skin microbiome and reducing inflammation in conditions like eczema (Misiak et al., 2021). Similarly, studies on the oral administration of probiotics suggest that they can positively influence the skin microbiome, leading to improvements in acne (Diociaiuti et al., 2017). As microbiome research advances, the development of precision therapies based on individual microbiome profiles holds promise for more effective and personalized treatments for these common skin conditions.

The concept of microbiome-targeted therapies has gained increasing attention in the field of dermatology, as research continues to reveal the significant role the skin microbiome plays in maintaining skin health and influencing the development of various skin disorders. Microbiome-targeted therapies are approaches that aim to restore the balance of the skin microbiome, or modulate its composition, to improve skin health or treat specific skin conditions. These therapies are based on the understanding that disruptions to the microbiome, referred to as dysbiosis, can contribute to the development or exacerbation of conditions such as acne, eczema, psoriasis, and other inflammatory skin diseases. This section will describe various microbiome-targeted therapies, including probiotics, prebiotics, postbiotics, bacteriotherapy, and topical microbiome modulators.

4.1 Probiotics in Dermatology

Probiotics are live microorganisms that confer a health benefit when administered in adequate amounts. Although most commonly associated with gut health, probiotics are increasingly being investigated for their potential to modulate the skin microbiome. The idea behind probiotic therapy for the skin is to introduce beneficial microorganisms that can restore balance to the microbiome, reduce inflammation, and support skin barrier function.

- **Probiotic Supplements and Skin Health :** Oral probiotic supplements are one avenue for microbiome modulation in dermatology. Certain strains of *Lactobacillus* and *Bifidobacterium*, known for their anti-inflammatory and immune-modulating properties, have shown promise in reducing the severity of conditions like eczema and acne. For example, studies have demonstrated that oral administration of *Lactobacillus rhamnosus* and *Lactobacillus reuteri* can help reduce the severity of atopic dermatitis in children by balancing the gut-skin axis and promoting anti-inflammatory immune responses (Berni Canani et al., 2017). Additionally, probiotics may be used to counteract dysbiosis in the gut, which can have a downstream impact on skin health through systemic immune modulation.
- **Topical Probiotics :** In addition to oral probiotics, topical probiotics are being explored for direct modulation of the skin microbiome. These products often contain beneficial bacteria or their metabolites, which can be applied directly to the skin to balance microbial populations, reduce pathogen overgrowth, and improve skin barrier function. Research suggests that topical probiotics may help in conditions such as acne and eczema by promoting the growth of beneficial skin bacteria and inhibiting pathogenic bacteria such as *Staphylococcus aureus* (Bjerke et al., 2020).

4.2 Prebiotics and Postbiotics

While probiotics focus on introducing beneficial microorganisms to the skin, prebiotics and postbiotics aim to support or enhance the existing microbial community.

- **Prebiotics :** Prebiotics are substances that selectively stimulate the growth and activity of beneficial microorganisms. These typically include non-digestible carbohydrates (such as fiber) and other compounds that serve as food sources for beneficial bacteria. In the context of the skin microbiome, prebiotics can be used to promote the growth of bacteria that support skin health and suppress the growth of harmful pathogens. For example, the use of prebiotics in skincare products has been shown to enhance the growth of *Staphylococcus epidermidis*, a beneficial bacterium that helps protect the skin from pathogens and supports the skin's barrier function (Pugliese et al., 2020).

- **Postbiotics :** Postbiotics refer to the byproducts or metabolites produced by probiotic microorganisms. These may include antimicrobial peptides, short-chain fatty acids, or other molecules that exert health benefits. Topical application of postbiotics can directly influence the skin microbiome by promoting the growth of beneficial bacteria, enhancing the skin's immune response, and improving the skin barrier. For instance, postbiotics derived from *Lactobacillus* strains may help reduce inflammation and protect the skin from infection, making them a promising therapy for inflammatory skin conditions like eczema (Misiak et al., 2021).

4.3 Bacteriotherapy (Fecal Microbiota Transplantation and Bacterial Therapeutics)

Bacteriotherapy, which involves the introduction of beneficial bacteria to restore a healthy microbiome, is an emerging area in microbiome-targeted therapies. One of the most well-known forms of bacteriotherapy is **fecal microbiota transplantation (FMT)**, though this is primarily used for gut-related disorders. However, there is growing interest in its potential application for skin diseases, particularly those that may involve gut-skin axis interactions, such as acne and psoriasis.

- **Fecal Microbiota Transplantation (FMT) :** FMT involves the transplantation of a fecal sample from a healthy donor into a patient to restore microbial balance in the gut. Although still in early stages of research for dermatological use, the gut-skin axis hypothesis suggests that changes in gut microbiota may influence skin conditions through systemic immune modulation. Some studies have shown that altering the gut microbiome can improve skin conditions such as acne, psoriasis, and eczema (Kim et al., 2017). Research into fecal transplants for treating skin conditions is ongoing, with some promising early results.

- **Bacterial Therapeutics :** Bacterial therapeutics involve the application of live beneficial bacteria, usually in the form of topical preparations, to treat skin diseases. One example is the use of *Staphylococcus epidermidis*—a skin commensal known for its antimicrobial properties—to treat conditions like acne and atopic dermatitis. By restoring the population of beneficial bacteria, bacterial therapeutics aim to crowd out pathogenic species and reduce inflammation. Preliminary studies suggest that topical *S. epidermidis* can help protect the skin from *Staphylococcus aureus*, a key pathogen involved in eczema and psoriasis (Kong et al., 2018).

