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AN ABSTRACT OF THE THESIS OF Michael James Gimbol for the  
Master of Science in Biology presented May 22, 1970.

Title: Studies on the Distribution and Habitat of Demodex  
folliculorum.

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:

  
Ralph W. Macy, Chairman

  
Earl Fisher Jr.

  
Richard B. Forbes

The present study was undertaken to determine the incidence of infestation with Demodex folliculorum, a skin mite parasitizing man, and to investigate those factors which influence its occurrence. These factors were the personal hygiene, sex, age and skin condition of the human host. A detailed view of the habitat of this parasite is also included so that the controversy surrounding its role as a possible pathogen or vector of disease could be explored in light of the current knowledge.

A number of sites of infestation were sampled by a

number of different techniques. The primary sample site was the nasal area of the face which was examined by slit lamp magnification after chemical application to partially expose the mites. A secondary site involved the eyelash follicles from which the lashes were epilated and examined for mites under the microscope.

The 441 subjects examined in the nasal area were tabulated by age, sex and skin condition and the incidence of infestation was computed for each of five age groups. There was a definite increase in incidence of Demodex with the advancing age of the host and the normal and oily skin conditions appeared to be much more involved than the dry skin condition. A similar increase in incidence with advancing age was apparent in the 143 subjects whose eyelashes were examined. The results from both areas exhibited a statistical correlation between the age and skin condition of the human host and the presence of mites.

The explanation of the increase in incidence with the advancing age of the human host is based on the development and secretory rate of the sebaceous glands of the human host. Past studies have shown that Demodex lives in and around the sebaceous glands of the skin and feeds on sebaceous material and cellular debris. The face appears to be the habitat of optimum occurrence which corresponds to the distribution of sebaceous follicles and glands whose size and rate of secretion are greater than those over most

of the body. The role of Demodex in the formation of ingrown hairs on the neck is discussed as a possible, new clinical entity.

The influence of the host's personal hygienic habits on demodectic infestation remains rather obscure. Although the accumulation of sebaceous material would tend to favor the maintenance of mites, the reservoirs of the sebaceous follicles of the face in which the mites are found are not effected by normal soap and water cleansing. Inhabitation of the eyelash follicles may be enhanced by ineffective cleansing, but more study is needed to determine the validity of this contention.

The finding of selective sites of infestation on the human host led to speculation on the possibility of physiological races of Demodex.

Although it is difficult to determine the validity of reports by earlier workers, there appears to be a decreasing trend in the incidence of Demodex folliculorum since its discovery over a century ago.

STUDIES ON THE DISTRIBUTION AND HABITAT OF  
DEMODEX FOLLICULORUM

by

MICHAEL JAMES GIMBOL

A thesis submitted in partial fulfillment of the  
requirements for the degree of

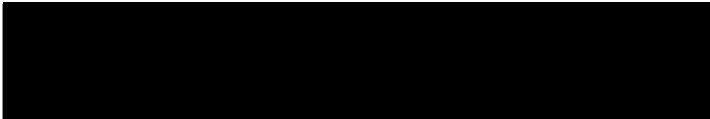
MASTER OF SCIENCE  
in  
BIOLOGY

Portland State University  
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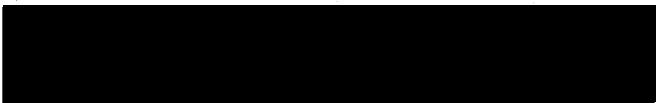
  
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May 22, 1970

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## INTRODUCTION

Mites comprise a large and important group of Arthropods, although they are not well known outside of the scientific world. Despite their obscure size, these Arachnids of the order Acarina are ubiquitous animals and Acarologists estimate the number of species to be at least one million. They have been found living on Mt. Everest, in hot water springs, on the walls of caves washed by seawater and some in the depths of deep freshwater wells. A handful of fertile soil contains an average of five different forms (Baker and Wharton, 1952). Interest in these tiny creatures may be enhanced by knowing the nearest location of a representative of the mites -- most likely on the end of the nose or in the eyelash follicles of the reader. Mites may be free-living, saprophytic, or parasitic on plants and animals, as practically all living things serve as hosts. Some mammals may have as many as five different mite forms as parasites on the same animal. Man is no exception and has been plagued by mites since the beginning of recorded history. There are five main groups or families which commonly infest man with varied consequences.

Members of the family Dermanyssidae are bloodsucking mites normally found on birds and rodents. Some however, may temporarily become annoying human pests in rat and mice

infested buildings when orphaned by its normal hosts being killed or driven off. These mites play a minor role in transmission among reservoir hosts, and occasionally to man, of endemic typhus, rickettsialpox, Q fever, tularemia, plague, and certain viruses.

Redbugs or chiggers are the six-legged larvae of mites of the family Trombiculidae which are parasitic on vertebrates but free-living as nymphs and adults. These cause tremendous discomfort for many people due to allergic tissue reaction from the animal's irritating saliva that is superficially injected into the skin. A few closely related species of the genus Trombicula in the Far East are responsible for the transmission of scrub typhus, caused by Rickettsia tsutsugamushi, to man.

Many mites, most of them belonging to the families Acaridae (Tyroglyphidae) and Glycyphagidae, are common pests of human dwellings, stores, and warehouses where they attack all sorts of food materials, stored seeds, stuffings of furniture and other similar commodities. People who come into close association with infested goods develop symptoms which most workers feel are of an allergic nature. Though allergy undoubtedly plays a part, there is evidence that the bodies or excretions of the mites are toxic with both dermal and respiratory symptoms occurring.

The itch mites, Sarcoptes scabiei, members of the Sarcoptidae family, are well documented for the thin

tortuous tunnels excavated by the impregnated female in the epidermis of man (Freidman, 1942). The daily excavations of a female may appear as a grayish burrow due to the eggs and excrement she deposits along the way and amount to 2 or 3 millimeters in length. Transference to a new host occurs by actual contact, normally at night, rarely in the daytime, on account of the secretive habits of the mites. It is possible for infection to be derived from mangy animals, although once adapted for several generations to a given host the mites do not often survive a transfer to a different species of host for more than a few days (Johnson and Mellanby, 1942).

The last group concerns the family Demodicidae which now includes 3 genera and 43 known species and subspecies, all of which are apparently obligate parasites of mammals (see review by Nutting, 1964). Several demodids are of concern to medical practitioners and veterinarians since they cause or are associated with marked pathologic conditions of man and domestic animals. One species in particular, Demodex folliculorum, the follicle mite of man, concerns the balance of this study.

Most species of Demodex are very similar and have been well illustrated by Hirst (1919). Demodex (from Gr. demos = fat, dex = worm) folliculorum is a tiny vermiform mite with an elongated abdomen which is ringed with striations giving an annular segmented appearance. The eight legs are short

stumpy projections without setae. The legs have five segments and end in claws. Setae are also lacking on the body. The palpi are closely appressed to the tiny rostrum; the chelicerae are tiny and needlelike. The female genital opening is located ventrally between coxae IV and in the male the penis opens on the dorsal surface of the cephalothorax, slightly in front of the interval between the first and second legs. It is bipronged, one branch being strongly chitinised and acting as a sheath for the more delicately pointed division (Figures 1 and 2).

The egg of Demodex folliculorum is approximately 0.08 mm. in length by 0.04 mm. in width (Gmiener, 1908). It is usually shield-shaped rather than oval (Figure 3). After hatching, the organism passes through larval, protonymph, deutonymph, and adult stages. The larvae have three pairs of legs which are poorly developed when compared with the adults (Figure 2). The adult has four paired appendages and is approximately 0.3 to 0.4 mm. in length. All stages below adulthood are equally as long, but often more slender (Figure 2). Hirst's (1919) measurements are given in Table I.

Demodex folliculorum was first seen and mentioned in print by Henle in 1841. Friedrich Gmeiner (1908) however, credits the discovery of this animal to Berger, a Frenchman who found it in ear wax in 1842. However, neither of the initial discoverer's work came to light until after that of G. Simon (1842), who discovered the parasites independently



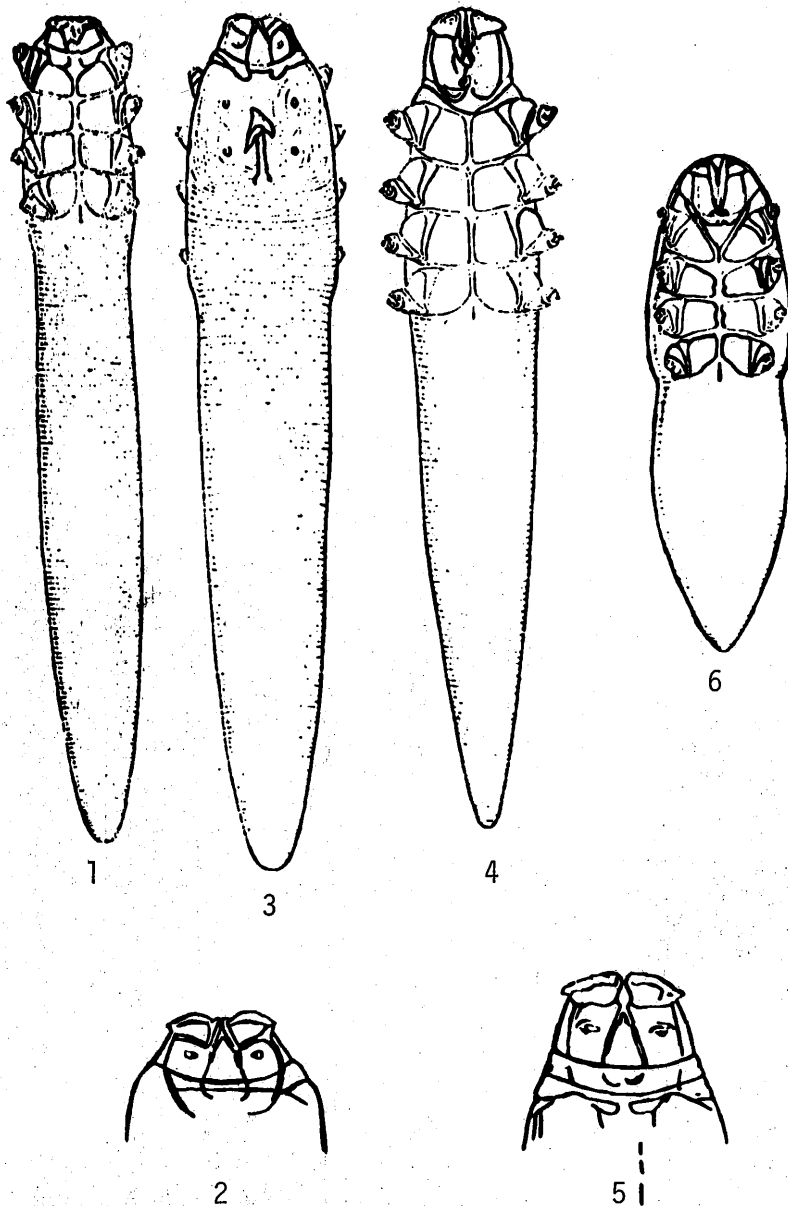


Figure 1. 1, Demodex folliculorum (Simon), ventral view (X 345); 2, Demodex folliculorum, capitulum from above; 3, Demodex folliculorum, dorsal view of male showing protruded penis; 4, Demodex canis (Leydig), ventral view (X 515); 5, Demodex canis, dorsal view of capitulum; 6 Demodex bovis (Stiles), ventral view. (From Hirst, 1919)

