The skin microbiome and mature skin

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The skin changes throughout life. This involves an increase in surface pH, a reduction in sebum secretion, lipid and tissue remodelling, and changes in the microbial ecosystem. The skin microbiome especially influences hydration, barrier function and inflammation. This bidirectional skin–microbiome relationship compels a re-evaluation of how products for mature skin are assessed: beyond surface observation, the objective measurement of a formula's impact on the composition and function of the microbiome is required.

Byome Labs places microbiome science at the core of its methods. We conduct customized *in vitro* assays to help cosmetic, dermocosmetic, and pharmaceutical brands quantify the effects of their finished products or ingredients on the skin, scalp, oral, and vaginal microbiomes, in contexts of dysbiosis or maintenance of microbial balance. This article focuses on mature skin and on the bidirectional relationship between skin ageing and the microbiome, with implications for microbiome compatible care.

Skin ageing: factors, causes, consequences

Factors: intrinsic versus extrinsic

Skin ageing results from a combination of intrinsic factors, such as hormonal regulation and genetics, and extrinsic factors, including UV exposure, pollution, and smoking.[1,2]

Within this framework, a distinction is commonly made between intrinsic ageing, which reflects the 'programmed' evolution of tissue functions, and extrinsic ageing, for example photoageing resulting from chronic solar exposure.[2,3] Indeed, photoageing acts as an accelerator of age-related alterations by modifying cutaneous lipid structure and sustaining low-grade chronic inflammation over time.[1]

Key mechanisms: barrier, lipids, and inflammation

With age, the skin undergoes profound functional changes: decreased activity of the sebaceous and sweat glands, reduced nutrient delivery to tissues, and alkalinization of surface pH, all factors that weaken barrier function.[2,4]

At the level of the stratum corneum, ageing is accompanied by structural alterations and a decline in epidermal lipids, which reduces water-retention capacity and increases vulnerability to external insults.[2]

More specifically, there is a significant reduction in the three major lipid components of the barrier : ceramides, cholesterol, and free fatty acids - the balance of which is essential to maintain controlled permeability.[2]

In parallel, ageing is associated with a pro-inflammatory state that disrupts cutaneous homeostasis: protection against external stressors declines, water retention deteriorates, and the overall integrity of the tissue becomes harder to preserve.[2]

Consequences

At the histological level, ageing is accompanied by epidermal atrophy, a decrease in fibroblast and collagen density, and alterations of the stratum corneum with reduced water holding capacity.[1]

Clinically, these rearrangements translate into thinner, drier, and more vulnerable skin, with slower wound healing and increased susceptibility to certain dermatologic conditions.[2]

Barrier disruption, through both lipid alterations and elevated surface pH, promotes cutaneous imbalance and makes it more difficult to maintain adequate day to day hydration.[2,4]

Skin microbiome

Architecture and composition

The skin is colonized by a diverse set of commensal microorganisms, referred to as the skin microbiome.

