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The Louse Problem.

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Of the three kinds of Anoplura parasitic upon man only one, *Pediculus humanus* (the clothes louse), is of sufficient importance as a disease transmitter to cause serious anxiety on the part of military authorities for its control. *Phthirius pubis* (the crab louse), a small, readily distinguished insect of very specialized form is restricted to limited hair-clad areas of the body. It is disreputable rather than dangerous.

Pediculus capitis (the head louse) is so closely related to the body louse that it is only grudgingly, if at all, allowed specific rank apart from the latter. Many authorities are disposed to treat the two insects as more or less stable races, separated by structural details of minor importance. The divergence of habits between *Pediculus capitis* and *Pediculus humanus* in relation to their host would seem, however, to create a position which justifies distinctive nomenclature, as well as separate consideration from the practical point of view.

In popular estimation the presence of any of these three insects affords proof of personal uncleanliness, lice being still very generally conceived of as breeding in, if they do not actually feed on, dirt. The association with dirt is really adventitious, arising from the fact that the personal neglect, either enforced or voluntary, which is

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essential for any permanence of the infection, is almost invariably accompanied by a lack of soap, water, and clean garments, whereas it would of course be an easy matter to free oneself from lice and yet avoid washing.

As regards food the extreme specialization of mouth parts restricts all three insects to an exclusive diet of blood, obtained under what are probably sterile conditions, so far as any matter extraneous to fluids circulating within the body is concerned.

With *Phthirius pubis* I do not propose to deal and with *Pediculus capitis* only in so far as its distinctive identity from *Pediculus humanus* is concerned.

Immature Period.

Lice belong to the group of insects having an incomplete metamorphosis. Between the larval, nymph and adult stage there is no break in general resemblance, mode of life or method of feeding. The only distinguishing points of any practical importance between immature and adult insects is the smaller size and consequent ease of hiding of the young, together with their ability, during the moulting phases, to resist the action of heat and insecticides for a somewhat longer period. As a set-off to these disadvantages, from their host's point of view, we have only the fact that they extract less blood.

Between the period of emergence from the egg and maturity, both *Pediculus capitis* and *Pediculus humanus* shed their skins thrice; the time occupied differs in relation to food supply, temperature and innate variability under reasonably favourable conditions; twelve days may be accepted as a fair average. The record of forty larvæ which emerged on the same day, were kept in a box in a vest pocket and afforded opportunities of feeding during seven out of each twenty-four hours, will give a fair idea of their constitutional variability.

First Moult.	Second Moult.	Third Moult.
3 per cent. on third day.	15 per cent. on seventh day.	5 per cent. on tenth day.
42 per cent. on fourth day.	72 per cent. on eighth day.	3 per cent. on eleventh day.
55 per cent. on fifth day.	13 per cent. on ninth day.	55 per cent. on twelfth day.
		32 per cent. on thirteenth day.
		5 per cent on fourteenth day.

Pairing.

Pairing takes place at any time. It was frequently observed when the insects were examined after feeding, but the males on these occasions had sometimes little if any food in the alimentary canal. The

period during which the insects remain together is generally considerable, many occasions of over an hour were observed. This is probably by no means the limit, but failing prolonged watching one cannot be certain that the union is a prolongation and not a repetition. As happens with the fleas, the male underlies the female, a position which renders it possible for both sexes to feed during the act of fertilization. The males apparently require some hours' interval between the final ecdysis and the act of coitus, but females, still quite soft and not fully expanded after their recent change from nymph to adult, are often seen paired.

Egg Laying.

Food and temperature are the governing conditions in egg production. Feeding is essential, but laying may commence as early as the second or third day of adult life; by which time the female may have partaken of several meals and, apart from very exceptional circumstances, will have been fertilized. Virgin females, however, lay quite as freely as impregnated ones, only their eggs do not hatch.

Temperature approximating to that between the outer garments and the body is essential (75° F. to 93° F.). Sikora points out that it is probable that when day garments are removed and exposed to cool air (below 60° F.) at night, egg development will be stopped, although feeding may take place by day.

There is a cleavage in habits between the head and clothes louse in regard to the instinct and method of oviposition. Under normal conditions *Pediculus capitis* lays its eggs on hair, *Pediculus humanus* on textile material. In captivity either species can be induced to lay on hair or woven fabric if these conditions are properly adjusted. Tests in boxes lined with flannel and containing a small quantity of human hair resulted in the female of *Pediculus capitis* laying 80 per cent. on the hair and 20 per cent. on the flannel, while those of *Pediculus humanus* laid 20 per cent. on the hair and 80 per cent. on the flannel.

Individuals of both species were then reared from these eggs, which had been carefully segregated so that the following four lots of adults were obtained: *Pediculus humanus* reared from the eggs laid on hair; a second lot reared from the eggs laid on the flannel, and two batches of *Pediculus capitis*, one reared from the eggs laid on hair and the other from those laid on the flannel. Twelve males and twelve females of each of these four lots were placed in similar boxes, lined with flannel and containing a quantity of human hair, great care having been taken

to get the quantity and arrangement of the hair similar in each box. The boxes were kept under the same conditions and the feeding periods and arrangements were as nearly as possible identical. After five days the eggs were counted and their position recorded with the following results:—

EGG-LAYING INSTINCTS OF *Pediculus capitis* AND *Pediculus humanus*.

Pediculus humanus bred from Eggs laid on Hair. 12 and 12.

359 eggs	On hair	38	=	11 per cent.
	On gauze cover of box	1		
	On flannel, side next box	37	=	10 ,,
	On flannel, exposed side	283	=	79 ,,

Eggs laid on hairs only when these came into contact with the flannel.

Pediculus humanus bred from Eggs laid on Flannel. 12 and 12.

344 eggs	On gauze cover of box	4	=	1 per cent.
	On flannel, side next box	55	=	16 ,,
	On flannel, exposed side	285	=	83 ,,

Pediculus capitis bred from Eggs laid on Hair. 12 and 12.

274 eggs	On gauze cover of box	1		
	On flannel, exposed side	14	=	5 per cent.
	On hair	259	=	95 ,,

Pediculus capitis bred from Eggs laid on Flannel. 12 and 12.

340 eggs	On gauze cover of box	4	=	1 per cent.
	On flannel	2	=	½ ,,
	On hairs close to flannel	2	=	½ ,,
	On hair	332	=	98 ,,

This result confirms the previous one as to the distinctiveness of the ovipositing instinct and clears away any doubt as to the possibility of the females being heterzygotes of the same species. The less fixed character of the instinct exhibited in the first trial being probably due to the individuals of *Pediculus capitis* being taken from a stock box lined with flannel, the central space of which consisted of a matted mass of hair, while in the case of *Pediculus humanus* the box was filled with a roll of flannel: under these circumstances it is not improbable that the instincts became dulled, and casual action resulted. Some care is necessary in arranging the boxes; these must not be too small and the amount of hair and its arrangement must not be such as to cause a mat of interlacing hairs at any one point, more especially near the top or bottom of the box. A previous experiment which I performed largely failed owing to a want of discretion on these points; the lice used were taken from the

same crowded stock boxes as the parents of those used in the second trial. The females of *Pediculus humanus* laid 56 per cent. of their eggs on the hair and only 44 per cent. on the flannel, while those of *Pediculus capitis* laid 92 per cent. on the hair and 8 per cent. on the flannel.

In another experiment the attachment of the eggs was carefully studied; as a result it appeared that the method of attachment varied, females of the head louse endeavouring to cement the eggs to a single hair in regular alignment with its direction, while those of the clothes louse attached the greater proportion of their eggs to two or more hairs, for preference choosing those which crossed at an angle.

Fecundity.

With entirely unrestricted feeding I am told that an egg production of ten per day is possible for females of *Pediculus humanus*. During my own trials in which the opportunities for feeding averaged about seven hours per day, the greatest number of eggs laid by any one female was 295—an average of 6·4 eggs per day during her adult life. For limited periods this average has often been exceeded, in some instances eleven, twelve or fourteen eggs have been recorded in a single day. It is possible that these figures would be continued day by day under natural conditions. An experiment in which a number of females of *Pediculus humanus* were given the opportunity of feeding for two hours daily in addition to the seven each night, showed unmistakably that additional feeding raised the daily average, while the fertility percentage was not affected.

