Dandruff

Daddy: why does Tristram's father always have "snowflakes" on his jacket

Photo by Brett Sayles: https://www.pexels.com/photo/man-in-green-zip-up-jacket-and-gray-fedora-hat-3598462/

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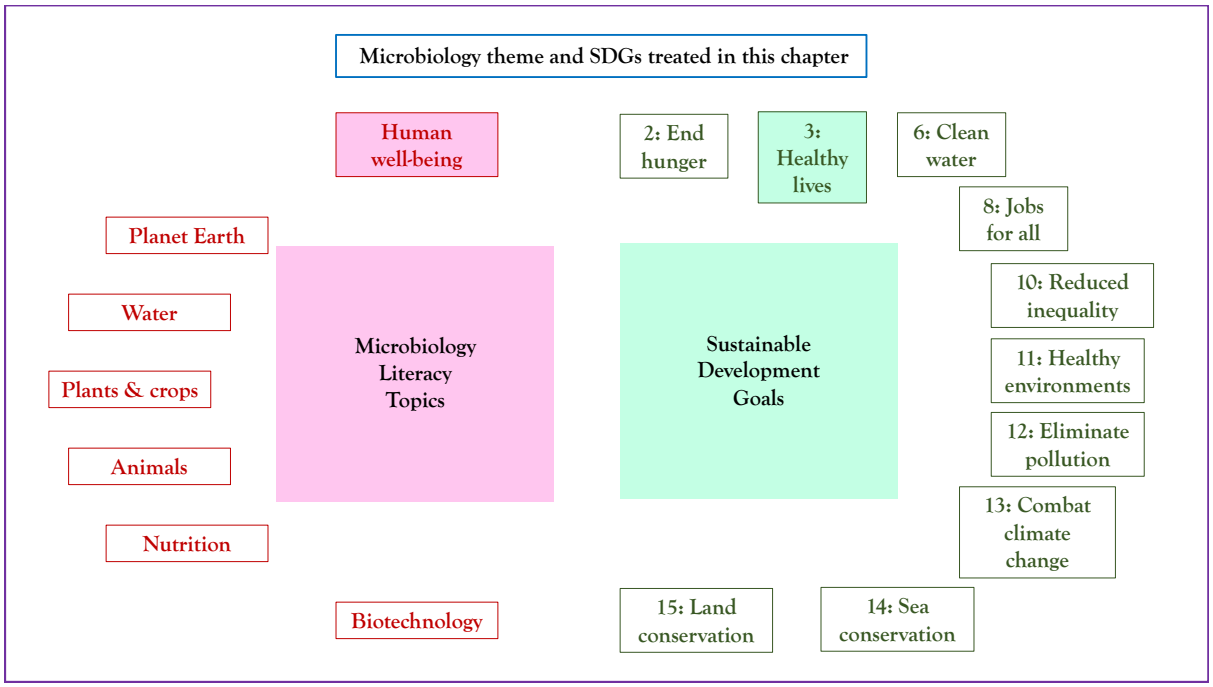
Storyline

What do you see when you look in the mirror? You see "you" right. But that's not entirely true. What you are looking at, but might not actually see, is a combination of a number of human cells but also a huge number of cells that are not your own. They belong to the bacteria, viruses, fungi and other small organisms that live on or in your body. Wait, no need to panic or reach for the anti-bacterial soap just yet. These microbial passengers are so much more than "germs" as you may have heard them described before. In fact, they provide a number of benefits to your everyday health and even your mood. As we learn more and more about this "microbiome" it's becoming clear that we need to create a partnership with these organisms as opposed to killing them. Here we will explore the different microbes that live on your skin, the sometimes-problematic non-medical skin conditions that they cause and how we can reset the balance in order to improve cosmetic appearance.

The Microbiology and Societal Context

The microbiology: the skin microbiome; skin secretions and their influence on the microbiome and key players; skin barrier-disruption-portal of entry; skin microbiome dysbiosis; dandruff; current and future treatments. *Sustainability issues:* health; food and nutrition.