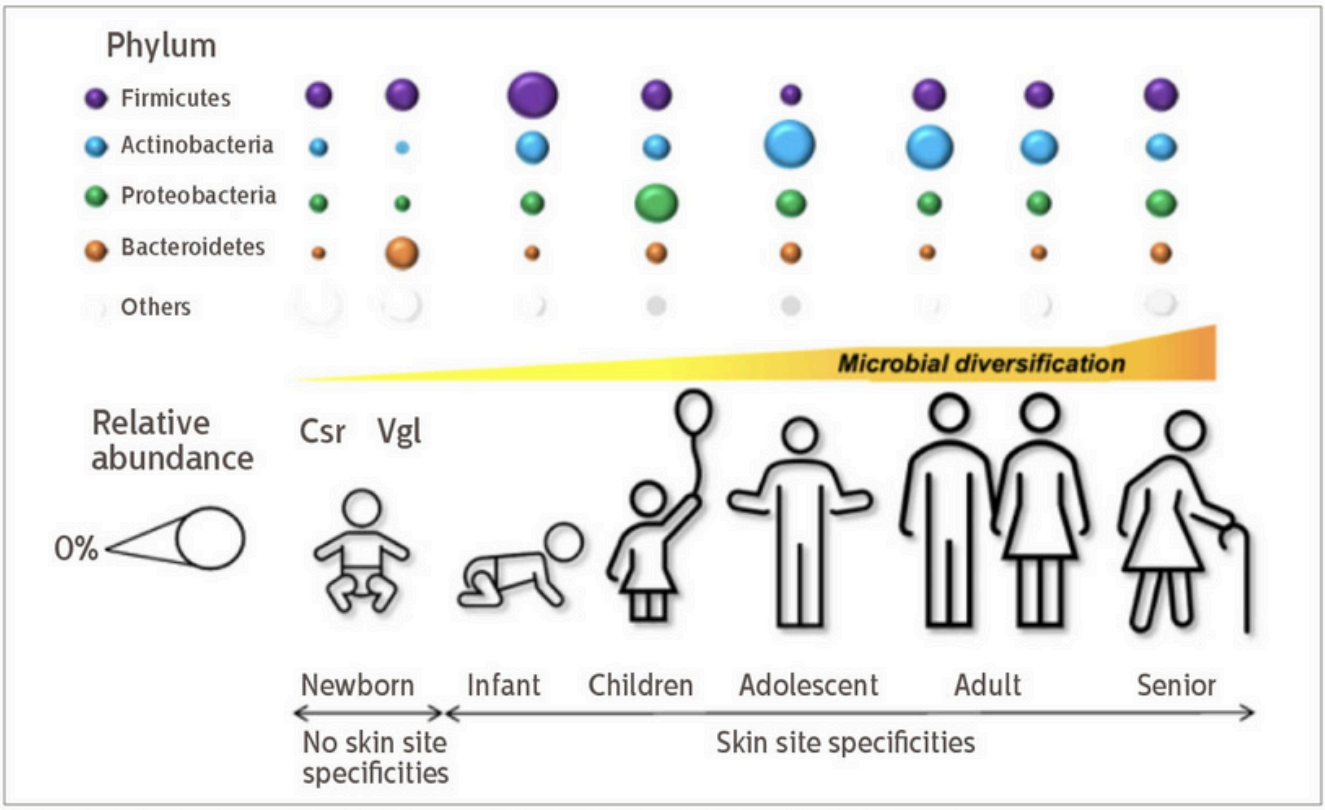


Figure 1: Bacterial diversity increases with age, whereas the relative abundance of bacterial families decreases[11]

Its heterogeneous topography creates distinct niches where temperature and humidity vary by site: higher in flexural areas such as the groin and axillae, close to 37°C, and lower at the extremities, such as fingers and toes, around 30°C.[5]

The density of sebaceous glands influences lipid secretion, including fatty acids, which contributes to acidifying the skin surface. As a result, surface pH fluctuates by site within an approximate range of 4.2 to 7.9.[5]

These gradients in temperature, humidity, sebum, and pH generate conditions that shape the density and composition of resident communities of bacteria, fungi including *Malassezia*, viruses, archaea, and mites.[5]

Within this ecosystem, the microbiome contributes to barrier function and supports cutaneous homeostasis through continuous interaction with its environment.[5]