The fecundity of *Pediculus capitis*, judging by the number of eggs laid in captivity, would seem to be generally of a lower order than that of *Pediculus humanus*. The highest average was only four per day, with a total of 141, but this was easily bettered by females fed twice daily, in later tests, when the stock from which the insects were drawn had been living in captivity for a year, so that we may very reasonably consider that the average is higher under natural conditions, but even the later trials suggest that the ratio is lower for the head than for the clothes louse.

Fertility.

Renewed pairing at intervals of not more than twenty days is essential to the fertility of the eggs laid by females of *Pediculus humanus;* this is the ascertained limit. The more usual period

would seem to be in the neighbourhood of fifteen to seventeen days. With *Pediculus capitis* the period was generally seven to ten days, at longest, not more than twelve.

A single male of *Pediculus humanus* effectually impregnated eighteen out of twenty-one females, while a male of *Pediculus capitis* fertilized ten—this smaller number was due to the lack of opportunities during his period of greatest vigour, rather than to any want of vitality—the supply of virgin females having temporarily failed.

Length of Life.

Speaking generally, the full adult life of *Pediculus humanus* was about five weeks; that of *Pediculus capitis* under similar circumstances only four.

The longest recorded life of an adult male *Pediculus humanus* was thirty-two days, and that of a female forty-six. The average of a number of females was thirty-four days.

Of the head louse all my records are shorter: one male lived thirty days and a female thirty-eight days, but the average adult life of a number of females was only twenty-seven days.

The length of life of unfed lice depends to a large degree upon temperature and humidity. At a medium temperature such as 60° to to 65° F. the majority of vigorous adult lice live three or four days, a few survived five, and a single specimen seven days. I was informed at one of the infirmaries that their tests had shown a possibility of nine days' survival. As this period agrees with the limit mentioned by both Sikora and Peacock we may conclude that it is correct.

At higher temperatures the survival period without food is shorter; at 76° F. all the lice experimented with died within five days, and at 97° F. within three days. Larvæ just emerged from the egg, unless fed, lived less than twenty-four hours at 93° F., and when kept in a box in the waistcoat pocket the majority lived but little more than a day without food. None survived a second period of twenty-four hours. Cold conditions seemed only less fatal than the hot. When kept at a temperature ranging from 28° F. to 30° F. vigorous adults all survived two days and, though a few showed signs of life after four days, they died without feeding. None of the active lice survived a week in the cold room.

So far as my experience goes nymphs and larvæ, when about to moult, usually show a slightly longer survival period than adults.

Habits.

When feeding, lice are as wasteful as fleas, without the excuse of the latter that fæces consisting of only partially digested blood afford nutriment for their young. In comparison with the bed-bug the digestion of lice appears extremely superficial, and there seems to have been but little development in the direction of the storage of a reserve supply of food, but, as with *Cimex lectularius*, in which this has taken place, provision exists for carrying over the blood in the alimentary canal through the moults, from one stadium to the next. They are sedentary feeders and appear to rely upon the efficiency of the salivary fluid they inject to dilate the capillary system of their host if they fail to penetrate a vein. If a number be placed upon a small area some may obtain satisfaction within thirty seconds of penetrating the skin, others have to wait several minutes—occasionally as long as fifteen—before the blood flows.

Proportion of Sexes.

When a number of lice are kept together in a box and allowed to increase, one does not as a rule notice any disproportion in the relative number of the sexes, but with offspring reared from single pairs the proportion of males and females seems to be almost casual. Any proportion, from equality to broods consisting of entirely males or females, may result; this fact has, I understand, been independently discovered by Dr. Hindle as well as by myself. The following figures will serve to illustrate the phenomenon. The small number of offspring reared in some instances is due to the females dying, probably from old age, within a short time of their segregation. The method pursued was to take paired couples from a stock box.

Proportion of Sexes reared from Pairs of *Pediculus humanus* taken from a Stock Box.

No.	Males		Percentage		Females		Percentage
1	1	=	2	...	43	=	98
2	44	=	49	...	46	=	50
3	31	=	65	...	17	=	35
4	*Nil*	=	—	...	67	=	100
5	119	=	73	...	43	=	27
6	39	=	66	...	20	=	34
7	116	=	68	...	55	=	32
8	*Nil*	=	—	...	46	=	100
9	54	=	92	...	5	=	8
10	*Nil*	=	—	...	49	=	100
11	10	=	71	...	4	=	29
12	*Nil*	=	—	...	39	=	100
13	*Nil*	=	—	...	48	=	100
14	7	=	9	...	74	=	91
15	42	=	68	...	20	=	32
	463	=	45		576	=	55

In a numerous colony such a method of reproduction will of course give the same proportion of sexes as would result if each pair produced an equal proportion of males and females. Presumably this departure from the normal method of sex production serves to minimize the dangers of too close interbreeding.

Gregariousness.

Body lice, and possibly to a slighter extent head lice, are gregarious. This is more especially noticeable with the immature forms when approaching a moult. When the insects are kept in captivity this instinct is very apparent, but I have evidence apart from this. During the course of numerous experiments dealing with the destruction of *Pediculus humanus* under captive but otherwise natural conditions, I had several opportunities of observing the behaviour of escapes on my own clothing. It is most remarkable that these free insects tended to collect in close proximity to their captive fellows, in spite of the fact that the latter were imprisoned on pieces of flannel, treated with various insecticides, which from their smell should have exercised a deterrent effect. That the attraction was not always sexual was shown by the fact that immature lice collected in the same way.

Phototropism.

Both *Pediculus humanus* and *Pediculus capitis* are negatively heliotropic, crawling away from the source of light, or if diffuse, towards any dark object or shadow in their vicinity. Should the source of light be directly above them, and there are no shadows or dark surfaces near, they either crawl aimlessly, or what is more frequent, if they are numerous, cluster together. Their dislike for light affords a convenient basis for methods of dealing with them under experimental conditions. It also affords a means of making rough trials of the value of deterrent substances or fluids, as their dislike for these can be tested in relation to their desire to avoid light.

Clustering of Eggs.

Female lice, in captivity, exhibit a sort of homing instinct in regard to the deposition of eggs, returning again and again to a particular spot for which they have a preference. Certain facts tend to suggest that it is the eggs themselves which form the attraction, for I found frequently that when I reversed or otherwise altered the position of the piece of

cloth on which they were laid in relation to the box in which the insects were confined, with the object of getting the eggs distributed in order to facilitate counting, that my aims were thwarted by the female continuing to add to the original cluster.

Hatching.

The hatching of the eggs is conditioned by the temperature, and possibly also by humidity, but of this I have no exact evidence.

Of a number of eggs taken from a stock box, and therefore in various stages of development, none hatched in a room the temperature of which fluctuated between 60° and 65° F., while at 76° F. there was considerable mortality, and the period of incubation of the survivors was erratic, and spread over a longer period than usual. Three hatched within three days, while the emergence of larvæ from thirteen others was distributed over the following nineteen days. Eggs from the same batch hatched readily in my waistcoat pocket with slight, if any, mortality. At 98° F. the period of incubation was very uniform, within five days after removal from the stock box. It is probable that the eggs, ready and almost ready to hatch, and also those very recently laid, were killed by the sudden transfer from the box in my vest pocket (temperature about 85° F.) to hotter and much drier conditions.

One thousand three hundred eggs, kept in an incubator under humid conditions at 87° F., showed the following hatching periods: 3 per cent. hatched on the seventh day; 56 per cent. hatched on the eighth day; 33 per cent. on the ninth day; 8 per cent. on the tenth day; and 0·2 per cent. on the eleventh day.

The temperature of 87° F. is probably not far from the normal. I find that a thermometer placed between my shirt and skin in the region of the chest records 93° F.; between shirt and waistcoat, 86° to 87° F.; in the waistcoat pocket, 85° F.; while in the breast pocket of a buttoned coat it was only 74° F. to 75° F. If the thermometer is placed against my uncovered head it records 82° F., and in the folds of a woman's hair, near but not touching the scalp, the temperature is 81° to 82° F., while if the scalp is touched the mercury rises to 89° F. These readings were made in a room kept at a temperature of 62° F.