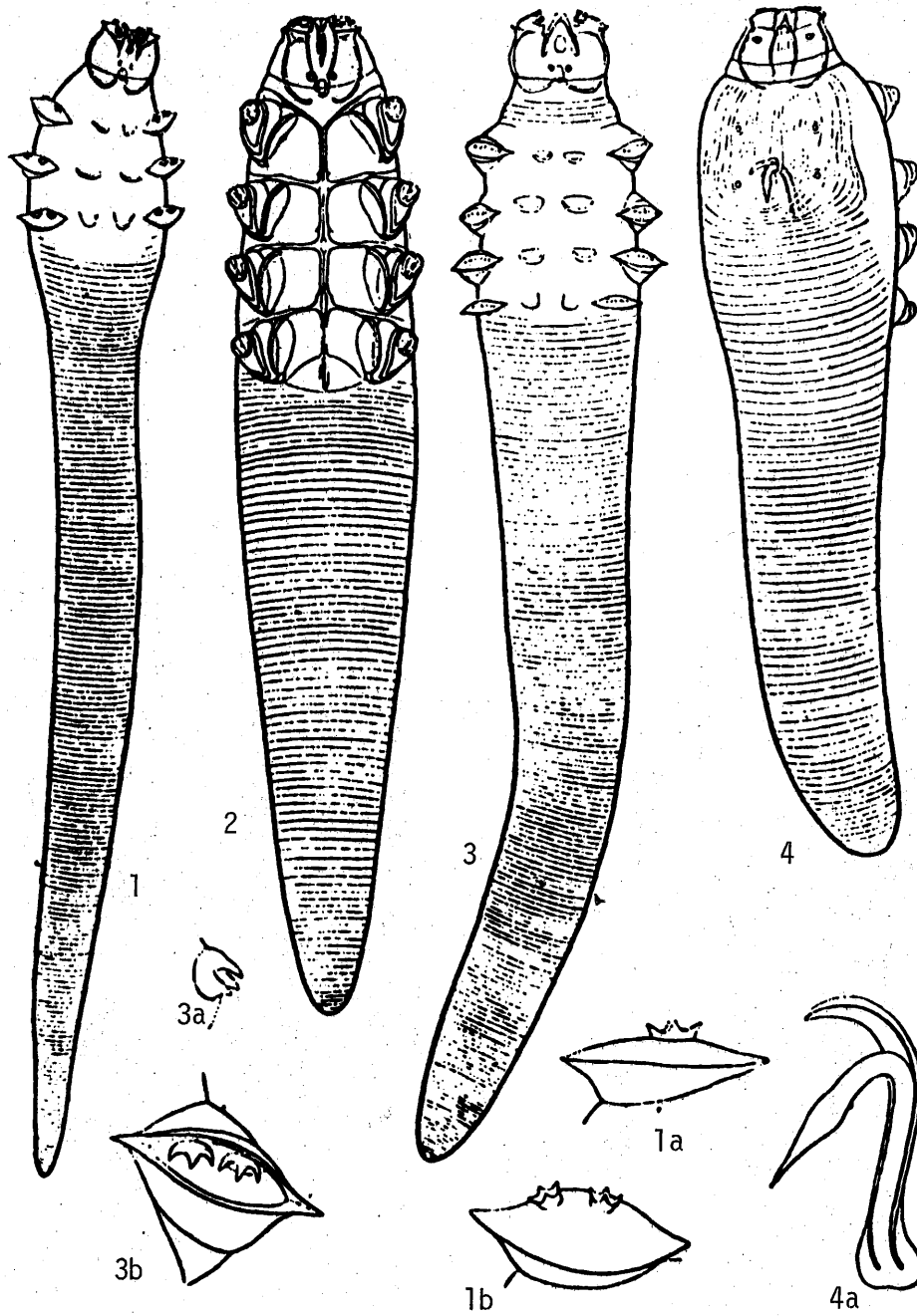


Figure 2. 1, *Demodex folliculorum*, elongated larval form, 1a and 1b, appendages of larval form; 2, *Demodex canis* var. *ovis* (Raill); 3, *Demodex folliculorum*, elongated nymph, 3a and 3b, appendages of nymph; 4, *Demodex folliculorum*, short form of adult male, 4a, penis greatly enlarged. (From Hirst, 1919)

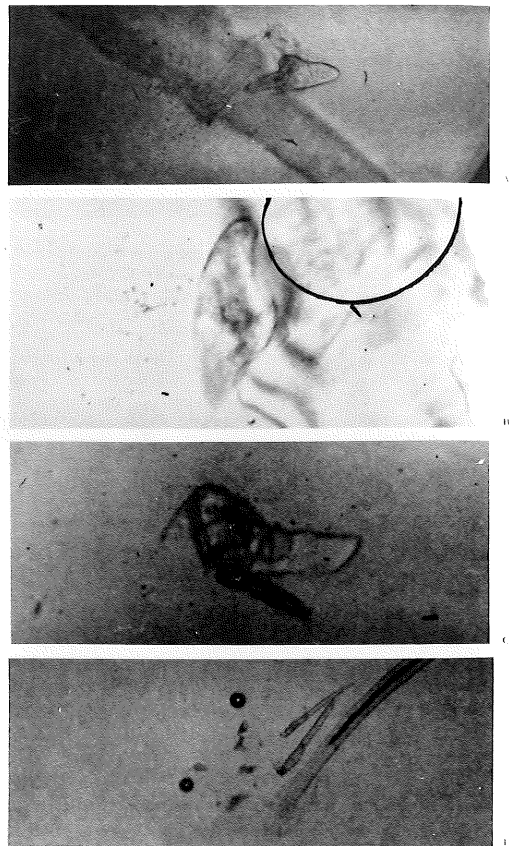


Figure 3. Demodex folliculorum. A, egg (approx.x60); B, egg ten minutes before hatching (approx. X240); C, larva with collapsed egg casing (approx. X60); D, immature forms (approx.X60). (From Coston, 1967)

TABLE I  
MEASUREMENTS OF DEMODEX FOLLICULORUM  
 FROM HIRST (1919)

	Female	Male
Total length of body	270-440 $\mu$	Elongated specimens 280 $\mu$ Small male with tail 170 $\mu$ Small male no tail 190-210 $\mu$
Length of cephalothorax + capitulum	95 $\mu$	85 $\mu$
Length of abdomen	170-340 $\mu$	200 $\mu$
Greatest width of cephalothorax	50-56 $\mu$	47-50 $\mu$
Greatest width of abdomen	49-58 $\mu$	46 $\mu$
Greatest width of capitulum	40 $\mu$	33 $\mu$
Length of capitulum	24 $\mu$	21-22 $\mu$
Length of spines on capitulum	3 $\mu$	3 $\mu$

in Berlin in his study of pathological findings of pimples. Simon published a good description of this parasite under the name of Acarus folliculorum, and stated that he found them in the follicles of the nose of all corpses except newborn babies. The generic name Demodex was created for it in 1843 by zoologist Richard Owen.

Demodex folliculorum (Simon, 1842) (the name reserved for the human parasite) may inhabit the follicles, with or without hair, anywhere on the body. It has a predilection for the nose, chin, cheeks, outer ear canal, and margins of the eyelids although other parts of the body may be affected. Reported surveys show the incidence of infestation with this parasite ranges from 0-100%. A detailed survey involving all the common sites of infestation had not been made in this country, and those of Europe were made over sixty years ago. Some publications state all adult humans harbor the organism, others say one half, and most are just as vague in assigning an accurate figure. Table II shows briefly the results obtained by early European biologists and illustrates the lack of consensus which in part helped to prompt this study. Essig (1958) said, "It is cosmopolitan but is rarely met with except in very unsanitary surroundings." Does hygiene play a role in its incidence? This is one question this study attempts to answer. Is Demodex found all over its generally reported habitats on man, or can selective sites be found? Possible

TABLE II

INCIDENCE OF DEMODEX FOLLICULORUM IN NORMAL AND  
DISEASE STATES IN MAN

<u>Author</u>	<u>Year</u>	<u>Total No.</u> <u>Subjects</u>	<u>% Positive</u>	<u>Sites</u> <u>Studied</u>	<u>Comments</u>
Simon	1842	8 dead	100	----	Adults
		2 dead	0	----	Infants
		11 living	36.4	----	Adults, children
Henle	1845	12 dead	91.6	----	----
Gruby	1846	60 living	66.7	----	----
Wilson	1847	-- living	100	----	----
Leydig	1859	-- living	100	----	----
Geber	1884	200 living	100	----	----
Megnin	1892	--- living	10	----	Soldiers
Moniez	1896	--- living	10	----	Students
Hunsche	1900	93 living	92.5	----	Children
Guiart	1902	10 living	100	----	----
Landois	1905	109 living	65.1	----	----
Gmeiner	1908	100 dead	97	Composite	All ages
			50		
			61		
			86		
			49		
DuBois	1910	200 living	100	Face	Ages 20-85
		50 living	0	"	Less than 5 yrs.
			50		5-10 yrs.
			100		10-20 yrs.

factors which might influence the incidence were a dry or oily (seborrheic) skin condition, the amount of facial hair, and the age and sex of the human host. A final question which proved to be difficult to answer was whether any contemporary patterns of incidence could be found which would indicate some trend in the distribution and habitat of this parasite since its discovery over a century ago.

The controversy surrounding this parasite as a possible pathogen or vector of disease is explored in light of the current knowledge. The question of distinct species is discussed in an attempt to point out some new possibilities for future study and the evolutionary implications this strange family of mites reveals for workers in the field.

## MATERIALS AND METHODS

Phototactic studies by Spickett (1961a) have shown that Demodex folliculorum avoids light and is undoubtedly a nocturnal creature. No one has reported seeing the organism on the surface of the skin, and its location, headfirst within the follicle, prohibits simple observation (Figure 4). A technique modified after Coston (1967) was adopted to overcome this obstacle. The mites partially back out of lash follicles and facial follicles upon the brief application, 45-60 seconds duration, of a highly volatile substance (ether, chloroform, camphor, spirits of ammonia, D.M.S.O., or acetone). After 3-5 minutes I could see, with slit lamp magnification, tiny cream-colored, cylindrical-shaped objects, the posterior ends of mites, partially emerging from follicles. A cotton applicator saturated with acetone proved most acceptable to subjects while ether and chloroform were rejected as too noxious, especially for children and the elderly. Utilizing this technique various areas of the face were sampled including the nose, chin and cheeks.