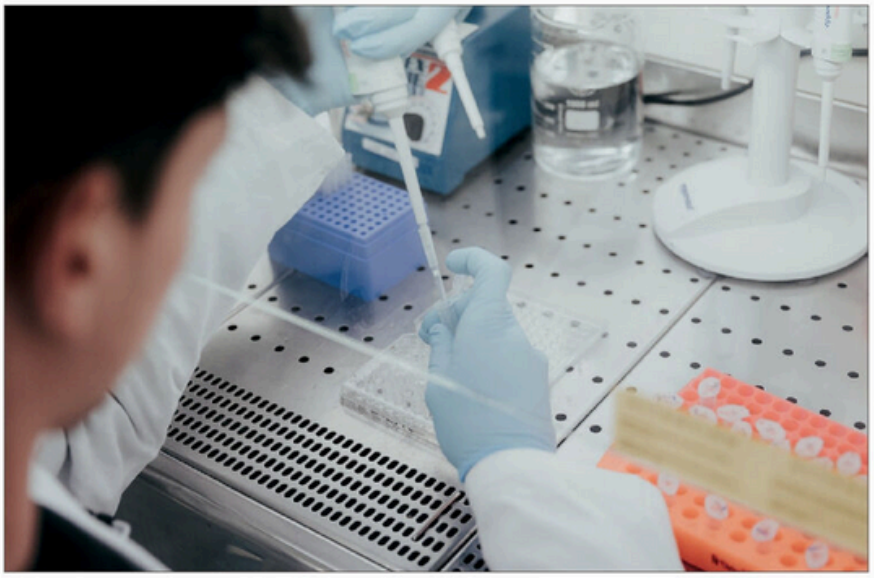
Study techniques

Advances in molecular biology and next generation sequencing (NGS) have enabled precise characterization of the skin microbiome, providing access to diversity and structural profiles that were previously inaccessible.[5]

Culture methods remain essential to characterize microbial properties, including phenotypes, functional interactions, and sensitivity to actives, as a complement to molecular approaches.[5]

Key functions: protection, hydration, and immunomodulation

Cutaneous microorganisms play a protective barrier role against exogenous and opportunistic microorganisms, notably through competition and antagonism.[6] This protection relies, among other mechanisms, on the production of antimicrobial peptides by commensal bacteria, notably *Staphylococci* and *Corynebacteria*.[7] *Malassezia* synthesizes indoles that can inhibit other yeasts and moulds, thereby limiting certain colonisations.[5]



Staphylococcus epidermidis produces a sphingomyelinase that hydrolyses sphingomyelin into ceramides, which strengthen the barrier and limit water loss, and into phosphocholine, which nourishes and protects the bacterium. This activity also promotes the colonization of *S. epidermidis*, contributing to the stability of the local community.[8,9]

In addition, certain acidic metabolites produced by *S. epidermidis* can activate receptors involved in recruiting T lymphocytes (T cells) to the skin, support keratinocyte proliferation, and increase the number of tight junctions between cells, mechanisms that strengthen barrier integrity.[9] Activation of TLR2 by commensal *S. epidermidis* also increases the tight junction barrier in keratinocyte cultures *in vitro*, which contributes to maintaining epithelial barrier homeostasis.[9]

In summary, the barrier function of the skin, supported in part by microbiome activity, operates at multiple levels: competitive exclusion of pathogens, antagonism via antimicrobial peptides and other inhibitory molecules, support for the production of key lipids such as ceramides, and immune signaling oriented toward effective local defence.[2,6,8,10]

Link between the skin microbiome and ageing

Composition across the life course

Figure 1 shows that it is not sufficient to oppose children and adults in study models; additional categories should be distinguished, namely newborn, infant, child, adolescent, adult, and senior, and sex should be taken into account.

Taxonomically, skin ageing is frequently associated with a decline in *Cutibacterium*, consistent with reduced sebum secretion, and with higher relative abundances of *Corynebacterium*, *Acinetobacter*, *Streptococcus*, and *Prevotella* in older subjects.[12] Overall, the literature reports higher diversity and greater variability among older individuals, a trend that should be confirmed in multiethnic studies that account for sex specificities.[11]

Bidirectional mechanisms

As skin ages, surface pH tends to rise, sebum production decreases, and tissues are remodelled. These changes alter the microbial environment and are often accompanied by a decline in *Cutibacterium* and, at times, commensal *staphylococci*, while *Corynebacterium* and certain *Proteobacteria* become more prevalent. These population shifts in turn drive age related changes in skin physiology.[2,4]

The influence also operates in the opposite direction. When *C. acnes* becomes scarce, fewer sebum derived fatty acids, including propionic acid, are available to maintain a naturally acidic surface pH, which therefore tends to increase.