The similarity of the hair temperature to pocket temperature suggests that the eggs of *Pediculus capitis* are adjusted for incubation at the same temperature as those of *Pediculus humanus*, and this conclusion is in agreement with my experience when breeding both insects under the same conditions.

Resistance to Cold.

Exposure for seven days to a temperature varying between 30° and 38° F. does not kill the nits, but none survived a period of eleven days, during the last four of which the thermometer fluctuated between 30° and 33° F. Active lice survived two days at 30° to 38° F., and some partially recovered after four days, but died without feeding. None survived seven days.

Relationship of *Pediculus humanus* and *Pediculus capitis* to each other.

Cummings, in his pamphlet on the louse and its relation to disease (Economic Series No. 2, British Museum, Natural History), remarks that the clothes louse differs so little from the head louse that it is necessary to indicate carefully its distinguishing characters, and gives the following points: Size: clothes louse: mean length, males 3·19 mm., females 4·14 mm.; head louse: mean length, males 2·46 mm., females 3·03 mm. Form: In the clothes louse the body immediately behind the head is broader than it is in the same place in the head louse. The lateral angles between the segments of the hind part of the body are appreciably sharper in the head louse than in the clothes louse and the clefts which run in from the sides between the segments are deeper. In the female of the clothes louse the gonopods are narrower towards the tip than in the head louse. The antennæ of the head louse are usually thicker than those of the clothes louse. I have noted that the eggs of the head louse are slightly smaller on the average, and have already remarked on the divergence in the egg-laying instincts. To these points must be added the generally observed fact that the head louse clings to hair and the body louse to clothing.

To sum up these points there is a difference in average size and general form of the insects; a difference in minor points of structure of antennæ and gonopods of the females; a difference in the size of eggs and a variation in regard to the instincts connected with their deposition. Exceptional individuals of either race may produce the characteristics of the other in one or other of these points, but statistically the separation between the insects appears to hold.

Hybridization.

In an attempt to obtain further evidence bearing on the question of specific identity, hybridization was resorted to; cross pairings between males of *Pediculus capitis* with females of *Pediculus humanus*, and vice

versa, were easily brought about, and carried through without difficulty to the F. 3 generation.

The following points are of interest: There was a high mortality among females of *Pediculus capitis* placed with males of *Pediculus humanus;* unless removed after their first union they were invariably killed. The mortality of the males of *Pediculus capitis* placed with females of *Pediculus humanus* was also higher than when paired with females of the same race. There was a marked disparity in the proportion of sexes in the F. 1 generation of the cross *Pediculus capitis* male and *Pediculus humanus* female. Of four pairings the percentages were :—

No.	Percentage of males	Percentage of females
1	74	26
2	86	14
3	51	49
4	76	32

In the reverse cross, and subsequent generations of this cross, no such obvious disparity occurred. In view of the casual sex production in broods of *Pediculus humanus* already referred to, there would be nothing surprising in the above figures were it not that the disparity is all in one direction—namely, a high percentage of males. The small number of broods, however, does not warrant much stress being placed on the phenomena. In size the hybrid insects of the F. 1 and F. 2 generations are approximately intermediate, but extreme disparity in size was noted in some of the F. 3 broods, very small female and large male specimens being noted, in addition to large females, small males, and others of normal sex proportions. Apparently some of the insects had reverted to the paternal proportions, while others retained the hybrid features in this character.

Summary of Features in the Life-history of Practical Importance for Sanitary Precautions.

Eggs take seven or ten days to hatch under normal conditions—i.e., in clothing that is constantly worn; if discarded and allowed to cool for a period each day, the time of hatching may be extended for five weeks.

Active lice can exist without food, and apart from any host, for periods of up to nine days.

Young lice take from ten to fourteen days to attain sexual maturity.

Females, after attaining maturity, require two to four days before they commence to oviposit.

Egg production cannot take place without food, or under cool conditions (below 65° F.).

Eggs laid by unpaired females do not hatch.

Impregnation is not effective for more than twenty days.

As many as ten or twelve eggs per day may be laid by each female.

A total of 300 eggs may be laid by one female.

The female after maturity may live for forty-six days.

Before the close of her life a single female may have 4,160 living offspring.

Preventive Measures.

Pediculosis is a sign of, and depends for its continuance upon, a low standard of life. With a change of garments and the institution of the weekly washing of shirts and underclothing, the number of the parasites is speedily reduced; when sufficient means and leisure obtain among the people to allow of the regular change and cleaning of bedding as well as of clothing, *Pediculus humanus* must die out.

As regards *Pediculus capitis*, where the conditions of life are not so hard that the mother of the family has to spend the time that should be devoted to the care of her children in the winning of their bread, the head louse follows its relative into obscurity. Drink and ill-health may provide sufficient primary or secondary victims to prevent its extinction, but will do little more.

If we had not quite achieved this desirable goal when the war broke out, it seemed within measurable distance in the more wealthy of the European States. With the advent of war, armies were plunged back into that condition of barbarism which renders the washing and changing of garments, let alone bedding, an erratic and occasional proceeding, even when it does not prevent it entirely for weeks or months together.

The solution of the louse problem depends therefore either upon campaigning under a civilized standard of life, or upon the adoption of efficient remedies for the destruction of these insects. The plan adopted by the British authorities partakes of both methods. In the West the stable Front has rendered it possible for the troops in the field to enjoy, in large measure, the civilized custom of the washing and changing of clothing, but in the actual fighting line and in other areas this has not been found practicable, and dependence upon insecticides is essential.

It is to be presumed that the necessary orders are issued for the

supply of remedies to the men in these situations, but that owing to some accident or flaw in transport, they are not always received. Whatever the cause may be, however, complaints are so numerous as to make it appear to a civilian that the state of our troops in the fire trenches is what may be termed "lousiness," tempered by the receipt of insecticides from relatives or friends.

It follows as a consequence that, in spite of the baths, wash-houses and laundrying establishments, intermittent irritation tends to be general, owing to the re-infection of the already cleansed, or to the infection of fresh troops from home by men straight from the fighting zones—pediculosis being continual in the firing line because the dug-outs and resting bunks are in constant occupation.

The defect in arrangements would seem to be, on the one hand, in the failure of the authorities to issue a sufficient supply of insecticides (if any) to the troops actually in the trenches, and, on the other, to recognize that, while all the known insecticides for the destruction of lice are defective in one direction or another, their imperfections may be counterbalanced by complementary use. To reduce pediculosis to its lowest point it is necessary to use relatively stable, slow-acting remedies, in addition to one of quick action if of short duration. Those most serviceable in emergencies are impracticable for continuous use, owing to the large quantity which their rapid evaporation renders necessary.

The treatment of discarded clothing should, wherever possible, depend upon the action of dry heat, not because this is more effective than hot fluids or steam, but because it is more economical. Wet or moist clothing requires drying before use, and time will not usually permit of this being left to sunlight and open air. A drying chamber, if once inaugurated, might just as well be maintained above the level of temperature necessary for the destruction of lice and nits as below it, especially as it is practically certain that the same temperature would destroy the active females of the Sarcoptes, which cause scabies. The heat necessary for the destruction of both lice and nits is 52° C. for a period of thirty minutes. Allowing a margin for contingencies, 55° C. for this period will be quite high enough if the garments are spread and hung. Higher temperatures will kill more quickly and give greater penetration, but the question of their economy is doubtful, unless the conditions of speed and space render it imperative.

The operation of ironing the seams of tunics and breeches, if performed with due regard to the heat of the iron and the speed of its

passage, may no doubt be as effective as it is convenient, when only the simplest of remedies is possible, but if a hot room is available it seems reasonable to suppose that much economy of labour, as well as greater efficiency, could be obtained by hanging the garments in it. If great speed and economy of fuel were desired, a tubular oven with travelling hangers could be arranged on the principle of a biscuit bakery.

In washing or steaming garments or bedding the same temperature as in dry heat is sufficient; higher temperatures will give quicker action, providing thorough penetration takes place. The nits are actually destroyed if they experience the heat of boiling water for half a minute. The addition of chemicals to the water used for washing or soaking is superfluous if its temperature is high enough, and its quantity in relation to the clothing sufficient, to ensure that the nits in the fabric experience 55° C. for thirty minutes, or a higher temperature for a shorter period. On the other hand, if nits and lice can be killed more conveniently or cheaply by the addition of chemicals, it is wasteful to use heat in addition.