Another source of sampling was the epilation of eyelashes. While waiting for the acetone to take effect, the eyelashes of the subject were examined with the slit lamp. A characteristic fine, waxy, dry debris, often slightly



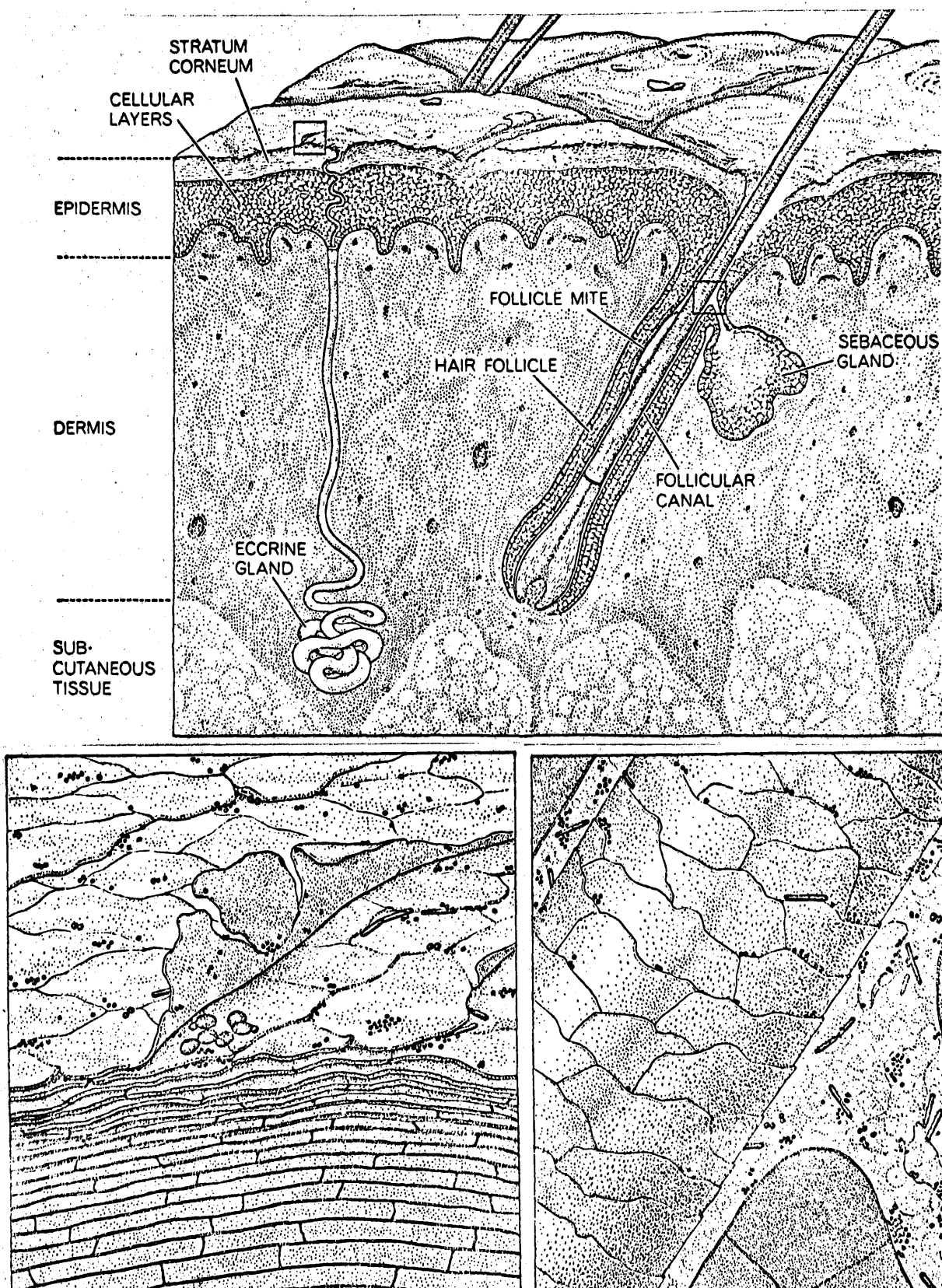


Figure 4. Habitat of *Demodex folliculorum*. Scarcely visible to the unaided eye, *Demodex* is 400 times larger than an average bacterium. The squares indicate regions that appear below enlarged about 1000 diameters showing bacterial and fungal cells on skin and within follicle.

yellow in color, lying on the skin about the bases of the cilia could often be seen. A smooth transparent collar of mite feces surrounds some lashes for one to two millimeters as they emerge from the follicle, and appears to enlarge the orifice at the skin surface (Figure 5). This collar has the appearance of clear plastic insulation about the lash and when they were observed and attempt was made to epilate those lashes, if the subject was willing to cooperate. The lashes were placed in a drop of peanut oil on a glass slide with a coverslip and under the microscope the mites are easily seen if present. Peanut oil or olive oil are best because the adult mites often imbibe some and live in such media for some time (Figure 6).

A third method for demonstrating the mites involved squeezing the skin follicles of the face and examining the material extruded under the microscope. DuBois (1910), the first to employ this technique stressed the importance of examining the follicular material obtained after the second squeeze since the first material from the follicle mouth sometimes contained no mites. Often soft, yellowish or whitish wormlike extrusions are forced out of sebaceous follicles of the nose and forehead having the appearance and consistency of jelly or petrolatum (Figure 7). These are neither comedones nor sebum, but almost solid masses of *Propionibacterium* (Kligman and Shelley, 1958).

The discomfort of ingrown hairs on the area of the

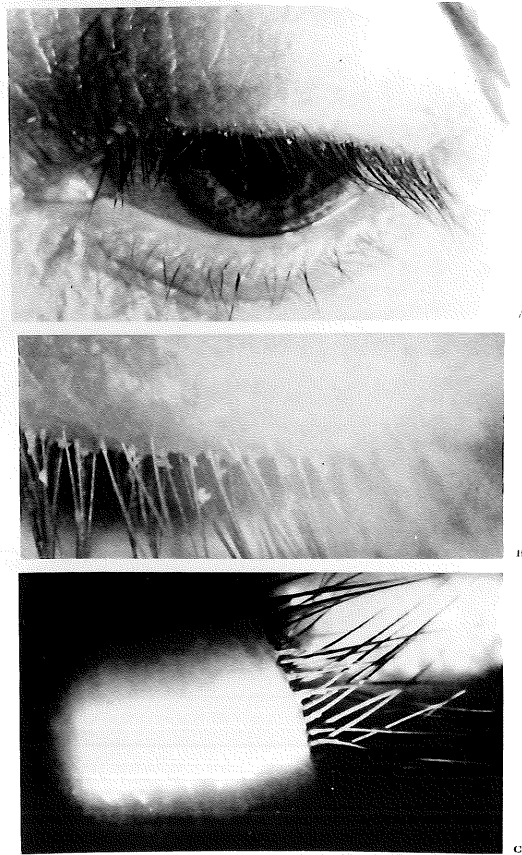


Figure 5. Views of the eyelashes showing debris and collaring about lashes which is characteristic of demodectic infestation. A, unaided view; B, slit lamp, low power; C, collaring about lashes, slit lamp, high power. (From Coston, 1967)

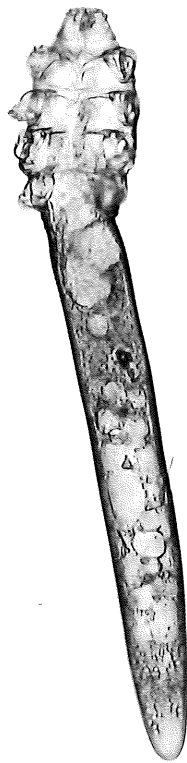


Figure 6. Adult Demodex folliculorum isolated from eyelash follicle and submerged in peanut oil (X 250).

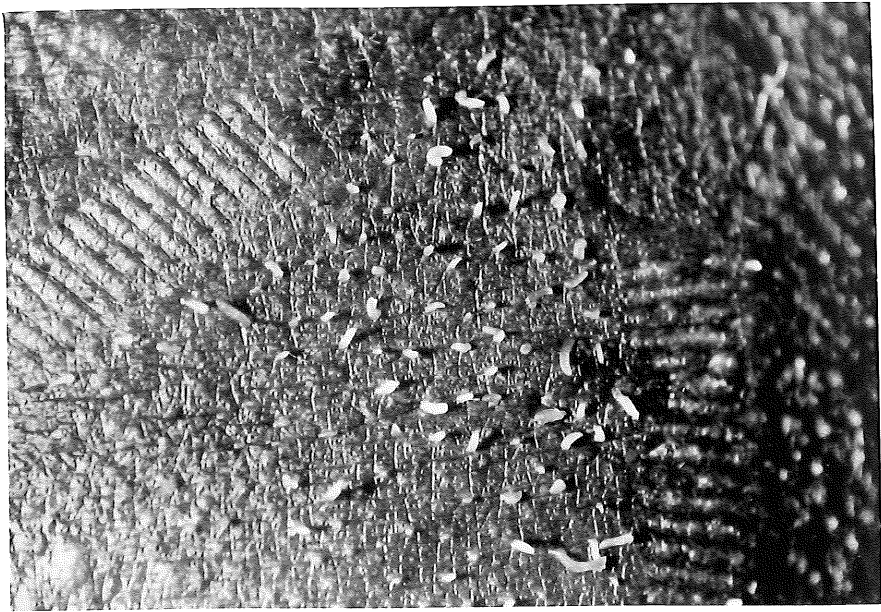


Figure 7. Worm-like extrusions forced out of sebaceous follicles of the face by squeezing. These have about the consistency and appearance of yellow petrolatum and a few can be found in most subjects. They are neither comedones nor sebum, but almost solid masses of *Propionibacterium* (X6). (From Kligman & Shelley, 1958)

neck shaved every day has plagued the author for about 7 years. Commonly an inflamed, pus-filled pimple forms at the site and upon examination of the material within the pustule, Demodex folliculorum was found. This comprised another sample group in this study.

Other sample areas utilized were the chest and pubic areas. In both cases hairs were plucked and examined under the microscope in a drop of peanut oil.

The final source of material was ear wax. The wax was collected by gently rubbing a blunt metal probe around the opening of the auditory passage and placing the material on a glass slide. By swirling the material in a few drops of xylene with a blunt probe a thin smooth layer was obtained and after a coverslip was added, microscopic examination followed.

In analyzing the results of this study the Contingency Chi-Square test for independence was utilized. If we call the total number of observations N, and the individual numerical contributions to this value a, b, c, and d, respectively, then the calculations are as follows:

Categories of observations		TOTALS
	1	2
A	a	b
B	c	d
	a + c	b + d
		a + b + c + d = N

$$\chi^2 = \frac{(|ad-bc| - \frac{1}{2}N)^2 N}{(a+b)(a+c)(c+d)(b+d)}$$

In an effort to obtain a wide range of age groupings subjects were solicited from a variety of institutions. It was also essential to have a large number of potential volunteers gathered in a single area before moving equipment to make the examinations. The types of organizations involved were public primary and secondary schools, rest and retirement homes, correctional institutions, and social rehabilitation and service centers. The faculty and students of Portland State University as well as family, friends, and "walk-in" volunteers were also utilized.