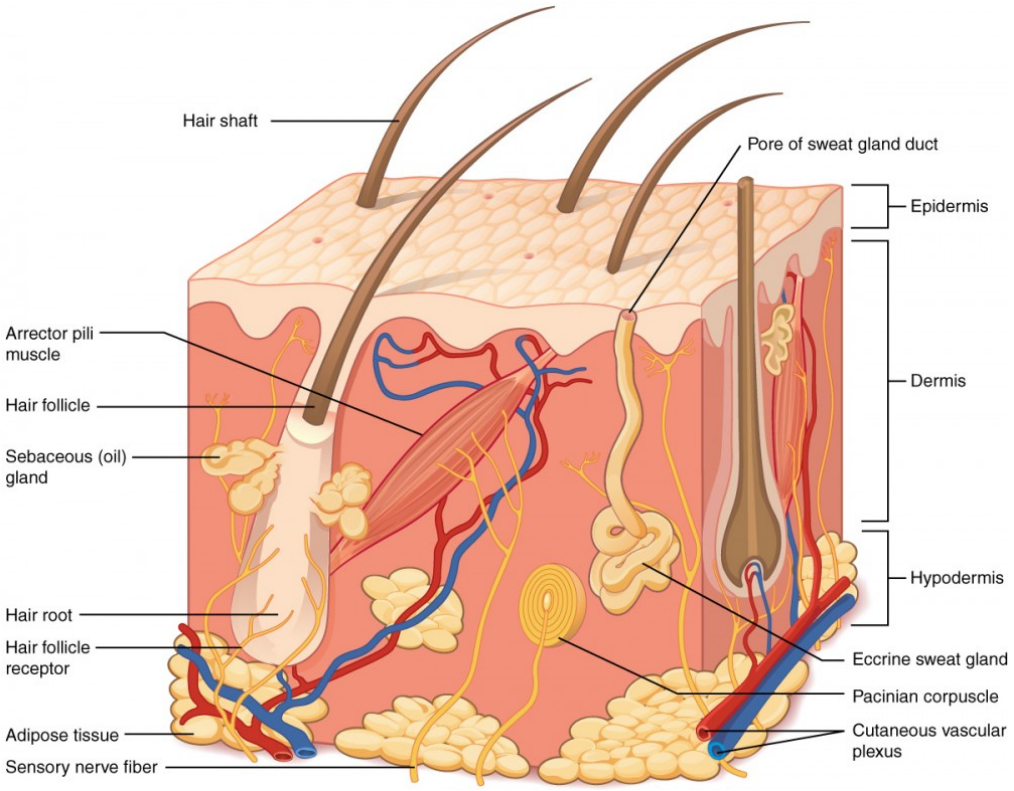


Dandruff: The Microbiology

1. ***The human microbiome.*** Our current understanding of the human body has revealed that we are not as much "human" as we once thought. The study of the microbiology of the human body has revealed that up to 50% of the cells that make up our bodies are not human at all. This human microbiome, the collection of microorganisms that include, among others, bacteria, viruses, archaea, fungi and even mites, that exists on and in us, far from being

detrimental, is in fact essential for human health and indeed existence. Bacteria can produce many compounds that are vital for the human body, including Vitamin K that is essential for blood clotting, help us digest multiple foodstuffs including vegetables, as well as providing protection against pathogenic bacteria that can cause human disease. However, our microbial inhabitants can also be responsible for a number of cosmetic conditions from acne, to body odour to dry skin. These conditions are not medical in nature, but can detrimentally impact a person's appearance or odour. Fortunately, a variety of products are available to control them, many of which you will already find in your own bathroom. Here we examine in more detail one of these conditions: dandruff.