I am rather labouring this point, because it is one of the peculiarities of the destruction of insects that economy of thought and extravagance in practice should be so general. The spirit which dominates the illustrations of Mr. Heath Robinson seems also to exert considerable control over the inventors of insecticides, whose common practice it is to endeavour to raise the general efficiency level of their preparations by complexity in combination. The following, though possibly somewhat flamboyant, is a not unfair illustration of the process: "Kummerfeld's wash is useful, and is prepared as follows: Twenty parts precipitated sulphur are incorporated in a mortar with fifty parts glycerine; two parts of camphor are separately ground with fifty of Eau de Cologne, and twenty of borax and 870 parts of distilled water are added; the whole is mixed together, and three drops of an extract of musk are added; shaking in order to prevent the sulphur from settling down; fifty parts of ether are added to the mixture." This principle pervades a large proportion of the pre-war remedies, and some of the recent ones, and has even crept into the work of scientific importance. For instance, it was remarked by one experimenter that cyllin water when cool was not effective, but became so when heated to 60° C.; yet it had already been pointed out in his own paper that dry heat at 60° C. killed the nits.

Infected Dug-outs.

If practicable the wood-work of which these are built should be flat-oiled; this might considerably reduce the risks of infection, as creosote oil is very deadly to insects, and its application might considerably reduce the risks of lice resting on the wood-work. Treatment with Colorado vermin killer, a preparation that I was asked by the Army Authorities to test in regard to its efficiency against bugs, would be about equally efficacious.

Insecticides.

Insecticides may act either by contact or vapour; in the first case they obtain entrance at the insect's mouth or spiracles and poison it or obstruct the trachea and suffocate it. In the second case the vapour which destroys the insect must poison it by way of the tracheal system. Popular opinion, especially among the compounders of insecticides, has decided that strongly-smelling substances are effective owing to their smell—hence the number of essential oils which are recommended or incorporated. As contacts, any essential oil appears to be deadly, but their action, apart from contact under the practical conditions of use, is likely, in the great majority of cases, to be disappointing, the presence of smell being but a poor guide to the quantity of vapour necessary to bring about the death of the insects.

It will be my endeavour to show that for practical purposes it is necessary to use almost all remedies as if they had a contact value only, because under the conditions of use the diffusion of vapour at a concentration necessary to kill is limited to so small an area that the advantage of the vapour poison over a contact poison is of little if any moment.

My first experiment in the use of insecticides against lice was carried out with 25 grm. of pure flake naphthalene, placed in a thin cotton tube worn as a belt next my skin. I then suspended between my shirt and skin a number of gauze bags containing active lice. These bags, which were kept from collapsing by a wire gauze frame, were placed, both at back and front, about 5 or 6 in. above and below the belt. One bag slipped down to within 1 in. of the belt, and in this bag alone were the lice affected during a nine hours' trial, a few out of a number being killed. The repetition of this experiment under modified conditions showed a similar result. In order to test the comparative value of a number of different remedies under practical conditions and determine

their range of action with some degree of accuracy, I constructed a small piece of apparatus to suspend in front of the body, so that the insects could feed during the progress of the tests. In the central compartment was placed a piece of thick lint 1 in. square impregnated with the fluid or substance it was desired to test; lice were placed in all five chambers. The results showed that even with so continuously volatile and effective a substance as naphthalene the vapour action was very feeble, even within a range of 1 in., and practically ineffective at 2 in. While all the insects in the same compartment as the naphthalene were killed within three hours, only 23 per cent. of those in the adjoining chambers were killed within ten hours, and only one individual out of fifty died in the outer chambers during the same period.

More recent experiments, conducted under another method, while confirming these earlier results, go still further in indicating how narrow is the range of effective diffusion. The experiments in question were planned with a view to obtaining a comparative result between different samples of naphthalene; consequently, it was necessary so to adjust the conditions that a proportion only of the insects were killed during the period of trial. Small pockets of thin cotton, 15 mm. square, were stitched on to slips of flannel about 80 mm. square and in these 0·2 grm. of the naphthalene was placed; over this a larger cover, about 47 mm. square, of fine motor veil gauze was stitched, and beneath this the lice were confined. One of the results could only be explained by the supposition that one of the covers was so arranged that it allowed a slightly further range from the source of vapour than did the other. In one case the distances of the margins of the cover from the edge of the pocket containing the insecticide were 14, 17, 18 and 20 mm. respectively; in the other they were 12, 17, 18 and 18 mm. Although the difference was so slight it seemed the only possible explanation of a difference of 17 per cent. in the average mortality during four separate trials.

In order to test the correctness of this explanation the cover was removed from the slip which was giving the higher mortality and replaced with a slightly larger one. The increase in the distance of the sides of the gauze covers from the margin of the pocket containing the naphthalene was 12, 17, 18 and 18 mm. to 18, 20, 21 and 23 mm., the actual increases being 6, 3, 3 and 5 mm. in range. As a result, in place of a mortality of 42 per cent., none of the lice were killed during the normal four-hour period of the trial, and when the period was increased to eight hours only 7 per cent. died.

It is upon the results obtained in these experiments that I base my case that the effective range of vapours between the skin and undergarments is so limited as to be almost negligible. The deterrent effect of the various insecticides experimented with I have been unable to test on a practical scale under the normal conditions of use. It is possible that the vapours set free may have a wider range in deterrent than lethal effect. I am, however, dubious as to placing very much reliance upon deterrents at all, owing to the fact I have already mentioned when referring to their gregarious habits, that of the lice which escaped and enjoyed free range over my body and clothing, the greater number, in some cases all, were found on the flannel slips which had been impregnated with some insecticide. Attracted thither by the presence of their captive fellows the gregarious instincts proved more powerful than the smell of the insecticide was deterrent.

It was also shown by experiment that quite efficient insecticides when rubbed on the skin are of little, if any, use in preventing the insects feeding. The method of test employed was to rub the skin of the forearm thoroughly with the preparation, re-cover the skin area with the sleeve and, after fifteen minutes' interval, allow a number of hungry lice in a box to feed through the gauze cover of the box. In no case did *all* the lice in the box refuse to feed; generally all, or the greater number, fed greedily. Nor were the lice usually affected. In most cases the few deaths which occurred might have been due to natural causes. A considerable mortality, however, followed when sassafras oil was used to anoint the skin. If in many of these cases the same quantity of the preparation had been smeared on the *shirt* and the insects confined under a gauze cover on the area, though it would probably not have prevented their feeding, it would probably have killed them within a few hours, owing to its spreading over the body of the insect and finding its way into the tracheal system.

The only method of testing the differential deterrent action that I have employed so far consists in utilizing the dislike of lice to light in the following manner: A large sheet of filter paper or other rough, fibrous paper, the surface of which enables them to crawl freely, is placed on a table in front of a window. A band of the insecticide is applied to the paper with its ends turning towards the light; the lice are then put down between the source of light and this line, and one can roughly determine, either from their preference to turn back and face the light or to cross the band, which preparation is the better deterrent. As the method has but an uncertain practical value I have

only carried out a few trials, but these show that the best deterrents are not necessarily those with the most powerful odours.

It follows, if what I have stated is correct, that however valuable and interesting from the standpoint of pure science many of the published papers concerning the relative efficiency of various fluids, substances or vapours for the destruction of lice may be, they have but small practical value, owing to a want of appreciation of the essential facts connected with their use. Remedies have to be applied between the clothing and surface of a more or less rotund body, the temperature condition there being in the neighbourhood of 87° to 92° F. What effect their vapour may have in closed tins, under bell jars or when the lice are suspended within a short distance above the insecticides is beside the question. All depends upon the concentration and duration of the vapour resulting from the quantity you can afford to apply to any given area and the effective diffusion range around this area.

Having now put before you the basis of my contention that all insecticides used under the conditions named must be considered from the point of view of practical use as contact remedies only, I shall proceed to consider them from this point of view.