## RESULTS

Nasal Area. The earlier work of Gmeiner (1908) and DuBois (1910) in Europe indicated that the skin of the nose was a common site of Demodex infestation. This sample area was therefore utilized in an attempt to correlate the incidence of mite infestation with the age, sex, skin condition, and amount of facial hair of the human host. In Table III all pertinent data has been compiled and a simple percentage of incidence has been computed for each of the five age groups. The sex of the human host was eliminated as a variable because there was no significant variation from the expected results within each age group. The only exception was in the oldest age group and here more women were infested than men. Testing for independence with a contingency chi-square, results showed statistical independence between the sex of the host and the presence of mites (Table IV). The chi-square value of 1.81 with one degree of freedom indicates independence. The amount of facial hair was also eliminated from consideration since the variance among hosts was small and no valid quantitative method was found that could measure the differences. Thus we are left with three categories of pertinent information. The age of the host, which was broken down into five age groups, the condition of the skin, normal, dry or oily, and whether mites



TABLE III

## ALL PERTINENT DATA FROM NASAL AREA EXAMINATIONS

Age	Skin	Subjects			Positive			Incidence
		M	F	Total	M	F	Total	
1-8	Normal	15	17	32	1	0	1	
	Oily	0	0	0	0	0	0	
	Dry	0	0	<u>0</u>	0	0	<u>0</u>	
Group Total				32			1	= 3.1%
9-17	Normal	10	12	22	5	2	7	
	Oily	12	7	19	1	1	2	
	Dry	1	1	<u>2</u>	0	0	<u>0</u>	
Group Total				43			9	= 20.9%
18-30	Normal	35	44	79	12	21	33	
	Oily	15	6	21	8	6	14	
	Dry	11	8	<u>19</u>	2	2	<u>4</u>	
Group Total				119			51	= 42.9%
31-50	Normal	29	43	72	16	20	36	
	Oily	10	7	17	5	4	9	
	Dry	1	6	<u>7</u>	0	1	<u>1</u>	
Group Total				96			46	= 47.9%
51-90	Normal	33	26	59	21	16	37	
	Oily	25	31	56	15	23	38	
	Dry	8	28	<u>36</u>	2	20	<u>22</u>	
Group Total				151			97	= 64.2%

TABLE IV  
SEX OF THE HOST AND THE INCIDENCE OF DEMODEX

Age	Males		Females		Total
	+	-	+	-	
1-8	1	14	0	17	32
9-17	6	17	3	17	43
18-30	22	39	29	29	119
31-50	21	19	25	31	96
51-90	<u>38</u>	<u>28</u>	<u>59</u>	<u>26</u>	<u>151</u>
	88	117	116	120	441

$$\chi^2 = 1.81 / 1 \text{ df.}$$

were present were the final variables considered.

In order to determine whether or not there was a correlation between the age, skin condition and presence of mites chi-square values were calculated for all combinations of variables. In these cases there are no definite expected values; the question is whether the results are dependent (contingent upon) or independent of the conditions under which they are observed. The statistical manipulation involving three categories of data in a test for independence is described in Kendall and Stuart, (1966). As shown in Table V contingency chi-square values were first calculated for the three possible combinations of data i.e., skin conditions x infestation, skin conditions x age, and age x infestation.

TABLE V  
CONTINGENCY CHI-SQUARE RESULTS FROM NASAL  
AREA EXAMINATIONS

Categories	Degree Free.	Chi-square	Significance
Skin x Inf.	2	7.6190	Dependence
Skin x Age	8	84.6429	Dependence
Age x Inf.	4	55.3299	Dependence
Skin x Inf. x Age	29	169.3816	Dependence- Partitioning

Then a table was constructed for skin conditions x age x infestation. This involved five age groups, three skin conditions, and two units for infested or uninfested, a

5 x 3 x 2 matrix with thirty expected values to compute in the contingency table. These row by column by layer tables enable a partitioning of the chi-square values so that the chi-squares of the three 2 x 2 tables were subtracted from the large 5 x 3 x 2 chi-square. The degrees of freedom are adjusted by subtracting in the same manner:

$$\chi^2 = 169.3816 - 55.3299 - 84.6429 - 7.6190 = \underline{21.9898} *$$

$$\text{Degrees of Freedom} = 29 - 4 - 2 - 1 - 8 - 2 - 4 = \underline{8} *$$

The final chi-square value, 21.9898 with 8 degrees of freedom is too large to show statistical independence, therefore we may conclude that there is a statistical dependence between the skin condition and age of the human host and infestation with Demodex folliculorum.

Having established a statistical dependence between these three categories we can now interpret the data as it is presented in Table III. First, there is a definite increase in the incidence of Demodex folliculorum with the advancing age of the human host. Secondly, the normal and oily skin conditions are favored over the dry state throughout each of the first four age groups. The exception is in the oldest age group and here all three skin conditions show similar numbers of positive cases. The biological aspects of this interdependency will be presented in the discussion portion of this paper.

Cheeks And Chin. Results of mite infestation from these two areas are shown in Table VI.

TABLE VI

RESULTS FROM THE CHEEKS AND CHIN UTILIZING THE  
CHEMICAL-SLIT LAMP TECHNIQUE

Age Range	<u>Cheeks</u>			Positive			Incidence
	Subjects			Subjects			
	M	F	Total	M	F	Total	
1-82	23	18	41	11	6	17	41.4%

Age Range	<u>Chin</u>			Positive			Incidence
	Subjects			Subjects			
	M	F	Total	M	F	Total	
1-79	16	9	25	4	2	6	24.0%

Although no statistical verification was attempted for these two areas the intended conclusions are clear. First, these areas of the face are involved along with the nasal area and this helps support the contention that the face does serve as the habitat of optimum occurrence. Secondly, although numbers are too small for statistical verification, further studies may show a truly lower incidence for the chin and cheeks in comparison with the nasal area or in fact a similar pattern. Finally, this brief survey did serve to illustrate that selective sites may be involved in Demodex infestation for as yet unknown reasons. In some subjects the nasal area was involved, yet no mites could be found on other areas of the face, and in others the reverse was true.

Eyelashes. The second source of sampling, epilated eyelashes, was undertaken to see if there was once again any correlation between the age of the host and the presence

of mites. The condition of the skin was not considered in this data because the eyelash follicles and their specialized sebaceous glands comprise a somewhat isolated system, independent of the condition of the facial follicles. The validity of this sampling method comes under suspicion when one considers that only those mites which hold on tight enough to the lash, or are caught at the base of the lash, with heads buried within the root tissue (most common), will be detected with this technique (Figure 8). Of course, any stages within the pilo-sebaceous canal or sebaceous gland itself will most likely remain undetected, although on two occasions eggs were found on epilated lashes. Some workers (Smith and McCulloch, 1969) have had good results by vigorously rubbing the lid margins with an ether-saturated cotton applicator prior to epilating lashes. The most valid method of diagnosis would seem to be examination with the slit lamp after ether swabbing to observe mites which have partially emerged from the follicles (Figure 9). However, the latter two methods involve the application of a topical anaesthetic to the eye by a qualified physician. In order to overcome the problem of validity with this sampling technique a preliminary test was conducted on a group of 40 subjects at a retirement home for the elderly. The results of this test are shown in Table VII. On the first visit two eyelashes were epilated from each lid at random and examined for mites. Eleven of the forty subjects were found positive for the presence of mites.

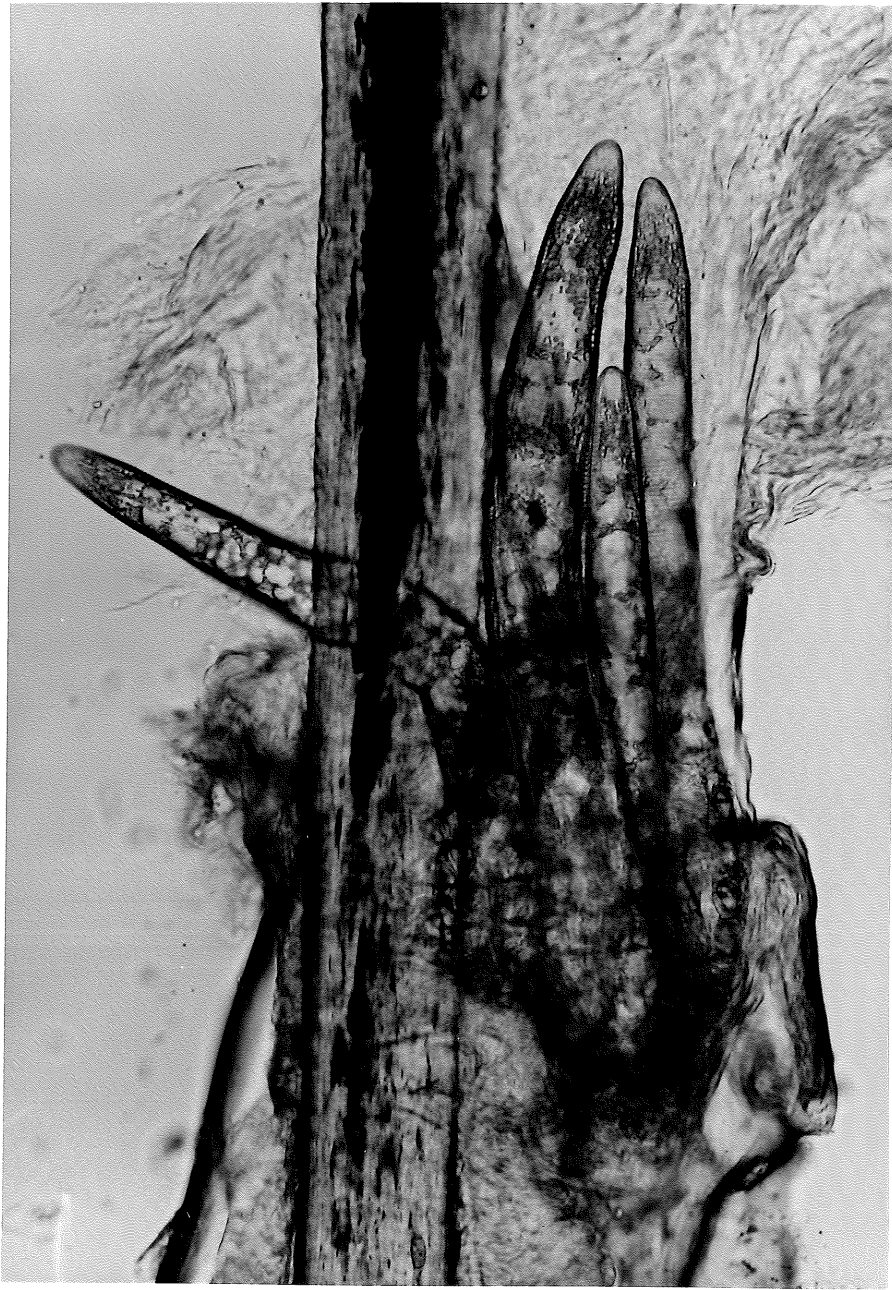


Figure 8. Epilated eyelash showing numerous mites caught with capitulums buried within root tissue near base of lash. Six mites were found on this one eyelash (X 310).