Likewise, if *S. epidermidis* is less abundant, the skin benefits less from its sphingomyelinase that supports ceramide production, and TLR2 activation by this species less effectively stimulates AMP production and the strengthening of tight junctions, leading to a more fragile barrier.

Certain metabolites from *S. epidermidis* may also shape local immunity by recruiting T lymphocytes and supporting keratinocyte proliferation. In sum, microbiome composition can in turn affect surface pH, hydration, and barrier integrity in mature skin.[8–10]

Implications for mature skin

The higher alpha diversity described in older skin indicates a more heterogeneous ecosystem that is potentially less stable, in which opportunistic species can persist more easily when the barrier is weakened.[5,11]

Added to this are changes in pH, reduced sebum, a decrease in *Cutibacterium* and *Staphylococcus*, and an increase in *Corynebacterium* and various Proteobacteria; dysbiosis profiles are therefore more frequent in older individuals. These microbial shifts may accelerate certain age related skin changes, reinforcing the vicious circle in which mature skin and the microbiome co influence one another.[2]

In this context, preserving the skin microbiome is essential for maintaining skin health, as it supports barrier integrity, protects against pathogens, sustains hydration, and enhances long-term resilience.[2,5]

Solutions and future perspectives — microbiome friendly approaches and microbiome studies

1. Strategy

Preventing and correcting signs of ageing relies on restoring the skin barrier and reducing exposome factors such as ultraviolet radiation and oxidative stress, through a combination of antioxidant containing products and daily photoprotection. This approach limits dysbiosis and supports barrier resilience in mature skin.

In this context, incorporating prebiotics, probiotics, and postbiotics into care for mature skin is considered a lever to strengthen barrier function, modulate inflammation, and improve tolerance to ultraviolet exposure and oxidative stress, while supporting the stability of commensal communities.[2]

2. Targeting microbiome functions hydration, pH, and immune defence

Within the cutaneous ecosystem, key commensals perform beneficial functions that can be directly leveraged by formulation and care routines:

- Hydration: supporting the population

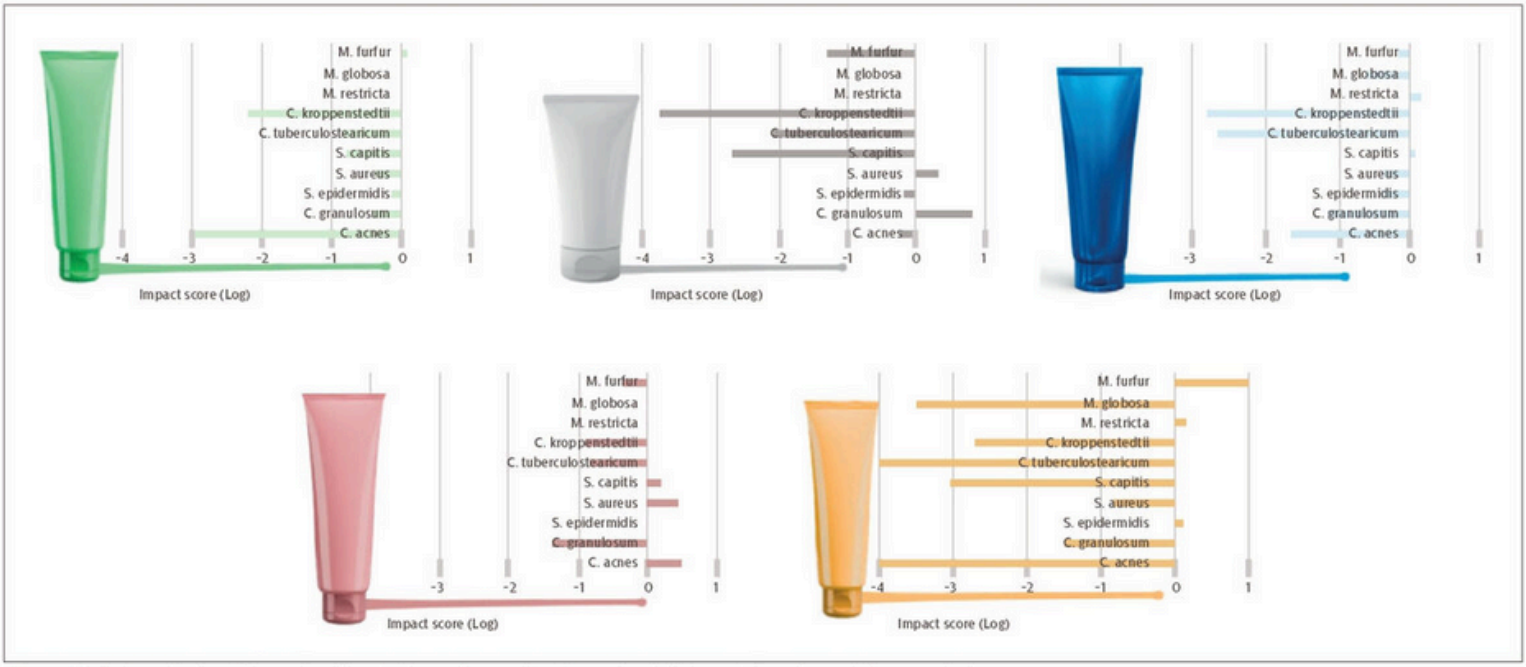


Figure 2: Data obtained from *in vitro* tests performed in the microbiology laboratory at Byome Labs

of *S. epidermidis* may be strategic, since its sphingomyelinase promotes ceramide production and strengthens barrier function. This activity also favours stable colonization of *S. epidermidis* in its niche, contributing to community stability.[8,9]

- pH and control of opportunists: *Cutibacterium acnes* hydrolyses sebaceous lipids into free fatty acids, including propionic acid, which lowers surface pH and creates an environment unfavourable to the growth of pathogens such as *Staphylococcus aureus*.[8–10]

Local immunomodulation and tight junctions: commensals such as *S. epidermidis* can stimulate TLR2 on keratinocytes, increasing endogenous AMP production and strengthening the tight junction barrier, thereby preserving homeostasis.[12]

In practice, this argues for microbiome compatible care that supports these natural functions through a managed acidic pH, appropriate lipid supply, antioxidants, and pre-, pro-, and postbiotics.

Conclusion

Figure 2 shows results from *in vitro* tests performed in the microbiology laboratory of Byome Labs. It displays impact profiles, expressed as log10 variation, for several formulas on a panel of microorganisms representative of the skin microbiome.

At Byome Labs, strains are selected from NGS sequencing data and the literature in order to refine our models, for example mature skin and dry, oily, or moist sites. Here, each product exhibits a distinct signature, which underscores the importance of measuring the effect of every formula on the microbiome to guide formulation and to objectively substantiate microbiome compatibility.

At Byome Labs, we are committed to understanding microbiomes to improve consumer health. Our ambition is to establish new standards in microbiome testing and product recommendations in order to reduce waste, strengthen the efficacy of care, and accelerate the transition toward transparent, microbiome respectful beauty.

To achieve this, we draw on more than 20 years of expertise in microbiology, with strong competencies in biofilm biology, immunology, genetic engineering, and artificial intelligence. We already apply these capabilities through customized services tailored to the specificities of our clients' products and needs, whether the focus is the skin, vaginal, oral, or scalp microbiome, and including issues such as dysbiosis or the scientific demonstration of microbiome compatibility.

Our expertise in *in vitro* microbiome testing has been concentrated into Byome Derma™, our instant skin microbiome test coupled with an artificial intelligence system designed with dermatologists, which recommends products adapted to each consumer's microbiome. **PC**

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