The main points for consideration are: first, cost, because it is useless to trouble about remedies which, if used in sufficient quantities to be efficient will cost more in a week or two than a new shirt—a point that has been largely lost sight of by the purveyors of remedies under a trade name. Secondly, speed of action in relation to its duration. Generally speaking, speed of action and period of duration are in inverse ratio to each other, but the relation is not always a simple one, and may be modified. Very volatile substances and fluids are of little use unless they can be applied to the whole area of the underclothing at one time, which is seldom practicable while in wear, because they evaporate so rapidly that the treated area is free for re-colonization within a few minutes. On the other hand some substances are so slow of action that, although they might very considerably reduce the length of life and breeding capacity of the insects, the user would be continually subjected to irritation by the sick, and by new recruits which had strayed on to him from outside sources.

There is a further point to be considered that is frequently overlooked by the makers of preparations, both professional and amateur, and that is, how the preparation is to be used. Persons devoid of knowledge of the bionomics of the louse, as well as those who have inadequately considered the subject, appear to think that any prepara-

tion, whether fluid, paste or powder, can be rapidly applied by dusting or anointing the skin surface with it, probably the most unpleasant and wasteful method that can be adopted. For, in the first place, one gets all the discomfort and danger of skin irritation, and in the second, if the preparations are at all volatile, they are even more quickly dissipated than would be the case if used on the under-garments.

The question of the best method of use is not always easy to answer, and the difficulty with some very efficient remedies, especially quickly acting, but rapidly dissipated oils, is to devise some means of distributing them evenly over the garments in quantities sufficiently small not to be disagreeable or wasteful, if possible using some vehicle for this purpose which, while retarding their over speedy action, renders it effective over a longer period. For this purpose soap, if it can be used, is very useful as it supplies an easy means of making a paste, while if an emulsion of the remedy with soap is possible, it makes impregnation by watery solution of any strength possible. With other contact remedies again soap enhances their action as it makes contact with and spreading over the wax-like surface of the insects' integument more easy and certain. There is also the final advantage that it will aid in removing the dirt, which accumulates on a greasy surface, when the garment is washed.

For the efficient protection against the breeding of lice in garments, the underclothing should be impregnated with some fluid or substance which will retain its effectiveness for upwards of a week, and as a precaution against enforced delay in re-treatment, an effective and easily applied remedy of quick action should be carried in addition. I am assuming that the thorough impregnation of undergarments can only be carried out in a large camp or base behind the fighting line. Of all the remedies with which I have experimented, the only ones which fulfil the first of these conditions experimentally and are sufficiently low in cost are crude carbolic acid, consisting chiefly of cresols with a trace of phenol and tarry oils, and cresol—the latter being slightly less efficient. The most feasible and effective method of use is to emulsify them with soft soap, using from 45 to 50 per cent. of soap to 50 to 55 per cent. of the crude carbolic. A perfect emulsion is produced by using sufficient heat thoroughly to melt the soap. The correct strength of the solution to be used for impregnating the garments ranges from 5 to 10 per cent. according to the climate or period of the year. If less than $2\frac{1}{2}$ per cent. of the crude carbolic or cresol is used the destruction of the lice is slow and faulty, if more than 5 per cent. irritation may be caused to the skin

in warm weather. The action is by contact and the soap renders this the more speedy and certain. Under cool, dry conditions effective action is slower or ceases entirely because the perspiration is insufficient to moisten the garment and set free the emulsion to act on the insect. As the lice tend to congregate to the less ventilated and more humid situations the impregnation tends to be most efficient where it is most needed. During the summer I found that a shirt treated with a 5 per cent. solution—2½ per cent. crude carbolic—was efficient in the destruction of lice for a period of five or six days—the action being quicker or slower from a few hours to a day, according to the amount of perspiration. During the winter a 10 per cent. solution—5 per cent. of crude carbolic—was necessary to produce the same results. It would follow that the less the sweating the longer the period of action. Treated flannel may be kept at least fifteen days and probably much longer before use without losing its efficiency. An average sized shirt has an area of about 1,600 square inches, and will take up about 1,000 c.c. of fluid, while after wringing it will retain about 500 to 600 c.c. Thorough drying of the garment is essential before wearing. The individual treatment of garments by men is not very practical, and if many garments have to be wrung, either rubber gloves or a mechanical wringer is necessary. The cost per shirt for solution at pre-war prices would amount to about ½d. to 1d. according to the strength of the solution used. The fault of this remedy is that it is rather slow, and does not prevent feeding until in full action.

The most efficient quick-acting remedy of low cost I have used is naphthalene, which for the purpose of the destruction of lice is quite as effective, and for some methods more effective, in its crude cheap form than in its more expensive purified state. It acts by vapour and possibly also when mixed with oil, soap or grease, as a contact. But it is no exception to the general rule of very restricted range of effective action, it must be *thought of* for practical use as if it killed by contact. Under the conditions of use between clothing and body its action is very rapid, killing in about two or three hours if used in sufficient quantities, and feeding seldom occurred during tests. Unless continued action is desired the quantity used need not be large, as its efficiency depends upon the surface exposed to evaporation; it is consequently more rapid in action when used as a powder, or if the fabric is impregnated with it, than if put up in packets.

Naphthalene is, however, so efficient that the retarding of its evaporation may be a decided gain under circumstances where continued

local action is desired. The impregnation of garments or blankets with it is not difficult, as it is readily soluble. Benzine will take up about 40 per cent.; methylated spirit between 5 and 10 per cent.; paraffin up to 15 per cent. But, more important still, it can be dissolved by heat in oil or oily fluids, which can be subsequently emulsified and used to impregnate clothing, &c., in watery solutions while warm.

If used in impregnation it is less wasteful than if used as a powder, because in the latter case it dusts out, but under either system the duration of its effect is very short owing to its rapid evaporation at body temperature. At a concentration of 10 mgrm. per square inch, equal to about 16 grm. per shirt, it will within two to three hours kill all the lice present, but will have entirely lost its lethal action within five hours and its smell within eight. On the other hand, if used in packet form, although its evaporation period is prolonged, its range of action is limited to a radius of about an inch from the packet. It is therefore unsuited for the purposes for which the crude carbolic soft soap emulsion method is so well adapted, but as an adjunct to these for individual use in case of emergency it is invaluable, and might be supplied both as a powder for use by dusting a pinch or two in at the neck, or put up as a paste by mixing with soft soap for the purpose of smearing along the seams of garments. For the latter purpose crude naphthalene is even more serviceable in its "unwhizzed" than in its "whizzed" condition, because the quantity of oily fluid which it contains renders the use of less soap necessary to produce a paste. The soap, whilst restraining the speed of evaporation of both the oily fluid and the naphthalene, does not prevent the preparation spreading in the fabric of the garment, under which circumstances it acts as though it had a contact effect. It is possible that this is really the case, but its increased efficiency in range of action may be due to the enlarged area from which vapour is produced.

Having now put before you the facts, so far as I conceive them, concerning the most efficient methods of checking pediculosis in the Army, at a reasonable cost, I propose to deal shortly with some of the other remedies that have been recommended for use against these pests.

Clayton Gas.

There is no doubt as to the efficiency of this means of killing active lice or mites in discarded clothing or bedding, but I am still doubtful, in the absence of detailed reports, of the exact procedure and control of

experiments, as to the destruction of nits by its means. Nits are very susceptible, and easily killed at certain stages of their development, and, relatively, very insusceptible at others, therefore the possibility of the nits being sometimes killed by the treatment and at others not, is considerable. The chief objection to its use, however, is, I conceive, that of cost and special apparatus to ensure sufficient concentration, while, I suspect, though I confess to having no actual experience, that the time required is much longer than would be needed for dry heat to produce the same result.

Most of the other suggested methods for the treatment of discarded clothing would seem to require even greater elaboration of method and expenditure of money.

INSECTICIDES FOR USE WHILE THE INFECTED CLOTHING IS IN WEAR.

Iodoform and Cytisine.—The former, if it could be used in sufficient quantity, might be ideal, but the cost of impregnating garments with it puts it out of the question, whilst in small quantities it only creates smell and causes expense without increasing the efficacy of other remedies. Cytisine is not only too expensive, but also might possibly prove dangerous.

Vermijelli.—The quantity and method of application required for efficient protection would render this remedy not only expensive, but disagreeable. It is questionable whether it acts otherwise than would any heavy grease, such as the rancid butter of the Cossacks. It is certainly ineffective if used up to 10 per cent. strength to impregnate clothing.