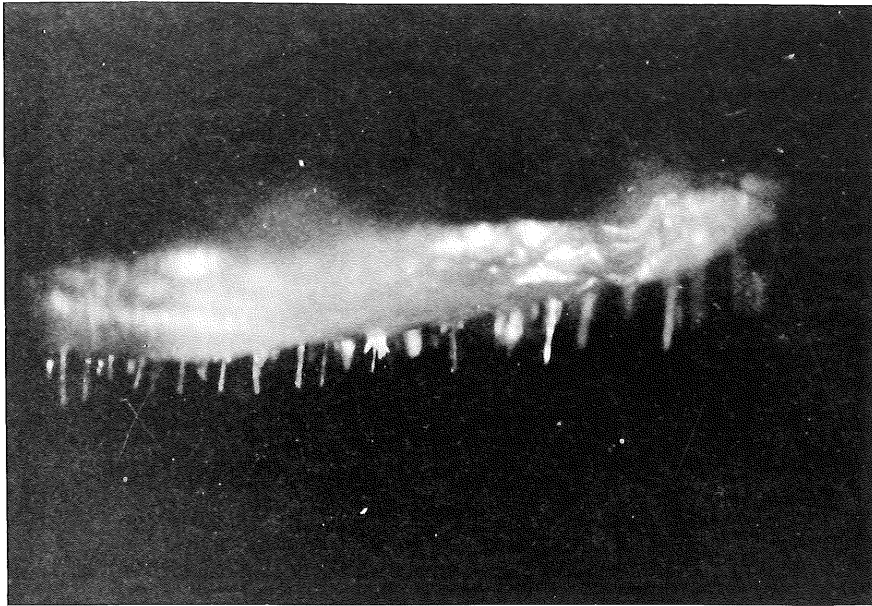


Figure 9. View of eyelid margin under slit lamp high power magnification showing mites partially emerging (center) around a lash after ether swabbing. (From Coston, 1967)



TABLE VII

RESULTS OF PRELIMINARY EYELASH TEST CONDUCTED ON  
SELECTED GROUP OF FORTY SUBJECTS

<u>40 Subjects</u> <u>Age Range</u>	<u>Random</u> <u>Dec. 20, 1969</u>	<u>Collars</u> <u>Jan. 3, 1970</u>
58-90	11 +	26 +

On a subsequent visit two weeks later the same forty subjects were again examined, but this time the lid margins were examined with the slit lamp prior to the epilating of lashes. Only those lashes exhibiting the characteristic transparent collar of mite feces or having fine, waxy, dry debris at their bases, were epilated. The number of positive cases increased to 26 including 8 of the first 11 and 18 new cases. This would seem to support Coston's (1967) contention that the collar about the base of a lash is pathognomonic for the presence of mites in that follicle.

The results shown in Table VIII were obtained utilizing a preference for collared lashes when they were found. There is a definite increase in incidence with the advancing age of the host and a contingency chi-square value of 31.9122 with 4 degrees of freedom indicates a lack of independence. Thus there appears to be a statistical dependence between the age of the human host and the presence of Demodex folliculorum in the eyelash follicles. Again it should be stated that selective sites could be found on some subjects.

TABLE VIII  
RESULTS FROM EPILATING EYELASHES OF  
143 SUBJECTS

Age	Subjects			Positive			Incidence
	M	F	Total	M	F	Total	
1-8	3	2	5	0	0	0	0%
9-17	12	6	18	3	0	3	16.7%
18-30	21	11	32	10	4	14	43.7%
31-50	13	16	29	5	7	12	41.4%
51-90	36	23	<u>59</u>	28	15	<u>43</u>	72.8%
			143			72	

The presence of Demodex in the eyelash follicles for instance did not necessarily mean the subject's facial pores were involved, and similarly, the reverse was often true.

Squeezing Facial Follicles. The results of the third method, squeezing facial follicles, are shown in Table IX.

TABLE IX  
RESULTS FROM SQUEEZING FACIAL FOLLICLES OF THE  
NOSE AND FOREHEAD REGIONS

Age Range	<u>Nose</u>			Positive			Incidence
	M	F	Total	M	F	Total	
12-78	21	13	34	5	2	7	20.6%
<u>Forehead</u>							
12-78	19	17	36	4	1	5	13.9%

This technique was used in the nasal area and forehead regions of a limited number of subjects until it became

apparent that the results were below expected levels as determined with the chemical and slit lamp method. This was the principle means of sampling used by all of the early workers in Europe and might indicate a trend in the incidence pattern for this parasite which will be discussed later in the paper.

Ingrown Hairs. Ingrown hairs on the neck comprised a small sample group of exclusively men (Table X).

TABLE X  
RESULTS FROM PUSTULE CONTENTS OF INGROWN  
HAIRS ON THE NECK

Age Range	Subjects			Positive			Incidence
	M	F	Total	M	F	Total	
17-41	13	0	13	5	0	5	38.4%

Although Breckenridge (1953) reported examples of ingrown hairs in skin sections in which Demodex were observed, the results in this study serve to support his contentions as well as indicate a new clinical entity involving this organism. Its possible role in the formation of ingrown hairs will be stated in the discussion.

Chest And Pubic Areas. Very small numbers of subjects were found for sampling the chest and pubic areas, and therefore little can be said of the results (Table XI). Although a physician's office would seem to be a much better place for volunteers, such facilities were not available.

TABLE XI  
RESULTS FROM EPILATING HAIRS FROM THE CHEST  
AND PUBIC AREAS

Age Range	<u>Chest</u>			<u>Positive</u>			Incidence
	Subjects M	F	Total	M	F	Total	
17-69	16	2	18	0	0	0	0%
<u>Pubic Area</u>							
19-28	12	2	14	0	0	0	0%

Ear Wax. The final set of results involves the findings from ear wax samples (Table XII). Again the number of subjects is small, but sufficient for the purpose of demonstrating that this is not an uncommon site of infestation, although with this technique the mites are easily overlooked and difficult to collect.

TABLE XII  
RESULTS FROM EAR WAX SCRAPINGS

Age Range	<u>Subjects</u>			<u>Positive</u>			Incidence
	M	F	Total	M	F	Total	
18-69	17	3	20	4	0	4	20.0%

## DISCUSSION

Nasal Area, Chin, Cheeks. In man, sebaceous glands vary widely in size, but are largest and most numerous in the scalp, forehead, cheeks, nose and chin, where 400 to 900 of them may be found in each square centimeter of skin surface (Montagna, 1962). Usually, although not necessarily, sebaceous glands are joined to hair follicles forming a pilo-sebaceous unit. The ducts of the glands, called pilo-sebaceous canals, open directly into the hair canals so that sebum is extruded onto and around the hairs. There are two types of pilo-sebaceous units in the glabrous skin of the face (Figure 10). The most numerous are tiny and superficial, generally not extending more than 0.75 mm. beneath the surface (Kligman and Shelley, 1958). With the naked eye, their ostia and minute hairs are all but invisible, but under slit lamp magnification they are easily seen. These lanugo follicles have characteristic and disproportionately large sebaceous glands, but slit lamp examination revealed that Demodex are rarely found in these follicles. The less numerous units whose ostia are easily visible to the naked eye are called sebaceous follicles and are practically limited to the adult facial skin (Kligman and Shelley, 1958). The gaping orifices were highly prominent in many oily subjects,

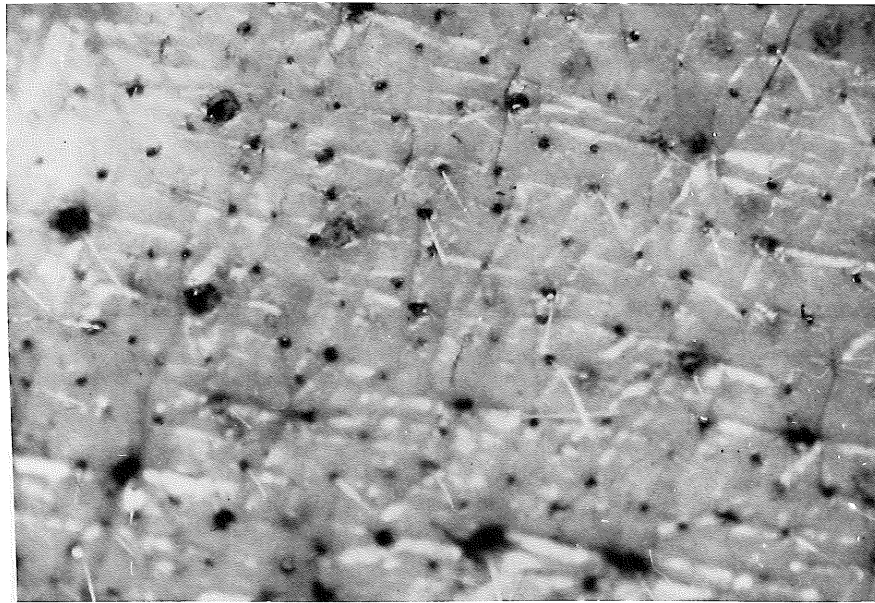


Figure 10. Comparison of the ostia of sebaceous follicles with the openings of superficial lanugo follicles. The larger black spots mark the ostia of sebaceous follicles while the smaller dots indicate the openings of lanugo follicles. The latter are more numerous and their associated hairs are generally too tiny to be visible (X10). (From Kligman and Shelley, 1958)

especially on the cheeks and nose. These sebaceous follicles have multilobular, spreading sebaceous glands of extravagant size and depth, enormously greater in volume than the much smaller glands of the superficial lanugo follicles (Figure 11). The huge gland empties to the surface through a wide duct which is in fact the follicle, and here Demodex could be seen partially emerged from the effect of the acetone or ether application when viewed through the slit lamp. Although large terminal hair follicles were often infested, the mites were found most frequently in the sebaceous follicles characterized by their spacious infundibula into which the products of many sebaceous glands empty. A relatively tiny hair of insignificant proportions and its follicle are reduced to mere appendages of the sebaceous gland, instead of the gland being an appendage of the external root sheath of the hair follicle (Kligman and Shelley, 1958). Although outnumbered by the tiny superficial hair follicles by a ratio of 3:1, the sebaceous follicles serve as the important habitat of Demodex folliculorum and their distribution coincides with the parasite's distribution on the skin of the face of man (Figure 12).

The size of sebaceous glands and their rate of secretion of sebum varies markedly with age. In newborn infants, sebaceous glands are large, but they become small shortly after birth, and remain small through infancy and childhood.