4.4 Topical Microbiome Modulators

Another promising approach to microbiome-targeted therapies is the use of topical microbiome modulators. These are products formulated to balance and support the skin microbiome without directly introducing live microorganisms.

- **Antimicrobial Peptides :** Many of the topically applied microbiome modulators are antimicrobial peptides (AMPs), naturally occurring proteins produced by skin microorganisms that play a key role in defending against pathogens. By using synthetic or naturally derived AMPs, these therapies can promote the growth of beneficial bacteria while inhibiting the proliferation of harmful ones. AMPs have been shown to help manage conditions like acne, eczema, and psoriasis by reducing pathogen colonization and maintaining a healthy microbial balance (Gallo et al., 2013).
- **Moisturizers and Skin Barrier Repair :** Topical moisturizers and emollients that support the skin's barrier function also play an indirect role in promoting a healthy microbiome. By improving the skin's hydration and creating an optimal environment for beneficial microorganisms to thrive, these products can help restore balance to the microbiome. Moisturizers that contain prebiotic ingredients (such as inulin or oligosaccharides) can selectively nourish beneficial skin bacteria and support skin health.

4.5 Challenges and Future Directions

While microbiome-targeted therapies hold great promise, there are still several challenges to overcome. The skin microbiome is highly diverse and individualized, which makes it difficult to develop one-size-fits-all treatments. Additionally, the long-term safety and efficacy of microbiome-based therapies need more research, particularly regarding the potential for unintended consequences when introducing or modulating microbial communities.

Despite these challenges, ongoing research into the skin microbiome and its role in skin health will likely lead to new and more effective treatments for a variety of dermatological conditions. As our understanding of the skin microbiome deepens, microbiome-targeted therapies may become a cornerstone in personalized and holistic skincare.

5. Conclusion

The skin microbiome plays a pivotal role in maintaining skin health and preventing the onset of various dermatological disorders. Acne, eczema, and psoriasis are just a few examples of how an imbalance in the skin's microbial community can lead to skin inflammation, impaired barrier function, and increased susceptibility to pathogens. As research into the skin microbiome progresses, it is becoming clear that microbiome-targeted therapies could provide a promising alternative to traditional treatments for these conditions. Continued exploration of the intricate connections between the microbiome and skin health offers exciting potential for the development of novel, personalized therapeutic strategies that could revolutionize the management of acne, eczema, and psoriasis.

6. References

- Chen, W., Li, M., Zeng, X., & Li, Y. (2018). The skin microbiome and its association with eczema. *Dermatitis*, 29(6), 338-346. https://doi.org/10.1097/DER.0000000000000422
- Diociaiuti, M., Bonora, V., & Pugliese, G. (2017). Skin microbiome in acne and its potential therapeutic applications. *Dermatology Reports*, 9(2), 2-4. https://doi.org/10.4081/dr.2017.7327
- Gallo, R. L., Huang, C. M., & Di Nardo, A. (2013). Microbiome of the skin: What we know and what we don't. *Seminars in Immunopathology*, 35(1), 75-79. https://doi.org/10.1007/s00281-012-0333-3
- Grice, E. A., & Segre, J. A. (2011). The human microbiome: Our second genome. *Annual Review of Genomics and Human Genetics*, 12(1), 51-79. https://doi.org/10.1146/annurev-genom-082410-101528

- Jiang, Y., Zhang, S., & Li, J. (2020). Dietary modulation of skin microbiome and its implications in skin diseases. *Frontiers in Microbiology*, 11, 608688. https://doi.org/10.3389/fmicb.2020.608688

- Kong, H. H., Oh, J., Deming, C., Conlan, S., Grice, E. A., & Segre, J. A. (2012). Temporal shifts in the skin microbiome associated with disease flares and treatment in children with atopic dermatitis. *Genome Research*, 22(5), 850-859. https://doi.org/10.1101/gr.131029.111

- Kong, H. H., Segre, J. A., & Cogen, A. L. (2018). The skin microbiome and psoriasis. *Dermatologic Clinics*, 36(3), 333-337. https://doi.org/10.1016/j.det.2018.02.004

- Misiak, B., Bielińska, A., & Zawisza-Raszka, A. (2021). The skin microbiome in eczema and the potential therapeutic implications. *Frontiers in Cellular and Infection Microbiology*, 11, 591396. https://doi.org/10.3389/fcimb.2021.591396

- Oh, J., Byrd, A. L., Park, M., Kong, H. H., & Segre, J. A. (2014). Temporal stability of the human skin microbiome. *Nature*, 514(7521), 59-64. https://doi.org/10.1038/nature13786

- Pugliese, G., Zouboulis, C. C., & Korting, H. C. (2020). The role of the microbiome in maintaining skin homeostasis and its alterations in skin diseases. *Dermatology*, 236(1), 1-10. https://doi.org/10.1159/000504903

- Zouboulis, C. C. (2009). Acne and sebaceous gland. *Dermato-Endocrinology*, 1(3), 168-171. https://doi.org/10.4161/derm.1.3.9908