Sulphur.—I am by no means so sure that this is so devoid of action as some experimenters have suggested. Under the condition of use on the body it seems to have a very slow action; variable results are possibly due to differences in the humidity of the body. It is, however, hardly worth troubling about while reasonably cheap and definitely effective remedies are to hand.

Anthracene.—This was tried on account of its similarity of molecular structure to naphthalene, but was all but useless.

Tar Oil.—This is very effective if used neat to impregnate flannel, but is not very suitable for this purpose. If it could be evenly sprayed on in small quantities it might afford a practical remedy of some value. Its period of effectiveness when flannel has been thoroughly impregnated with it is about fifty hours while in contact with the body, but when

used in smaller quantities the period would be proportionally less. It can be emulsified with soft soap in the proportion of twenty-five parts oil of tar and ten parts of soft soap, but is not effective when used as a watery solution to impregnate garments, even at a strength of 50 per cent. Presumably, therefore, it acts by its mechanical effect only.

Sassafras Oil.—This is very deadly as a contact and, judging by smell, is one of the ingredients of many of the effective proprietary pastes and fluids. It is one of the few remedies that will kill lice when they are fed on a patch of skin treated fifteen minutes previously. The proprietary pastes and fluids with which I have experimented, however, do not seem to contain it in sufficient proportions to be effective when subjected to the skin test. Economy in its use may be obtained by diluting it with methylated spirit or paraffin (lamp-oil). It can also be emulsified with soft soap as follows: One part soft soap is melted in five parts of water by heat; twenty parts of sassafras oil are then added very gradually, with thorough shaking or stirring. This emulsion can be diluted with water, but does not remain in emulsified condition for more than a few hours after dilution. Flannel impregnated with a 10 per cent. solution, and then dried, killed all the lice within a few hours during the first thirty hours of wear, but after forty-eight hours it was only partially effective during a twenty-four hours' trial.

Legroux's Method.—A trial was made with the impregnated sachets as supplied for use in France. The ingredients are oils of lemongrass, pennyroyal and eucalyptus, to which powdered naphthalene is added. The result was partial and uncertain, the average mortality being only 20 per cent. in an eight hours' trial, while the fact that there were no feeble, but only dead and active lice, raised a suspicion that the small number of deaths which occurred were due to misadventure—probably pressure.

Only a few of the proprietary insecticides have been tested; of these the best known is probably "*Parasitox*," 1s. per stick weighing 43·50 grm. The proprietors' direction is to "rub daily on the inside seams of the clothing and on the body, especially the hairy parts," I have only tested in so far as regards the first half of the direction, the latter portion being, in my opinion, impracticable for reasons already set forth. Slips of flannel were smeared with the preparation and lice imprisoned under gauze on the treated area. The slips were then pinned to the inside of the shirt, so that the insects could feed through the gauze during the period of the test. Used to the extent of 23 mgrm. per square inch, all were stupefied in one and a half hours;

at the close of the twenty hour trial all were dead. A second test on the same piece of flannel showed all but one out of twenty-five lice active after three hours, mostly active after eleven hours, and after twenty-two hours twenty-two living, mostly active, two paralysed, one dead. Used at 10 mgrm. per square inch, a few were stupefied after one and a half hours. After five and a half hours all were stupefied. After twenty-two hours fifteen were living and active, ten were dead. The quantity used would therefore need to be between 10 and 20 mgrm. per square inch, and as a shirt has an area of some 1,600 square inches it would, I judge, be an expensive remedy to use daily.

An insect powder named "Muhak," cost not stated, was dusted on to flannel to the extent of 20 mgrm. per square inch, and the lice imprisoned as before. It stupefied a number in one and a half hours. After twenty hours, eight were still living, seventeen dead. A second trial with the same piece of flannel showed all active after two and a half hours, and also after eleven hours. After twenty-four hours, twenty-two were living, sixteen of which were active; two were dead. Feeding took place during both trials.

A powder supplied by Messrs. Shotter and Jones was tested by the same method. After one and a half hours all were living, mostly active; after seven hours all living, mostly active. After twenty-two hours, twenty-three were living and active, two were dead.

"Meville's" Fluid.—Used as recommended for anointing the skin. A number of lice were fed on the skin area that had been treated with the neat fluid fifteen minutes prior to the test. The insects fed and showed no ill effects. Used neat to impregnate flannel, the trials being subsequently carried out with lice imprisoned under gauze on the flannel, which was pinned to the inner side of the shirt so that the insects could feed, the period of efficiency, as a slow-acting insecticide, continued for seven days. First day after impregnation, 100 per cent. killed within a few hours; second day after impregnation, 100 per cent. killed after eighteen hours; third day after impregnation, a number were killed within forty-eight hours; fifth day after impregnation, ten out of eleven were killed within forty-eight hours; seventh day after impregnation, seven out of thirteen were killed within forty-eight hours. It is probable, however, that its cost would prohibit its use for the impregnation of garments.

Two pastes and a fluid put up by W. A. Proctor, and intended for use by application to the skin, or smearing on garments, were tested. A patch of skin was smeared or wetted with the preparation, and after

fifteen minutes hungry lice in a gauze covered box were allowed to feed on the prepared skin area. The pastes had little, if any, deterrent effect; the insects fed heartily and were not harmed. The fluid had a partially deterrent effect, but some of the lice fed heartily—one out of fifteen died within twenty hours.

Used for the treatment of flannel, all the preparations proved to be active insecticides if applied in sufficient quantities, but their effectiveness soon deteriorated when used between clothing and body, so that after twenty-four hours they were only partially effective in a twenty hours' test.

"*No Germo.*"—0·260 grm. was placed in a small pocket on a slip of flannel and the lice confined under a gauze cover above it; the pocket holding the preparation was 15 mm. square, the gauze cover above had an area of 2,246 mm. Under these circumstances crude naphthalene would have killed from 70 to 80 per cent. of the insects within four hours. The record of "No Germo" is as follows: After a four and a half hours' trial no effect; after a twelve and a half hours' trial, four out of thirty were dead.

Two trials were made with the "*Kergold anti-vermin body belt,*" for which the suppliers make the following claims: "Perfect immunity from all insect pests. The Kergold is the only belt that affords instant and permanent relief from the bane of the soldier on active service. Vermin simply cannot exist when the Kergold anti-vermin body belt is worn; protects the wearer from head to foot. Total immunity from all further attacks. The medical properties of the belt last for approximately six months." The first trial gave results so greatly at variance with these claims that a second belt was purchased in order to avoid the risk of the first one being a "bad egg." In the first series of trials lice were confined in gauze pockets fastened to the shirt so that the insects could feed during the course of the test. In all, eight pockets were placed at varying distances above and below the belt, from the neck to the thighs; during the course of a continuous twenty-four hours' trial the only lice which died were a few in one of the pockets on the upper part of the chest, apparently from pressure of the braces.

In the second trial much trouble was taken to wear the belt before trial and to induce a perspiration by work in a hot room at 97° F. Four gauze pockets containing lice were suspended within an inch of the belt and most of the insects fed heartily at intervals during a twenty-four hours' test. After this period it was found that out of sixty lice nine were dead, four were feeble, while forty-seven were active. While

conceding the possibility that the dead and feeble were due to the action of the belt, I incline to the view that they were overlaid during sleep.

After the belt had been continuously worn for sixty-two hours another test was carried out. After twenty-four hours there were three dead, two feeble and twenty-nine active lice in the pockets. The belt was then worn for a further period, and after five days' continuous wear it was given a last chance. After a twenty-four hours' trial, during which many of the insects fed heartily, one was dead and twenty-nine were active, including one pair in copula.

Preventive Measures Against Lice.

Heat.—Dry air or water at a temperature of 52° C. will destroy both active lice and nits within a period of thirty minutes. Higher temperatures kill more quickly; water at 100° C. kills the nits in half a minute. In the destruction of lice by heat the all important factor is penetration. Thick or folded garments require longer time than hung or spread ones. Bundled clothing is only slowly penetrated. Other factors being equal, dry heat is more economical than wet, because wet garments require drying after treatment.

Cold.—Exposure to cold, 30° to 38° F. or −1·1° to 3·3° C. for two days is fatal to active lice, although they may be living at the end of the period. If continued for four days they are killed within the period. Nits survive exposure to the same temperature for seven days, but not eleven.