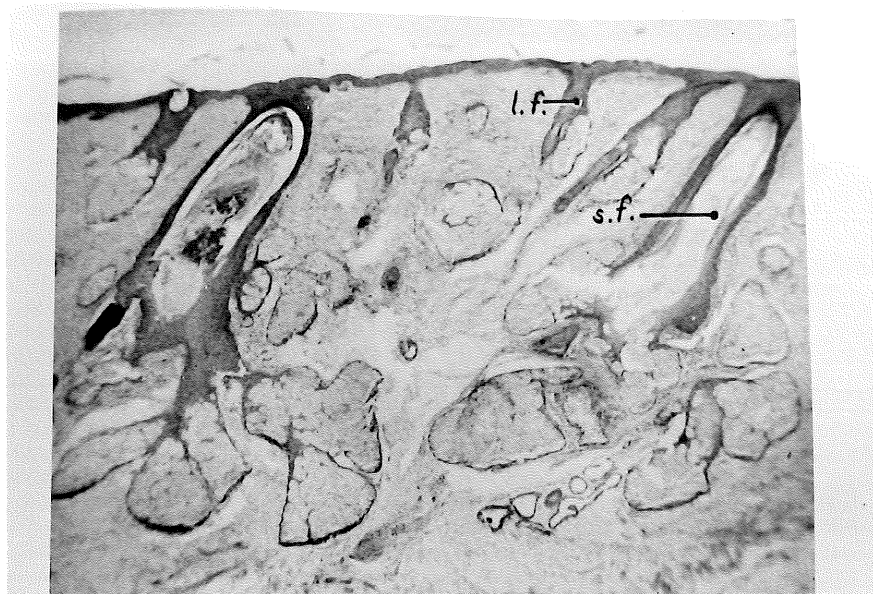


Figure 11. Comparison of deep sebaceous follicles (s.f.) with superficial lanugo follicles (l.f.). Note large lumen of sebaceous follicle and the extravagant size of their attached glands. This section contains two sebaceous follicles and four superficial lanugo follicles (X34). (From Kligman and Shelley, 1958)





Figure 12. A, Epidermal sheet showing two adult mites in the infundibulum of a sebaceous follicle (X 6); B, same follicle, (X18). (From Riechers and Kopf, 1969)

They are fully developed by the onset of puberty (Montagna, 1962). Sebaceous secretion in the newborn baby is high, even when measured one week after removal of the vernix caseosa. On the other hand the values obtained in the examination of children between the ages of 2 and 12 years are only one-third to one-half of those found in adults (Emanuel, 1936). Boys and girls between the ages of 13 and 16 show a somewhat higher lipid secretion than in the younger children, but lower than the average value observed in adults (Kirk, 1948). The total amount of lipid secreted in a twelve hour period is approximately the same in adult men and women until the age of 70. After this age the sebaceous secretion remains high in men and even shows a tendency to increase, whereas the values for women in the age group 70-100 years are much lower than those found in men (Kirk, 1948). By this age however, women are "fortifying" their facial moisture by substituting cold creams for soap and water and these cosmetic cleansers do not remove the sebum from the pores.

Applying these facts to the results in Table III there appears to be a required level of sebaceous gland development and secretion before Demodex infestation reaches a significant level. In the 1-8 year age group incidence is lowest. With the onset of puberty in the 9-17 year age group, Demodex infestation seems to be increasing. In the next two age groups of adults, the incidence has

not only reached a significant level, but the normal and oily skin conditions are clearly much more involved than the dry skin condition. In the oldest age group, although the overall incidence is higher, the dry skin condition shows 22 positive cases and 20 of these are women; a significant difference when compared with the other four age groups. However, one criterion on which determination of the skin condition was based was questioning of the subject. A considerable number replied that their skin was very dry and in order to retain facial moisture many of the ladies had reduced or eliminated soap and water cleansing of the face and relied on cosmetic creams for this purpose. Ayres (1930) described a clinical condition he calls pityriasis folliculorum which often results from this type of facial hygiene, however it was not detected in any of the subjects in this study. The only other criterion used to determine skin condition was observation. A quantitative sampling method would have been desirable, but this technique requires complete isolation and protection of the test site and complete immobilization of the subject.

The clinical impression of oiliness is not an entirely reliable index of surface lipids according to Kligman and Shelley (1958). It is the presence of sweat which imparts the clinical appearance of oiliness. How oily a subject will appear at any one time will be influenced by the chance of his having recently sweated or of having been

in an environment of high humidity. Oiliness will often appear in a sudden wave-like fashion if on a cool, dry day a subject with moderate to high casual lipid level is suddenly made to sweat. Likewise, emotional sweating will cause a sudden wave-like development of oiliness, if appreciable amounts of oil are present originally. Oiliness is less prominent in winter time and especially marked in hot, humid climates. For these reasons, except for frankly seborrheic patients, the correlation between the clinical impression of oiliness and the actual level of surface lipids is far from perfect. Nevertheless, I still believe the relationship between normal and oily skin, sebaceous gland distribution, development and secretion, and infestation with Demodex folliculorum is not coincidental, but a partial explanation of the parasite's distribution and incidence.

Although Demodex folliculorum lives in and about the sebaceous glands and their fatty secretions, it would seemingly enhance support for the animal's pattern of incidence if sebum served as its food. This is most likely the case, although some workers feel the diet is supplemented with other nutrients. The fine work of S.G. Spickett (1961a) in which Demodex was successfully cultured in vitro in a medium of human sebum leaves little doubt that sebum is the principle, if not exclusive, source of nutrition.

Further support for the increase in incidence of this

parasite with the advancing age of the host involves the mode of transmission of the mite from person to person. Most workers agree that direct skin to skin contact is the principle means of transference. Spickett's (1961a) work on the life history of Demodex showed that dispersal takes place in the dark, or at least in very dim light. The obvious implication is that human social contact meeting these requirements is more prevalent in adults than in children. But why does the incidence continue to rise in the 51-90 age group? The mother-infant relationship is an intimate one involving much skin contact, yet infestation in infants and young children is negligible or nonexistent. There must be a required level of sebaceous gland development and secretion before mite infestation is enhanced, but the continued increase of incidence into the 51-90 age group requires further study. Cowdry (1939) described a skin condition commonly found after 40 years of age he termed sebaceous hyperplasia in which the sebaceous glands become enlarged and overactive. An abnormal condition such as this however, cannot account for the majority of the population with normal skin conditions which harbor the parasite.

The overall question of hygiene remains rather obscure as far as infestation with Demodex is concerned. In an attempt to remain random and objective in this survey, subjects were examined for this parasite from all walks of life.

Although no direct evidence can be cited in this regard, one observation should be noted. Subjects examined in a "skid road" soup kitchen showed no significant deviation in the level of incidence from that of college professors. Without intending to offend either group, it would appear that the only parameters influencing the pattern of incidence are the age of the host which in turn influences the size, development and secretory rate of the sebaceous glands, and social contact with other infested individuals. This can probably be explained by the partitioning of sebum in and on the skin. Free sebum is the excess portion which flows out and over the skin surface from a higher to a lower concentration. It is easily washed away with soap and water and is chiefly responsible for the appearance of oiliness. Further down is the capillary reservoir which contains sebum in the interstices of the stratum corneum network. Repeated washings with soap and water will remove essentially all of this sebum as well. Finally there is the follicular reservoir which lies beneath the surface and includes all the fully formed sebum in the ducts and follicular infundibulum. The largest reservoirs by far are in the sebaceous follicles of the face, and no amount of scrubbing with soap and water will significantly remove this sebum. There is no physiological way to empty the follicular reservoir of sebaceous follicles and mechanical means, such as hemostat pressure, lead to injury of the

tissue, yet this is the habitat of these mites. For these reasons then, personal hygiene is apparently not a factor in the incidence of infestation of the facial skin with Demodex folliculorum.

The findings of a number of pathologists gives further support to the theory that the face is definitely the area of optimum occurrence of Demodex folliculorum. Nicholas (1943) in a survey of 1750 consecutive samples of unselected tissue submitted for routine histological examination reported the presence of Demodex in 40 (2.28%). Of the 40, 32 were facial skin samples. Breckenridge (1953) found Demodex in 186 of 1,435 skin sections from various regions of the body and 146 of these were from the face. Finally, Riechers and Kopf (1969) took epidermal sheets from sixteen selected sites on nine randomly selected cadavers for histological examination. All nine subjects were infested to variable degrees, but the organisms were found only in specimens obtained from the face, neck and chest. It should be noted that all nine subjects were elderly (53 to 91 years of age).

Since Demodex is light sensitive, other areas of the body which receive less light than the face, would seem more favorable to infestation. Although other areas of the body may be infested, sebaceous gland distribution and activity seem to be more essential to establishment, and the dark confines of the follicles present no lighting problems. Clothing would also be a hindrance to dispersal

and skin to skin contact, although transfer by towels and clothing should not be ruled out.

A number of workers have mentioned the possibility of seasonal influences on the incidence of Demodex. Baksht (1965) reported an increased incidence in warmer weather and Smith and McCulloch (1969) stated that in cold weather they are not easily isolated while in warm weather they are more readily found along the lid margin. Since this study was carried out from November to March, this possibility was not investigated. Spickett's (1961a) experiments have shown that the optimum temperature range for Demodex is 20-37° C and further investigations along this line should be undertaken.

It should be noted that the scalp of man fulfills many of the requirements for Demodex infestation that have been discussed, yet infestation of the scalp remains extremely rare according to the literature. Miskjian (1951) reported only two such cases in more than ten years of practice as a dermatologist and there are no reports in the literature prior to his paper. Both were bald men in their fifties and the mites were found in small papules containing a clear oily liquid. Further study is needed to determine the reasons for the absence of scalp infestations.

Eyelashes. Becker (1876) was the first to find Demodex in the eyelash follicles of man. There are two



types of sebaceous glands within the eyelids of man; the meibomian glands, which open onto the palpebral margin of the eyelids, and the glands of Zeis, with ducts opening into eyelash follicles.

The rows of evenly-spaced meibomian glands at the border of the eyelids are so large that they are easily seen with the naked eye when one inverts the eyelids before a mirror. Although these glands open directly to the surface of the skin and contain vast amounts of sebum like the sebaceous follicles of the face described earlier, there is no evidence that they are more heavily or less heavily infested than the glands of Zeis which empty into the follicles. Coston (1967), in his thesis on Blepharitis, made no attempt to differentiate between the two glands and the presence of mites as they were seen partially emerged from follicles (Fig. 9). The glands of Zeis were assumed to be involved since the sampling was done by epilating lashes from the lid margins.

The increase in incidence of infestation with the advancing age of the host is most likely due to many of the same factors influencing the chin, cheeks and nasal area of the face. The size and secretory activity of the modified sebaceous glands of the eyelids undoubtedly is part of the answer. Their functioning in lubrication of the specialized cilia provides an ideal habitat for Demodex. Social contact is also a possibility here. The

influence of personal hygiene is somewhat debateable. In the normal procedure of washing the face very few people actually soap the palpebral margins of the lids, in fact the general pattern is just the opposite. Beginning on the cheeks or forehead, the hands usually pass in a circular motion as far as the inner orbit of the eye with the fingers covering both sides and the bridge of the nose. When the soapy hands or washcloth pass over the eyelids, the lids are tightly shut to avoid getting soap in the eyes, thus depriving the lid margins of a thorough cleansing. This favors the accumulation of waxy dry debris and collars of mite feces about the base of the cilia and the sebaceous material is not cleaned away, thus providing the mites with a veritable sea of sebum in which to carry on activities.