2. ***Human skin: the underappreciated organ.*** Human skin provides our body with a first layer defence (also known as its "first line of defence"). Responsible for thermal regulation, protection from microbial infection and other external aggressors, our skin in covered in micro-crevices and invaginations, such as hair follicles and ducts, that facilitate excretion of multiple compounds onto the skin surface. Amazingly once these features are accounted for, the surface area of skin of an average human has been estimated at approximately $30m^2$ (about the size of a garage that can fit 2 cars!!!), significantly more than previously thought. Despite offering protection against human pathogens, our skin provides a much more hospitable environment for its commensal microbiome. Skin produces a number of compounds that are fed on by our resident microbes and, in turn, these microbes produce compounds that both directly nourish the skin as well as keep invading organisms at bay.



https://commons.wikimedia.org/wiki/File:501_Structure_of_the_skin.jpg

Skin is in a continuous state of turnover with lower layers dividing and maturing as they migrate to the skin surface. This epidermal renewal (the epidermis is the part of your skin that you can see) takes approximately 6 weeks with fully developed (differentiated) cells being removed

from the cell surface through washing or other abrasive actions. A general conceptual model for skin is one of a wall, made of bricks and mortar, where the bricks are the skin cells and the mortar consists of lipids and fats that hold the cells together. An over-production of skin cells or a reduction in the available lipids and fats can result in excessive skin cell shedding. This can give rise to skin issues which people recognise as dandruff on the scalp or dry skin on other skin sites. Reduced turnover can lead to dark skin spots and other related conditions.

3. ***The skin microbiome: Location, Location, Location.*** The secretions from the afore-mentioned glands and ducts provide a rich collection of nutritious materials that encourage microbial colonisation. The skin provides three distinct micro-environments for its microbial inhabitants. Dry sites such as the legs and forearm support a sparce microbial community with a number of different species of bacteria with none consistently dominant. Moist sites, such as the underarm, have high level of moisture and a more nutritious food source, and the bacterial genera *Staphylococcus*, *Corynebacterium* and *Cutibacterium* dominate here. Finally, the least diverse sebaceous sites such as the face and scalp, characterised by increased number of sebaceous glands, are dominated by *Cutibacterium*. Sebaceous glands provide a lipid-rich food source for both bacteria and yeasts alike, and the colonising organisms are specifically adapted to make efficient use of the nutrients available.

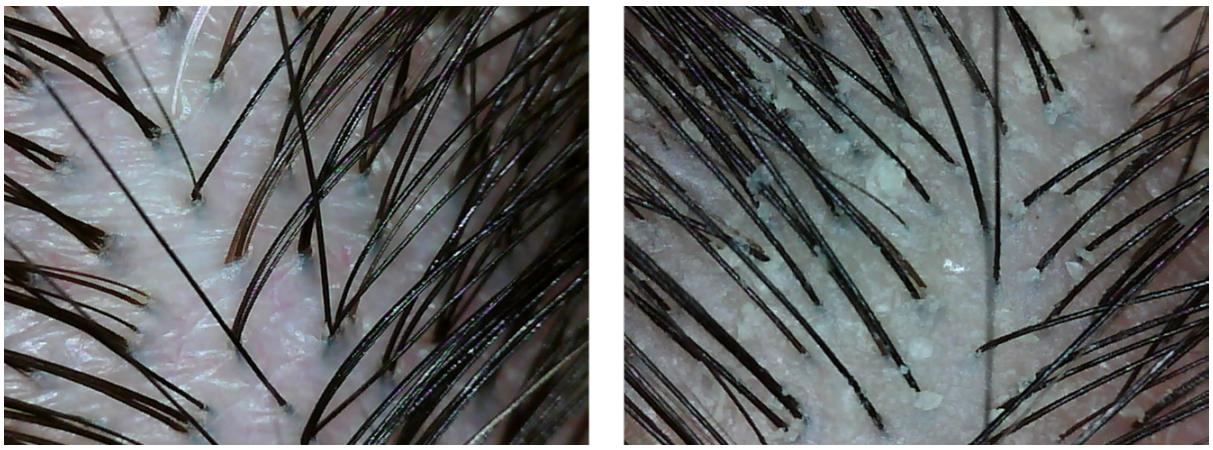
4. ***Common cosmetic conditions mediated by the human microbiome.*** Skin and scalp conditions that can impact our appearance in a non-medical way affect almost all humans worldwide and some point in their lives, from the development of cradle cap (a harmless skin condition where crusty skin appears) in new-born babies to the development of acne, axillary odour (smelly armpits), dandruff and dry skin, as we grow older. These conditions are not limited to the skin, with oral malodour and gingivitis (gum inflammation and bleeding caused by bacterial build up) also being prevalent across the globe. In some of these cases, a causal association of these conditions with a single, or small groups of microbes, has been unequivocally demonstrated. For example, the levels of odour generated in the underarm is directly correlated with specific species of bacteria of the genus *Staphylococcus*. Bacteria from the genera *Fusobacterium*, *Porphyromonas* and *Treponema* are commonly associated with gingivitis and oral halitosis (bad breath).