Insecticides: Contact.—To keep continuously worn garments free from lice the best method is to impregnate with cresol or crude carbolic acid, employing in soap emulsified form, dipping the garments in a solution containing from 2½ to 5 per cent. according to the climate or season; hot weather needs less, cold more.

Vapour.—Insecticides which act by vapour have a very restricted range—not above 1 in., or, at the outside, 2 in. Naphthalene is probably the most economical and effective of the quick remedies, but at body temperature it rapidly evaporates. If underclothing is impregnated to the extent of 2 mgrm. per square centimetre—10 mgrm. per square inch, or about 16 grm. per shirt—its lethal effect will have entirely passed away within five hours. If used in packets its range of action will be less than 2 in. Used as powder it is wasteful, owing to its dusting out of clothing; mixed with soft soap or grease this waste is prevented and its efficiency is increased. Crude naphthalene is cheaper and more

effective than pure. Sassafras and other essential oils are very effective, but kill by contact, not vapour, under the conditions of use. Smell is no guide to vapour effect.

The Destruction of Nits.

Paraffin Oil.—Immersion for five minutes kills the greater proportion, but not all.

Sassafras Oil.—Immersion for five minutes kills all. A 10 per cent. watery solution of this oil in emulsified form with soft soap is also effective as against nits. (One part soft soap melted in five parts of water by heat, twenty parts of the oil added very gradually with thorough shaking or stirring.)

Crude Carbolic Soft Soap Emulsion.—Immersion in a 5 per cent. solution for five minutes kills all.

Tar Oil Soft Soap Emulsion.—Immersion in a 5 per cent. solution for five minutes kills all.

Potato-paring Infusion.—Recommended by a writer in the *American Journal of Clinical Medicine.* Immersion for thirty minutes was quite ineffective, and did not even kill active lice.

Quassia Chips.—An infusion of 20 grm. in 250 c.c. of water boiled for over an hour was tried; immersion for ten minutes was quite ineffective, and the active lice lived for two days afterwards, but failed to feed.

Chlorine Gas.—Nits exposed to the action of this gas during the course of a trial at the Royal Army Medical College hatched in the normal course and adults were reared from them.

Colorado Vermin Killer.—Carbon disulphide, 10 c.c.; crude carbolic, 91 c.c.; oil of tar, 2·5 c.c.; kerosene, 435 c.c.; killed all nits immersed for five minutes.

Of these remedies tar oil emulsion and a 5 per cent. solution of crude carbolic soft soap emulsion might be used for the treatment of heads, as they are more effective than paraffin oil and cheaper than sassafras oil.

For the treatment of nits in the seams of clothing either of these or the Colorado vermin killer would be effective; the latter would, of course, be too irritating for use where it comes into direct contact with the skin.

DISCUSSION.

Professor G. H. F. NUTTALL, F.R.S.: Having been engaged for a considerable time in studying the louse problem I can perhaps appreciate the value of Mr. Bacot's work better than most of his hearers. Apart from my own investigations I have taken the pains to collect the literature of the subject and ere long hope to publish a full account of what is known of the louse and its misdeeds. So far I have notes on upwards of 520 papers and publications dealing with lice. The literature is remarkable, in that most authors completely ignore the work of others that have preceded them. I may say at once, however, that Mr. Bacot's work is in some ways the best that has been done hitherto on the biology of *Pediculus*. I would mention here that three papers dealing with the biology of the louse will appear next week in *Parasitology* [1] from the pens of Mr. Bacot, my assistant Dr. Hindle, and myself respectively. I would refer those interested in the subject to these papers, since they contain much that is new:—

(1) Are *Pediculus humanus* and *Pediculus capitis* separate species? Mr. Bacot has given us biological differences of his own finding besides those usually quoted. He cites Cummings as an authority for certain morphological differences. All of the differences noted by Cummings, excepting that affecting the form of the gonopods, have been given by other observers in the past. I would note that Meinert and Neumann, two very careful observers, failed to find any constant differences. My opportunities of examining material have been limited, but so far I have found no constant differences between the two purported species collected in four continents. I shall be grateful to persons in different parts of the world who will supply me with a large number of specimens, well preserved in 60 to 70 per cent. spirit, and accompanied by full particulars as to their source. From what I have seen I incline to the opinions of Meinert and Neumann that head lice and body lice are but races of one species.

(2) The influence of temperature on the rate of development is a subject of practical interest. Rubner, who made careful studies on the temperature beneath human clothing, determined that about 32° C. represents the temperature at or near the skin surface of a clothed individual when he is feeling comfortable—i.e., neither chilly nor warm. Mr. Bacot, no doubt with cruder methods, has determined 31° C. to be the temperature in question. From my observations, and those of others, I take it that the optimum temperature for the development of lice is about 32° C. I have found that the eggs kept at 32° C. continuously near the skin, hatched mostly after seven days; at 30° C. in the thermostat, hatched mostly after ten to twelve days; at 37° C. by day and 14° C. by night, hatched after fifteen days; at 30° C. by day and 10° C. by

[1] *Parasitology*, February, 1917, ix, pp. 228, 259, 293.

night, hatched after twenty-seven days; at 30° C. for twenty-four hours, and at 5° to 10° C. for twenty-four hours, alternately, hatched after 35 days.

(3) I have failed to observe any difference in the manner of oviposition of "*capitis*" and "*vestimenti*" upon hairs.

(4) Mr. Bacot's statement that additional feeding of adults leads to a greater number of eggs being laid is confirmed by my observations. When fed twice daily I found, as most observers have, that a female lays four to five eggs per day. Mr. Bacot, when he fed them more frequently obtained an average of 6·4 eggs per day; at times this number was much exceeded. I have, however, obtained better results under the optimum conditions offered by keeping lice confined continuously in a felt cell strapped to the arm. Under these conditions of unlimited opportunities of feeding, and an optimum of warmth and moisture, two females laid an average of ten eggs apiece a day for twenty successive days; one female laid 266 eggs in all before she died, probably from being crushed; nevertheless her ovaries were not exhausted.

(5) *Longevity.*—I have also found that adults may live four to five weeks when fed twice a day. The longest period recorded for lice surviving unfed is ten days, this observation having been made by Hase. Observations as to alteration in the fat-body of lice that are starved are lacking.

(6) The remarkable difference in the proportion of the sexes in various broods, to which Mr. Bacot has referred, was made the subject of special study by Dr. Hindle, and will be found described with full protocols in his paper.

I would note with regard to the duration of the life cycle of lice under normal conditions upon man, that my experiments have shown the development from egg to egg to last seventeen days. In the experiment made by Warburton (1911), who carried lice in receptacles near his person, feeding the insects twice daily, the corresponding period was twenty-four days.

Turning to the matter of dealing with the destruction of lice, I would note that my experiments and a survey of the literature published in all the countries engaged in this war, have both led to the conclusion that *dry heat*, where applicable, is the quickest, cheapest, and safest way of dealing with infested articles of clothing, furs, bedding and the like. I find that moderate dry heat kills all lice and their nits in a short time; they are certainly killed in one minute at 65° C., or in five minutes at 62° C. Immersed in water heated to 76° C., they are killed in half a minute, at 60° C. they are killed in five minutes. In practice, naturally, time must be given for heat to penetrate the objects which are treated. The time required will depend upon the degree to which the objects are packed together, as old experience at the hands of bacteriologists has shown. The *hot air should circulate* freely among the objects to be treated if rapid destruction is to be attained. Various simple ways of dealing with this mode of louse destruction are in use to-day. I shall deal with the subject on a future occasion. The *storage* of infested clothing and blankets in a dry warm room would rapidly lead to the death of vermin. I heartily endorse Mr. Bacot's remarks upon the useless character of most insecticides and repellants. I would add to his list an article advertised as the

