Skin as a microhabitat*

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Summary

Only recently has it become appreciated how complex an ecological medium is formed by the human skin. There are many chemical substances, both inorganic and organic, which contribute to the maintenance of the skin population. Nevertheless, it seems probable that some microbial growth factors are contributed by organisms resident on the skin.

Introduction

Although it has been appreciated since the dawn of microbiology that the human body forms a habitat for very many microbes [Williams (1973) recently calculated the total bacterial load of the human as more than 10^{14} organisms], an appreciation of the skin as an area worthy of study for its own intrinsic interest is comparatively recent. The skin maintains a large population of micro-organisms derived from several genera and subject to change in response to ecological pressures which include temperature, humidity, pH and probably stimulation and inhibition by other members of the flora. These are reviewed in detail by Noble and Somerville (1974).

In the work to be discussed here, recently carried out in the Institute of Dermatology, attention will be directed to the physical habitat, the mode of growth and the availability of nutrient materials.

Microbial populations

Total microbial populations vary from site to site on the body and vary also with the age of the host. Somerville and Murphy (1973), in a quantitative study of *Corynebacterium acnes* at eighteen sites on the skin of adults, found the total anaerobic organisms to vary more than did the aerobic organisms although there was very great variation between individuals (Table 1). Children younger than 10 years rarely carry *C. acnes*, however (Fig. 1). The appearance of this organism on the forehead is probably related to the onset of sebum secretion at puberty (Matta, 1974) but the precise factors governing the growth of *C. acnes* on the skin are unknown.

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FIG. 1. Increase in carriage of *C. acnes* on the forehead in relation to age. Based on results from 1100 children.

Even in the most densely colonized area, the forehead, each organism has a living area equal to 100 times its own area. If organisms were spread out evenly over the surface there would be only one organism per $100 \mu^2$. However, organisms do not live spread out evenly over the skin, but live in microcolonies containing hundreds or thousands of individual cells (Somerville and Noble, 1973). It can be seen from Table 2, that females had smaller microcolonies of aerobes than did the males but had larger colonies of anaerobes. There is no obvious explanation for this; all were adult laboratory workers from the same environment. It is known from the work of others that females have larger skin scales than males and there may be other, as yet unexplored, differences.

It has proved singularly difficult to visualize these microcolonies on the skin surface except in persons with diseases of the skin, though, even in erythrasma, bacteria are scarcely more numerous than on normal skin (Somerville, 1972). Transmission light microscopy has yielded material suggestive of microcolonies when specimens are taken with the skin surface biopsy, but the three-dimensional nature of the skin surface makes photographic recording a difficult practice. The scanning electron microscope has proved more valuable and microcolonies have been seen on the surface of stratum corneum cut from the foot (Fig. 2).

TABLE 1. Counts of aerobic and anaerobic bacteria on the skin of young adults (Williamson scrub technique 4 cm²)

Site	Eleven males				Eleven females			
	Aerobes		<i>C. acnes</i>		Aerobes		<i>C. acnes</i>	
	Geometric mean	Range	Geometric mean	Range	Geometric mean	Range	Geometric mean	Range
Forehead	8300	60-2900000	32000	6-5700000	4900	26-43000	54000	6-1700000
Sternum	8500	190-140000	200000	2600-4900000	660	66-39000	14000	6-990000
Subclavicle	1400	53-62000	74000	130-550000	520	140-28000	9100	6-1500000
Centre back	1800	7-82000	270000	92000-1500000	620	59-55000	30000	6-570000
Shoulder	510	46-50000	4100	67-250000	190	33-1300	4300	6-400000
Deltoid area	470	20-13000	230	6-26000	260	7-3500	510	6-4200000
Forearm	1000	46-520000	38	6-350	140	26-1000	51	6-4100
Palm	390	66-4900	130	7-14000	620	72-56000	340	13-4300
Lower axilla	2000	26-240000	57	6-920	370	13-280000	47	6-12000
Lumbar area	1200	33-57000	710	6-16000	130	7-4100	570	6-510000
Periumbilical area	3400	340-800000	220	33-7200	690	79-4300	320	6-750000
Thigh, upper front	1300	160-24000	34	6-220	560	99-5300	140	6-7200
Thigh, lower front	1400	320-35000	56	6-460	270	33-3200	56	6-500
Thigh, back	1300	320-17000	15	6-250	330	13-5700	19	6-1900
Shin	760	190-2600	28	6-300	310	51-2500	33	6-2200
Calf	690	46-15000	9	6-20	140	6-1100	21	6-130
Dorsum of foot	320	46-3600	14	6-160	500	33-5400	41	6-130
Sole	91000	660-1600000	42	6-33000	2700	72-66000	18	6-200

Based on data summarized in Somerville and Murphy (1973).