5. ***Some common conditions remain unexplained.*** Despite considerable research, the exact cause of some of the most commons skin complaints remain elusive. Acne mainly effects adolescents with almost 100% of this group being affected at some point. This multifactorial condition has been correlated with elements including host genetics, hormone levels, diet, Body Mass Index (BMI) and potentially smoking status. Bacteria on skin, specifically *Cutibacterium acnes* (named for the condition) have consistently been associated with progress of acne but some elements remain unexplained. All humans have *C. acnes* resident on their skin, although we don't all suffer from acne at all times. Recent evidence suggests that not all *C. acnes* are made equal and specific types or strains may be responsible for healthy skin and others for acne-prone skin. Another example of a condition whose initiation and progress remains elusive is dandruff. Effecting approximately 50% of people globally at some point in their lives, this complex condition results in excessive shedding of skin cell from the scalp and, while treatable, continues to confound researchers as to the exact reasons for its progression.

6. ***Dandruff: a complex multifactorial condition.*** Dandruff is a cosmetic condition, specifically affecting the scalp, which results in excess shedding of skin cells that can form large

unsightly flakes on the scalp and on clothes. Commonly manifesting with itchy skin, dandruff affects almost half of the population at some point in their lives and is prevalent across genders, ethnicities, and countries.

Normal scalp sheds cells at a rate of approximately 500,000 per sq cm of skin per month but this can almost double in individuals with dandruff. The onset and progression of dandruff is still not fully understood and remains an area of active research. However, there are a number of potential causes that will be explored here. The most commonly accepted offender are yeasts (fungi) that live on the scalp. It has been recognised since the 1870's that these yeasts increase when people have dandruff. Following the most common treatment, the use of anti-fungal containing shampoos, the levels of yeast decrease, and the condition improves. However, all humans have a significant number of yeasts on their scalp but not everyone get dandruff. Indeed, early work which examined the scalps of individuals who did not wash their hair for 6 months revealed a 10-fold increase in these yeasts, although none of the individuals in question suffered from dandruff. This suggests that there is more to dandruff than fungal over-growth. However, these yeasts (*Malassezia*) are an important biomarker and are an important research area