One final variable in the extremely high incidence in the oldest age group is not intended to offend. In talking with attendants and supervisory personnel at the rest and retirement homes, (from which many of the subjects in the 51-90 groups came) two points should be noted. First, in some, and by no means all, of the elderly residents there appears to be a general loss of interest in personal hygiene and a thorough cleansing of the eyelids was probably lacking. Secondly, many of the female residents use a great deal of makeup and consequently, cold creams are substituted for soap and water. Although these two points are debateable,

there could be some question as to the subjects in my 51-90 year age group being a truly representative sample of the group as a whole.

Squeezing Facial Follicles. The principle reason for utilizing this method was to demonstrate the technique responsible for early reports on the incidence of infestation. It is interesting to note the same general pattern of incidence with respect to age as has been discussed in this paper was evident in the work of DuBois (1910). Table II shows children under five years were free of mites, half of those from five to ten years were infested, and everyone beyond ten years was infested. It is this 100% incidence from many early workers (Simon, 1842; Wilson, 1845; Leydig, 1859; Geber, 1884; Guiart, 1902) that leads to speculation on the trend in demodectic infestation. With this technique it is extremely easy to overlook low populations of mites and one must squeeze very hard to exude sebum rather than *Propionibacterium*. Although my sample size is too small for valid comparison, there is the possibility of a downward trend in incidence due to certain contemporary patterns of living less conducive to Demodex infestation.

Ingrown Hairs. Since many subjects examined in other areas were checked for ingrown hairs on the face or neck it would appear that this is a rather uncommon entity. Of the thirteen males with ingrown hairs on the neck, five

showed the presence of Demodex within pustule contents. Since the organisms were not found in all thirteen subjects exhibiting the pimple-like cysts, the role Demodex may play in their formation is only speculation at best.

According to Breckenridge (1953) the mites which lodge in the hair follicles not only cause dilation of the follicle, but also may act as a barrier to the normal flow of sebum. The lack of the lubricant may result in fragmentation of the hair shafts and hyperkeratosis. Occasionally a plugged follicle leads to formation of a cyst lined with epidermis and containing the mites as well as the fragmented hair shaft which continues to grow in a curled manner. The projection of the capsule-like sheath of keratin surrounding the parasites above the skin surface produce nodules which become apparent to the host. An inflammatory reaction may occur producing slight erythema. Most likely, this explanation is a valid one, but what of the ingrown hairs and nodules which contain no parasites. Dirt and other foreign debris can become a barrier to the normal flow of sebum and the daily razor can provide constant fragmentation of the hair shafts. Cyst formation and inflammation can then follow producing the same results without any mites; or mites found within may not have been the cause of the condition. Whatever the case, the role Demodex may play in the formation of ingrown hairs could be of a facultative nature.

Chest And Pubic Area. These areas were sampled because reported findings of other workers had indicated the chest and genitals were sometimes infested with Demodex. This does not seem unusual in light of the criteria for establishment of the mites which has already been discussed. Essentially the presence and high secretory rate of sebaceous glands is often all that is required for infestation. If the glands are large in size and sebum storage capacity, infestation is further enhanced. The areolar glands of the two areola of the chest are modified sebaceous glands and suitable for demodectic infestation. Breckenridge (1953) however, reported finding the mites in the main collecting ducts of the nipple of the breasts and Garven (1946) found them in ten of thirteen nipples after mastectomy. The obvious implication here is the possibility of the parasites being transferred to the nursing infant, however the internal establishment of these mites has never been reported in humans. Modified sebaceous glands on the prepuce, glans penis, and labia minoris produce copious and continuous amounts of smegma. Breckenridge found Demodex in one skin sample of the penis.

Although my sample sizes are too small for valid comparison, the incidence in the chest and genital areas throughout the literature indicate these are uncommon sites of demodectic infestation. Since the modified sebaceous glands located in these areas open directly to the surface

and are primarily hairless, the technique of plucking hairs for examination from the chest and pubic areas was given little chance of success. The chemical and slit lamp method was not utilized for obvious reasons and skin sections from cadavers appears to be the best way to demonstrate infestation in these areas.

Ear Wax. The historical significance of this site of infestation was the primary reason for demonstrating the mites in this study. Berger (1842), a Frenchman, was one of the first men to discover Demodex and he found the organisms in ear wax. The modified sebaceous glands located in the external auditory canal secrete a much different type of material than the sebaceous follicles of the face. Most likely the sticky, waxy secretion helps, along with the hairs within the ear, to collect debris which might otherwise enter the internal canal. Daniel, et al. (1959) reported that Demodex folliculorum lived four months in ear wax in the laboratory. Demodex which I isolated from eyelash follicles were placed in ear wax under controlled conditions in the laboratory, however, they died within a week. Perhaps there are physiological races of Demodex which, once adapted to a particular site on the host for a few generations, are unable to make the transition. Further study is needed in this area.

Demodex: A Pathogen Or A Vector Of Disease? It should

be clear from introductory statements that some mites are capable of causing serious dermal and respiratory problems for man through allergic and toxic reactions. Some are also capable of transmitting viral or bacterial disease organisms to man, sometimes with lethal results. The status of Demodex folliculorum as a pathogen or vector is on uncertain ground in so far as irrefutable evidence is concerned, because it is a difficult matter to investigate with scientific accuracy. We must examine the habitat and habits of Demodex to determine what opportunities for pathogenicity exist. The anatomical tools and physiological mechanisms possessed by the parasite which would enable it to act as a vector or pathogen must also be discussed.

Demodex folliculorum is the only animal consumer found in healthy, undamaged skin. Animals such as itch mites, Sarcoptes scabiei, cause obvious damage and proper treatment quickly follows. The remaining cutaneous organisms are yeasts, bacteria, and viruses. Among the residents of the healthy skin are several pathogenic species that live in an uneasy balance with the host. After a long period during which they remain harmless, a change of the internal or external cutaneous environment can upset the equilibrium; then these species multiply and cause problems.

Only a few yeasts are represented in the normal skin flora. Some of them are partially or entirely dependent on

lipids and grow most abundantly on the scalp and in greasy areas of the face, such as the folds of the nose and the ear. Thus their food and location coincides with that of Demodex, however no other relationships are known. The dominant members of the cutaneous community are Gram-positive bacteria represented by two groups. Almost all of the aerobic cocci are harmless, except in very special circumstances, but one species, Staphylococcus aureus, is the cause of pimples, boils and more serious infections. The chief domicile of this species is the nostrils and the perineum (the region between the genitalia and the anus). Both locations are frequented by Demodex, and their possible association cannot be overlooked. The other group is the rod shaped diphtheroids. One species, Corynebacterium acnes, the "acne bacillus," is anaerobic and lives in the depths of the hair follicle where its association with Demodex has been implicated in acne vulgaris, but never proven. It is impossible to say to what extent viruses inhabit the healthy skin, since their presence is difficult to recognize in the absence of damage to the host. Because viruses are parasites on living cells and there are no living cells in the upper layer of skin, any cutaneous virus would have to be living in deeper levels. The transmission of viruses by Demodex would therefore seem to be eliminated, but this may not be so as will be discussed later. On the other hand, the viruses that parasitize



bacteria (bacteriophages) are present on the skin in significant numbers. The relationship between Demodex and lysogenic bacteria has never been investigated. All of these organisms discussed are normally present on the skin. The great number of other species which are transients, for failing to become established, present other possibilities for associations with Demodex folliculorum and must not be overlooked. It is important that we know the habits of this animal if we are to implicate any of the above associations in a pathogenic situation.

The details of the life cycle of Demodex folliculorum are now known (Spickett, 1961a). The parasite is oviparous, the egg being deposited in the sebaceous gland, the newly emerged larva feeds on sebaceous material in the sebaceous gland. It is slowly carried to the mouth of the follicle by the flow of sebum, and undergoes two molts, firstly to protonymph and secondly to deutonymph. The deutonymph is the distributive stage, it leaves the follicle and moves over the skin surface. New infestations are started by skin to skin contact and transfer of deutonymphs. The deutonymph enters a new follicle and molts into the adult. The males move over the skin surface entering follicles to feed. Copulation occurs in the mouth of the follicle. The ovigerous female moves further into the follicle and from there into the sebaceous gland. The entire life cycle is about fourteen days; the period between a mite leaving one

sebaceous gland as a larva and entering another as an ovigerous female is about eight days. Distribution over the skin surface is accomplished in not more than 36 hours and probably is as short a period as 12 hours. The parasite is not usually found outside the confines of the pilosebaceous apparatus except when on the skin surface during dark or dimly lit hours. It goes in and out of follicles, carrying on its legs and body all manner of bacteria and fungi that may be present on the skin, but without cellular destruction or tissue damage these organisms cannot gain entry to the body of the host.

Does Demodex provide entry by puncturing cells of the host tissue? Nutting and Rauch (1961) have taken the position, based on anatomical observations of the mites and a study of serial sections of mites in situ, that all members of the genus Demodex at sometime during their life cycle puncture cells and feed upon cell contents. The head or capitulum has been best described anatomically by Hirst (1919) (Fig. 13 and 14). The palpi consist of three distinct segments and each palp can be protruded separately. The second and third segments are freely movable, with the last segment bearing four or five rod-like spines. The chelicerae are needlelike stylets fully capable of puncturing cells, the lower pair being over twice as long as the upper pair, leading Hirst to the conclusion that the food was liquid in form. Other authors (Spickett,

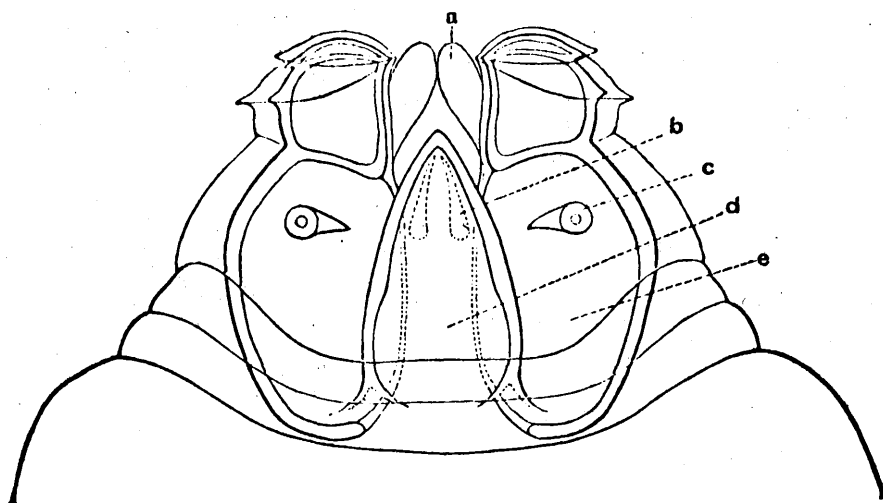


Figure 13. Capitulum of *Demodex folliculorum*, Owen, from above.

- a. Labial sheaths of chelicerae. b. Chelicera (upper finger).  
c. Spine on palp. d. Epistome. e. Palp.