TABLE 2. Microcolony size of organisms from skin of young adults

Site	Five males				Five females			
	Aerobes		<i>C. acnes</i>		Aerobes		<i>C. acnes</i>	
	Mean microcolony size	No. of samples	Mean microcolony size	No. of samples	Mean microcolony size	No. of samples	Mean microcolony size	No. of samples
Forehead	2026	26	1776	29	586	35	3915	35
Forearm	163	29	129	21	67	32	355	20
Periumbilical area	338	27	508	21	26	28	2297	19

Based on Somerville and Noble (1973).

FIG. 2. Microcolony on the skin of the foot. Note the filamentous appearance of the diphtheroid organisms. Scanning electron micrograph.

Physical factors

What factors contribute to the maintenance of these bacteria on the skin? One great physical factor is the humidity. Occlusion of the skin produces a massive increase in the population. Figure 3 shows the area around an eccrine sweat gland after the skin has been occluded for 4 hr; there has been an obvious increase in the skin flora. This visually confirms the work of others. It is frequently said that a surgeon wearing rubber gloves sweats bacteria out of the glands (hence the danger of a punctured glove). These studies suggest, however, that multiplication, rather than extrusion, is responsible. It may be that freshly secreted sweat is inhibitory to bacteria, perhaps owing to high concentrations of lactic acid and, as shown in Fig. 4, this may result in lack of growth directly around an eccrine sweat gland.

Although there is a wide range of pH values found on normal skin (Noble, 1968) the values are probably too close to permit differences due to pH to be detected. Temperature fluctuates over a restricted range and under normal uncontrolled environmental

conditions it is probably not possible to identify changes associated with temperature alone.

Nutrient materials

Until recently little attention seems to have been paid to the nutrient materials available at the skin surface although a study of the composition of sweat shows a great variety of materials to be available (Table 3). There are, in addition, very many fat-soluble substances present on the skin. These include triglycerides, saturated and unsaturated free fatty acids, fatty acid esters (waxes), cholesterol, cholesterol esters, hydrocarbons and squalene. The richness of this source of compounds may be judged by the work of Kellum and Strangfeld (1972) who detected fifty-nine different fatty acids in the range C_8 to C_{18} in samples from skin. We have concentrated on the water-soluble fraction but it has been surprising to find that this rich collection of nutrient is not sufficient for the growth of all organisms which grow on human skin.

FIG. 3. Increase in growth of bacteria around an eccrine sweat gland following 4 hr occlusion. Scanning electron micrograph.

FIG. 4. Growth around an eccrine sweat gland after 4 hr occlusion. Note apparent zone of inhibition round gland orifice. Scanning electron micrograph.

TABLE 3. Availability of some water-soluble nutrient substances at the skin surface

Amino acids	1400 mg/l
Other N compounds	2000 mg/l
Lactic acid or lactates	500 mg/l
Inorganic ions	25 mg/l
Carbohydrates	5 mg/l
Mucoprotein	500 mg/l
DNA	
RNA	
Vitamin B complex	
Vitamin C	

In studies of factors affecting microbial growth, Murphy (1973) devised a medium based on known cutaneous nutrients but failed to grow more than a few of known skin inhabitants on this medium. Extract of human stratum corneum, however, readily supported growth and it was clear that some accessory factor was present in stratum corneum which had not been reported. This factor could be shown to be present by chromatographic and autobiograph techniques but has not yet been identified. Serendipitous observations, however, revealed that some

microbial colonies which appeared as contaminants were able to contribute an accessory substance to the medium. Coenzyme A has been found to act as an accessory factor in this system but does not correspond to the factor detected in stratum corneum. It seems to us probable that some bacterial species readily able to colonize the skin may release substances which enable others to colonize this habitat. These observations take us one stage nearer to understanding stimulation and inhibition *in vivo*.

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