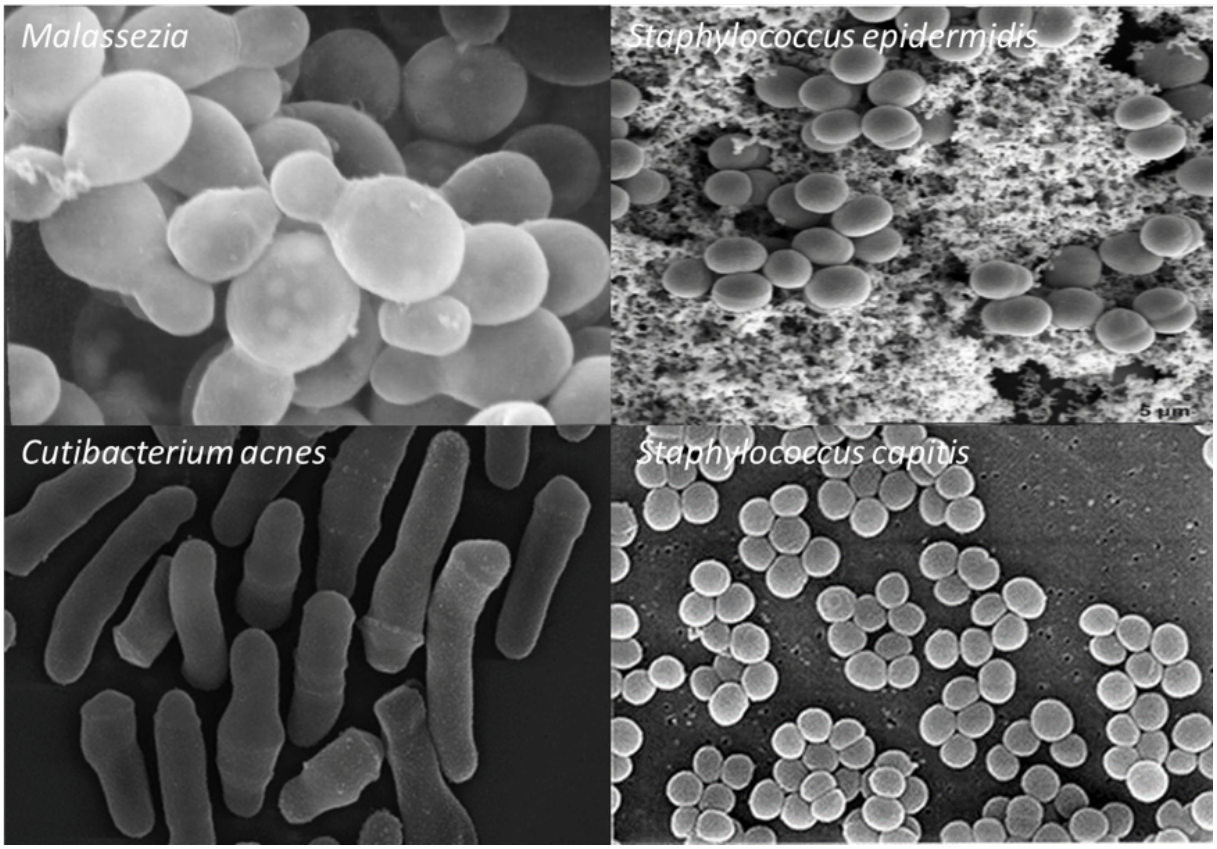
Close up pictures of healthy and dandruff scalp.

7. **Malassezia*: the most common yeast on human skin.*** The main type of fungi found on the scalp belong to the genus *Malassezia*. Currently, this group consists of 18 different species, some of which are perfectly suited to living on skin. Other types live on dogs, horses and even parrots. The most common types found on scalp include *Malassezia restricta*, *M. globosa* and *M. sympiodaylis*. Recent analysis, however, has shown that there are other species dominant on some individuals but as of yet, these have still to be grown in a lab and remain unclassified. A key feature of these fungi is that they are unable to generate their own fatty acids. These fatty acids are essential for cellular function and since *Malassezia* cannot make their own, they must get them from an external source. The perfect source of these fatty acids is human skin, specifically sebum produced in our hair follicles by sebaceous glands. These glands significantly increase their activity during puberty, resulting in an increase in the available food source for *Malassezia* and coinciding with a large increase in the levels of both *Malassezia* and *C. acnes.* Both of these organisms excrete a number of enzymes (lipases) that break down sebum into multiple saturated and unsaturated fatty acids. *Malassezia* preferentially consumes a number of specific fatty acids and it has been hypothesized that those fatty acids that are left behind could potentially have a role to play in the progression of dandruff.