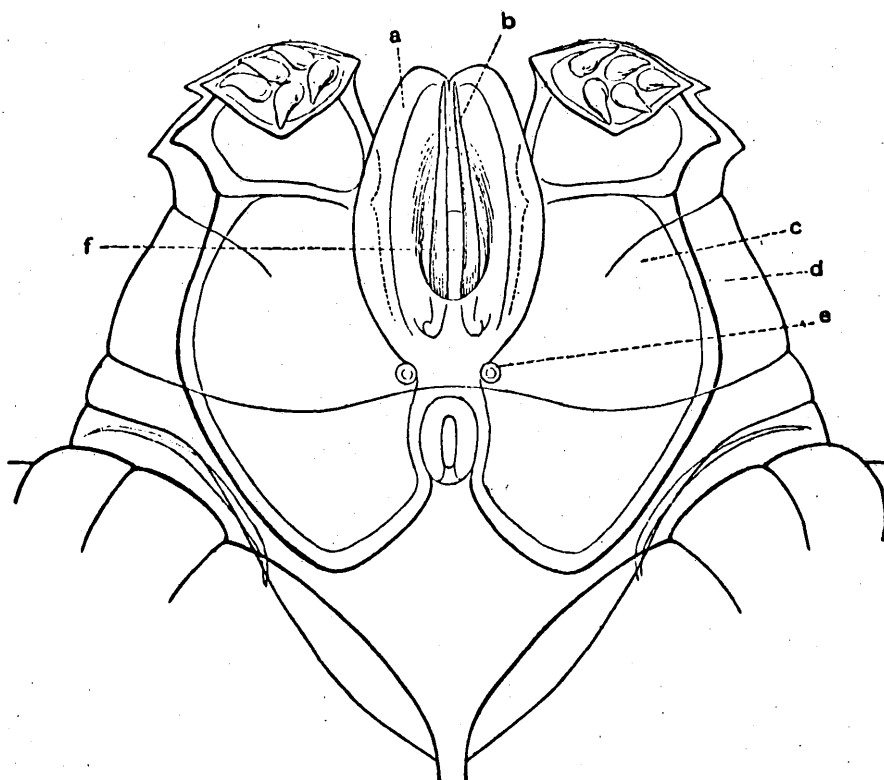


Figure 14. Capitulum of *Demodex folliculorum* from below.

- a. Labial sheaths of chelicerae. b. Chelicera (lower finger). c. Palp. d. Membranous capitulum. e. Supposed opening of respiratory system. f. Mouth.

1961a; Ayres and Ayres, 1961) still subscribe to the view that sebum alone is sufficient for maintenance and development of the mites. Spickett successfully cultured Demodex in vitro in human sebum. In 1964, Nutting strengthened his position by pointing out that sebum is very low in nitrogen which makes it unlikely as sole food for development of any organism, especially one in which several exoskeletal covers of chitin (a glucosamine) must be secreted. Perhaps there are other sources of nitrogen within the habitat of this animal.

Within the sebaceous gland, the mature cells laden with numerous droplets or sebum vesicles, are centrally located near the junction of the sebaceous duct with the hair follicle. During secretion, these cells die when their products are extruded; this process is called holocrine secretion and is brought about through the action of lysosomes (Bell, 1970). The sebum is made up not only of lipid material, but the cellular debris containing nitrogenous compounds. Another source might be the glandular secretions and the byproducts of the process that forms keratin which provides free amino acids as nutrients for the inhabitants of the skin according to Marples (1969). Finally, the habitat of Demodex is literally alive with bacteria (Fig. 4) which when taken in with the sebum and cellular debris would provide more nitrogenous nutrients.

So if these possibilities are fact, there would appear

to be no gain for the parasite in the destruction of cells. However, it has been noted that in infestations involving classes of individuals (e.g. children) or sites (e.g. the arm) where parasitism is uncommon owing to the low level of sebaceous activity, the animals may penetrate the epithelium of the sebaceous gland (Spickett, unpublished).

Demodex has mouthparts adapted for piercing and cutting.

It has been shown that the related species Demodex criceti is capable of burrowing into the epidermis of the hamster (Nutting and Rauch, 1958). Observations on Demodex folliculorum suggest that penetration of the sebaceous epithelium can occur, but does so only when there are very many mites in a follicle or where there are mites in follicles in which the associated sebaceous glands are relatively small or inactive as compared with those of the facial skin of adult Oregonians.

Demodex molts three times between leaving one sebaceous gland as a larva and entering another as an adult female. This suggests that it is unlikely that bacteria could be transmitted on the outside of the parasite's body. However, bacilli have been demonstrated on the outside of the body as well as in the gut of Demodex folliculorum (Spickett, 1961b). The bacilli could escape from the alimentary tract of the vector in three ways, either in the feces, in regurgitated material or by the vector being scratched into wounds inflicted by the host

in response to the irritation it causes.

It has been reported by Ayres (1930) that gross demodicidosis may produce symptoms of itching, but infestations sufficiently heavy to do this are rare. It is unlikely, but not impossible, that transmission of bacteria could be effected through self-inflicted wounds caused by scratching in response to irritation caused by the mites.

The only external opening to the gut of Demodex is the mouth. There is no anus. If the parasite transmits an organism from the subepidermal tissues of one host to those of another it must be through disgorgement of the contents of the alimentary tract. Studies on the feeding mechanism of this mite have shown that there is regurgitation of part of the contents of the alimentary tract; this is probably associated with predigestion of food material. It has been found in an unpublished experiment by Spickett that small particles of undigested material (plastic and resin particles were used in lieu of bacteria) may be regurgitated several days after they were first ingested. The shortest time interval between leaving one sebaceous gland and entering another is about five days, in the normal life cycle according to Spickett. It is therefore probable that bacteria could be transmitted by these means. Two ovigerous females have been found by Spickett (1961b) with acid fast bacilli in their gut. These bacilli could only have come from the sebaceous gland of another follicle

since at this stage in the life cycle the sebaceous gland of the newly entered follicle has not been reached.

It is, therefore, plausible that any protozoan, fungal, bacterial or viridial agent of a host which is a contaminant of the skin complex may be transmitted by Demodex folliculorum.

It should be noted that Koch's postulates have not been fulfilled, and in fact very few diseases have even been implicated in an association with Demodex folliculorum. Table XIII gives ten conditions in which D. folliculorum bears a suspect causal or cooperative relationship.

TABLE XIII

CASES IN WHICH DEMODEX FOLLICULORUM BEARS A SUSPECT CAUSAL OR COOPERATIVE RELATIONSHIP

Acne	Simon, 1842
Blepharitis	Coston, 1967; Smith and McCulloch, 1969
Rosacea	Ayres and Anderson, 1932
Micro-vesicular rx	Miskjian, 1951
Pityriasis	Ayres, 1930
Leprosy	Borrel, 1909a,b; Spickett, 1961b
Cancer	Borrel, 1909c
Hyperkeratinization	Ayres and Ayres, 1961
Depilation	Breckenridge, 1953
Inflammatory rx	Garven, 1946

Distinct Species? Many workers (Coston, 1967; Smith and McCulloch, 1969) are not completely convinced that the

Demodex on different animals are really different species: Demodex canis (dog), Demodex bovis (cattle), Demodex cati (cat), Demodex cuniculi (rabbit), Demodex phylloides (swine). This list is not complete by any means. There are a number of criteria available which seem sufficient for distinct species differentiation.

Gross morphology is strikingly different in some species. D. bovis and D. criceti are short and plump animals only half the size of D. folliculorum and D. canis (Figure 1). For finer distinction there is a well-marked tubercle or spine on the largest, most proximal segment of the palp which differs greatly in development in the different species and affords a good specific character (Hirst, 1919) (Figure 13).

The habitats of many Demodex species differ markedly and help to determine specificity. D. criceti is found singly in epidermal pits on hamsters, the dimensions of which are rarely larger than the body of the mite. They lie with mouthparts and legs towards the dermis and have never been found in normal hair follicles (Nutting and Rauch, 1958). This, of course, is altogether different from the habitat of D. folliculorum.

Failure of attempts at interspecific host transfer of demodids by Borrel (1908) and Nutting (1950) would seem to leave little doubt that distinct species of mites do exist. Although Gruby (1846) and Maynard (1922) reported



positive transfer between dog and man they both failed to use either marked mites or taxonomic criteria to distinguish the species supposedly transferred from the endemic host to the recipient host.

Finally, it seems reasonable that transfer from dog to man fails because of specific species requirements, but the failure of man to man transfer in the laboratory is a different matter. Once again, the thought of physiological races of D. folliculorum is intriguing and should be studied in the future. It should be recalled from introductory remarks that Sarcoptes scabiei often fails to survive a transfer to a new host once adapted for several generations to a given host. So it would appear from the literature to date that there are not only distinct species of Demodex, but possibly more specific races highly attuned to a given habitat on a given host.

Evolutionary Implications. Demodicids are of interest from the point of view of parasite evolution since they (1) show remarkable adaptations to match their unique environment, (2) are seemingly host specific, and (3) are apparently one of the few arthropod ectoparasitic groups which are capable of an endoparasitic existence (Nutting, 1965).

The basic adaptive features of Demodex folliculorum are readily apparent. The vermiform body lacking marked sensory structures, such as eyes or setae, and short legs

are well adapted for life in the narrow follicles. However, the overall reduction in size is also apparent when the follicle mites are compared to their surface dwelling counterparts. The stylet-like mouthparts and sac-like alimentary tract are adaptations favoring food sources liquid in nature which are entirely absorbed. It is interesting that two separate species of demodicids, Demodex aurati and Demodex criceti, both found on the Golden Hamster are markedly different in body configurations (Nutting, 1961). D. aurati is elongate which conforms to its habitat in the hair follicle whereas D. criceti is squat. The latter is found in simple pits which it apparently excavates in the epidermis. Larval and nymphal stages of D. caprae (goat) and D. bovis which inhabit papules or nodules are remarkable either for their reduced appendages or greatly modified opisthommata. Nutting feels that as new demodicids are discovered such adaptive features will form a coherent evolutionary pattern.

Even though host specificity is far from assured in the Demodicidae the fact that (1) they are so weakly mobile, (2) no intermediate host is apparently involved in transference (Nutting, 1950) and (3) interspecific transfer, if it ever occurs in nature, is certainly difficult would indicate marked species stability.

Nutting (1964) has added some additional information to the original work of Hirst (1919) regarding evolutionary

affinities of Demodex folliculorum. There appears to be a pattern of evolution leading from originally commensal-predator types to mites which wandered freely over the buccal mucosa of a variety of animals. Increasing specialization can be traced from our present knowledge of the niche requirements of certain species. D. criceti in epidermal pits, D. folliculorum and D. aurati in hair follicles, D. bovis and D. caprae in nodules and finally D. canis in the blood system show the increasing intimacy of the host-parasite relationship with a corresponding increase in pathogenicity. Nutting suggests a symbiotic relationship between bacteria (Staphylococcus pyogenes albus) and D. canis as the latest step in the progress of the Demodicidae from ectoparasitism to endoparasitism.

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