8. ***Host factors: it could be in your genes.*** As mentioned, all humans have *Malassezia* on their scalp, and other skin sites, although not everyone suffers with dandruff. As such there must

be additional factors that are important in the condition's aetiology. One of the main host factors associated with dandruff is a disrupted scalp skin barrier. Skin plays a vital role in protecting us from external stressors, including UV radiation, toxic materials and even the weather. However, one of the most crucial functions of skin is to prevent water loss from the body. "Epidermal differentiation", the ordered shedding of skin cells, is disrupted in dandruff resulting in the shedding of clumps of skin cells and formation of a so-called "leaky" barrier. This is mediated through the generation of an inflammatory response in the skin that potentially can be caused by the overgrowth of *Malassezia* on the scalp. However, it is currently unclear what initiates this cycle of infection. Does overgrowth of *Malassezia* cause a disrupted barrier, or does the disrupted barrier allow products of the *Malassezia* cells access to deeper layers of the skin, which in turn initiates an inflammatory response that facilitates additional infection? This element of individual predisposition to dandruff could potentially be the result of human genetics, and it is possible that whether you suffer from dandruff or not is a result of the genes you inherit from your parents.

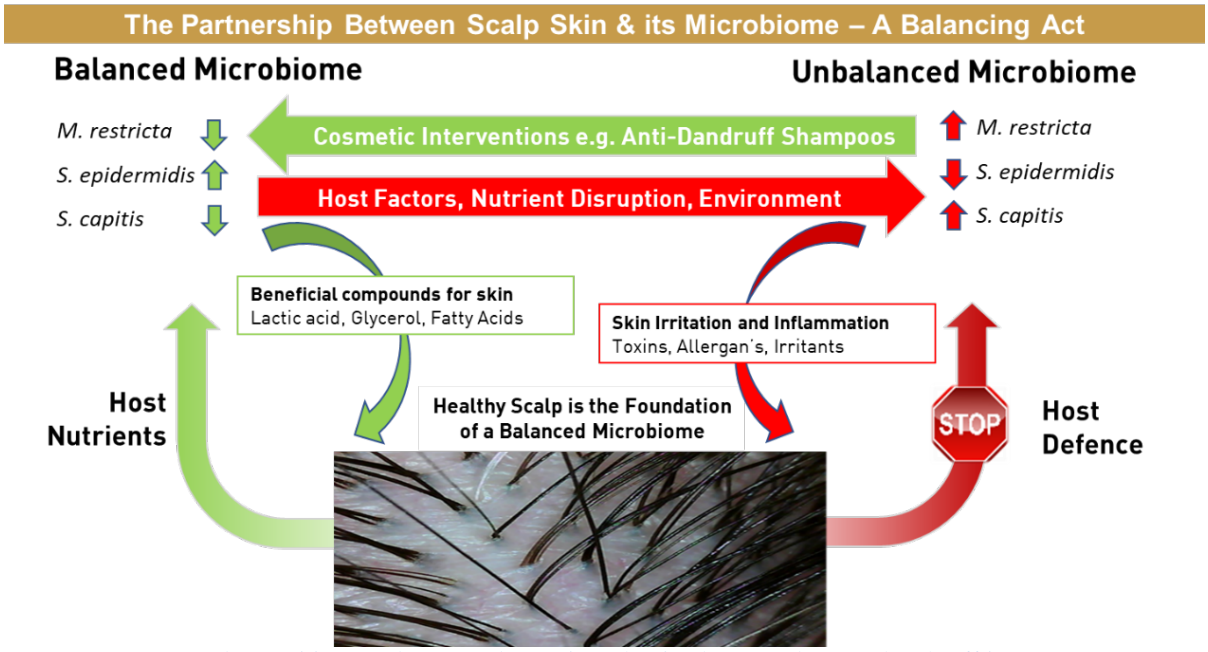
9. ***Bacteria: a new player in dandruff progression?*** In the search for a definitive explanation for the progression of dandruff, most of the attention rightly focused on *Malassezia* and the human host. However recent research interest is turning to the bacteria on the scalp. There are three main species of bacteria on the scalp, *C. acnes*, *Staphylococcus epidermidis* and *Staphylococcus capitis*.



Microscope images of the fungi / bacteria commonly found on scalp

On a healthy scalp there is an abundance of *C. acnes*. Like *Malassezia*, it feeds on sebaceous secretions and indeed can produce compounds that can kill *Malassezia* and keep its numbers down. A similar scenario exists for *S. epidermidis* and it produces anti-microbial

compounds that also reduce the proliferation of *Malassezia*. Both of these bacteria are abundant on healthy scalps. However, on a dandruff scalp there is a significant reduction in the number of *C. acnes* and *S. epidermidis* which are partially replaced by *S. capitis*. Recent research has shown that *S. capitis* could potentially be detrimental to the skin barrier and may not be as efficient at controlling the growth of *Malassezia*. Indeed, it has been shown that some types of *S. capitis* can kill *C. acnes and*, as such, reduces the ability of your skin's good bacteria to fight the overgrowth of *Malassezia*. While more work is needed in this area it presents the intriguing possibility that the key to controlling the yeasts on our scalps may be to provide the weapons that our good bacteria need to fight them.



https://researchoutreach.org/articles/scalp-microbiome-dandruff/

10. ***Environmental factors: some things you cannot control.*** There are however some potential factors to dandruff progression that are outside our control. Dandruff is more common in winter. It is thought that colder weather results in an alteration of the skin barrier lipids (mortar) produced on skin and, as a result, the ensuing disrupted skin barrier may be more prone to infection. Additionally, stress may have a role to play. As previously mentioned, hormone levels control the activity of the sebaceous glands which in turn impact the growth of *Malassezia*, so it is conceivable that this could have a role to play in the condition.

11. ***Treatment of dandruff: now and into the future.*** There are currently multiple marketed products to control and treat dandruff. In the main, these products contain one of a number of key anti-fungal ingredients e.g., zinc pyrithione, selenium sulphide or octopirox. In all of these instances, the target for treatment is *Malassezia*, with repeated treatment resulting in decreased levels of the yeast which, in turn, results in improvement in the skin barrier and resolution to health. However, dandruff can return, and further courses of treatment may be required. Research continues on the next generation of antidandruff products. These products will not only directly target *Malassezia*, but will also directly address the skin barrier through the provision of fatty acids to repair the barrier, or by decreasing the levels of the host immune response to

infection. Some of the most recent developments suggest a potential role for the gut microbiome in the treatment of skin conditions. Compounds produced by the bacteria in our gut have been hypothesised to impact skin conditions, the quality of our hair, how well we sleep and even our mood. It may not be long before you begin to see edible supplements for the treatment of dandruff on the shelf next to your anti dandruff shampoo.

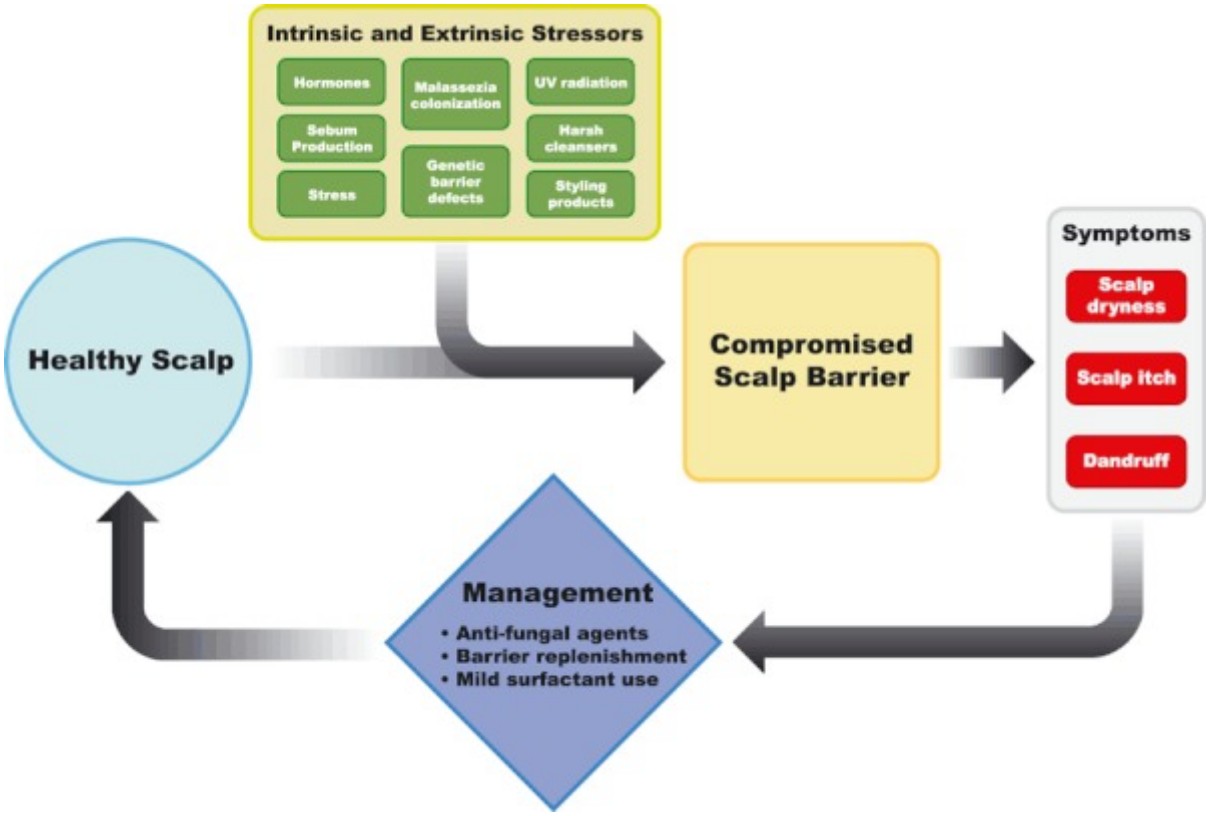


Image from Unilever paper - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3494381/

Relevance for Sustainable Development Goals and Grand Challenges

- **Goal 3. Ensure healthy lives and promote well-being for all at all ages**. Dandruff, while more of an irritation than a disease, may constitute a disorder of enough concern for some of those affected that they feel the need to take steps to counteract it. Moreover, it represents one example in a continuum of skin microbiota dysbiosis conditions that range from mild itching to serious forms of dermatitis, and even invasive infections that can be life-threatening. As such, is relevant to SDG 3.

Potential Implications for Decisions

1. ***Individual***
   a. If I have dandruff, is it of sufficient concern that I need to use an anti-dandruff product?

Pupil participation

2. ***Class discussion of the issues associated with dandruff***
   a. Discussion about the number and different types of bacteria, fungi and viruses that live on and in us

b. Understanding that microbes are for the most part beneficial. While of course hygiene and handwashing are important, the knowledge that most members of the human microbiome are either benign or essential.

c. Microbes play an essential part in human health and despite the fact that we regular wash them away, they will grow back, and we need them to.

d. The more microbes the body is exposed to the better. Link to e.g., Chicken Pox – will cause sickness but the body learns to develop immunity and you will not get sick again. Link immunity to vaccines and Covid-19.

e. We are familiar with the work of bacteria but may not realise it. e.g., bacteria in your gut are essential for health and in fact, a large portion of your poo are bacteria, fungi and viruses.

f. Open discussion on cosmetic conditions to normalise the impacts that they have on people so people will not be embarrassed about searching for solutions e.g., Acne, axillary odour, dry skin, dandruff, smelly feet.

3. ***Exercises***

a. Get pupils to measure the size of the classroom that they are in to discover just how large an area your skin can cover – 30 square metres – 5m x 6m.

b. Get pupils to list things that they do already to keep microbes under control to prevent the development of different conditions – wash hands, brush teeth, shower or bathe, shampoo hair, anti-perspirants and deodorants.

c. Ask children to look at the ingredients on bottles of anti-dandruff shampoo to see if they can spot the ingredients that are anti-fungal – list can be provided.

The Evidence Base, Further Reading and Teaching Aids

https://researchoutreach.org/articles/scalp-microbiome-dandruff/

Glossary

Microbiome: The collection of bacteria, viruses and fungi that live on and in us and plat a crucial role in human health.
Epidermis: The outermost skin layer that you can see with the naked eye.
Sebaceous glands: Glands on our skin that secrete oils to keep out skin and hair moist.
Cosmetic Condition: A non-medical condition that impacts a person's appearance.