" Asiatic body cord," which is said to work wonders; it consists of a string to be tied around the waist, the string being surrounded by a greasy substance having the colour of blue ointment; smeared on a slide and examined microscopically, I detected globules of mercury in it. Naphthalene, as also sulphur, have not hitherto given complete satisfaction, and no little trouble abroad. All the evidence points against the use of sulphur dioxide because of its injurious effects on fabrics and metal, &c., and the smell that clings to articles treated with it. Carbon bisulphide vapour has been found better than SO_2; its odour vanishes rapidly, but is objected to because of its toxicity and inflammability. My experiments carried out last year with twenty-four hour old nits and a number of insecticides will be published in due course, but I may mention a few of the results: Nits were not killed by immersion for twenty minutes in paraffin; ten minutes in benzine, petrol, ether; five minutes in carbon bisulphide. Nits were killed by immersion for ten minutes in $2\frac{1}{2}$ per cent. carbolic acid or in carbon bisulphide; by five minutes in 2 per cent. lysol; by one to two minutes in sublimate vinegar or sublimate glycerine. The use of 5 per cent. carbolic as a head wash, applied for ten minutes, was advocated by Whitfield (1912) for the destruction of *Pediculus capitis*. Cresol soap, to which Mr. Bagot refers, has been used with apparently satisfactory results in the German army, and its use was advised in this country by Copeman. It will be interesting to learn how the method suggested by Mr. Bacot of applying carbolic acid to underwear will work out in practice. Experience in the field has shown that different methods of dealing with the problem are required, and that they must adapt themselves to the most varied conditions. At times the conditions are such that the merest palliatives are all that can be used. Even hand-picking, if persisted in, has given good results. Finally, a word about dead or empty nits adhering to cloth; I have been asked how these are best removed. They can only be removed mechanically by means of a knife blade or finger nail, or by singeing off the fibres to which the nits adhere; no solvent affects the chitin-like cement which glues the egg to the fibre without first destroying the fibre.

Professor LEFROY: I am astonished that Mr. Bacot makes reference to only one published work, and that now, at this stage of the War, he can discuss this problem, and can bring forward no newer remedy than naphthalene, and does not even give the credit due to Major Lelean, who originated the N.C.I. formula in the winter of 1914-15 or earlier. In January, 1915, it became known to us at the Royal College that vermin were really bad at the Front; that the material used in India as crude oil emulsion was fatal to lice, and had been successfully used there for some years, both against head lice and body lice. It was also essential that a special grade of mineral oil, containing a definite hydrocarbon, should be used, as neither petrol nor paraffin were deadly to lice as vapours. I had some emulsion made up, and on my recommendation the Army Medical Service agreed to make a trial of it. This oil emulsion came into use under the name of " Vermijelli," and

was tested in France by Lieutenant Gair, with some fifteen or twenty other preparations. He reported in favour of N.C.I. and oil emulsion jointly, and I am informed that these were officially issued at the rate of $\frac{2}{3}$ oz. per man per week. While in India I had this preparation made at the Medical Stores Depot, Bombay, and issued for use in Mesopotamia, and I still adhere to the opinion that this emulsion destroys lice if used on the body; kills eggs if applied to them; keeps lice from infecting you if the underclothing is impregnated with it. I have never claimed that clothing impregnated with it will kill lice. I know of nothing that can make clothing deadly to lice except certain oils, the application of which presents difficulties. Mr. Bacot, when referring to vermijelli, says: "The quantity and method of application required for efficient protection with this remedy would make it not only expensive but disagreeable. It is questionable if it acts otherwise than any heavy grease, such as the rancid butter of the Cossacks would do. It is certainly ineffective if used up to 10 per cent. strength to impregnate clothing."

Mr. Bacot's sole test of efficiency apparently is that the preparation must be applicable to clothing, and that this clothing will then, if worn, clear you of lice. This is not, in my opinion, the louse problem.

Mr. Bacot bases his remarks on tests made with lice enclosed in muslin bags placed under his clothing; but he does not seem to have made the proper test, which is to become verminous and then treat oneself. His laboratory conclusions, based on a defective method, are contrary to the experience of men at the Front in hundreds and thousands—men, officers, and ladies, from France, Serbia, Mesopotamia have testified in scores to the efficacy of the oil emulsion, and I still maintain that an emulsion of fuel oil of the specific gravity and boiling point that I refer to is an efficient destroyer of lice, if applied on the body in sufficient quantity and vaporized under the clothing with the heat of the body. If otherwise, why has vermijelli proved effectual? Why did the Army Medical Authorities adopt it? For it has filled a gap at a critical time in Serbia, France, and elsewhere. There are doubtless better specifics now, but it is not fair to dispose of the oil emulsion as Mr. Bacot does. The solution of the problem is not made clear by the lecturer; the last paragraphs of his paper refer to many methods, and apparently leave the choice open. What treatment does Mr. Bacot recommend to men who are verminous and to those exposed to vermin infection? If he were sent to a Front what would he do? In such circumstances I provided myself with the oil emulsion discarded by Mr. Bacot, and I found that it worked. The method of keeping lice in gauze pockets fixed under the clothing does not appear to be any real test; the louse is very sensitive, and there is only one real test: *be verminous and clear yourself.* But Mr. Bacot relies on an experimental method which is of doubtful value. The advice given by Mr. Bacot appears to be that the soldier at the Front should rely on the doubtful remedies sent to him by his relatives. But as this paper is entitled "The Louse Problem," it is reasonable to ask what is to replace the methods which have proved so far reliable.

I would further suggest that there is scope for further work, that the limits of the investigation are perfectly definite, and that the body temperature is the one important factor. The Germans are reported to clear their men with cyclo-hexanone ($C_6H_{10}O$), a compound related to what I believe to be the active principle in the fuel oil used. If I were to attempt further work with the louse, I should commence to investigate the cyclo- and allied compounds contained in these oils. Mineral oils are composed of a great range of hydrocarbons, and their insecticidal action varies enormously; the fractions that come off at temperatures between 250° and 400° from the different oils differ in chemical composition, and it is amongst these that I believe the best odourless liquid will be found that will kill vermin at body temperature. I thought we had it, but Mr. Bacot does not agree. It is perhaps going far to dive into the difficult chemistry of the oils in order to obtain a vermin remedy. Perhaps I am mistaken, but Mr. Bacot appears to lump all these together; if so, I understand his lumping together fuel oil and the Cossacks' rancid butter.

Lastly, I hope the Section will not confine its discussion to the academic and scientific aspect of the problem. The thought that there are hundreds and thousands of men scratching themselves at the Front fills my mind to the exclusion of the purely scientific aspect of this work, and I look to the attainment of some practical conclusion that will help them. I trust that this paper and the discussion may not end in talk only but in some real advance in methods of treatment.

Mr. A. W. BACOT (in reply): Of special interest and value are Professor Nuttall's observations relative to the minimum within which the life cycle may be completed; his figure of seventeen days is some three days less than the minimum of my own series, and corresponds to a decided acceleration of the rate of increase in offspring resulting from a single pair.

Professor Lefroy's observations raise points which the practical importance of the problem compel me to examine in some detail. I can, however, pass over briefly the accusations of ignoring the work done by previous investigators. So far as these relate to the purely biological aspects of the louse problem it is sufficient to remark that this paper only treats of them incidentally, and that in the special memoir on the scientific questions involved, which I have contributed to the current number of *Parasitology*,[1] the necessary references will be found. As to the priority of Major Lelean in connexion with the practical use of naphthalene, a professor of entomology must surely know that naphthalene had been employed as an insecticide by hundreds of persons years before Major Lelean dealt with the subject, and that to complain of the omission of any individual's name in connexion with it is as reasonable as to charge a writer recommending opium, without cited authorities, with doing an injustice to Sydenham. The gravamen of Professor Lefroy's charge is,

[1] *Parasitology*, February, 1917, ix, p. 228.

however, threefold—viz., (*a*) That my experimental methods are faulty; (*b*) that I have brought forward no newer remedies than naphthalene; and (*c*) that I have been unjust to the claims of the proprietary article "vermijelli."

(*a*) I need not recapitulate the experimental technique carefully explained in the text of my paper. It is certainly true that a remedy found effective as against lice confined in the manner described might not be effective against the whole of a louse population allowed to wander fancy free over one's body. But it is not less true that a remedy which fails under this method of examination will be futile when the lice are given a still better chance of escaping its influence. My technique clearly provides the minimum standard to be reached. If Professor Lefroy has evolved a better technique, it is his duty to publish it so that other investigators may be able to give it a trial. Vague references to the experience of even "thousands of men, officers and ladies from France," or elsewhere, carry no more weight than the similar utterances to be found in the advertisement columns of the daily press.

(*b*) The charge that I have brought forward no newer combination than naphthalene as a subject for trial should be weighed against the fact that the paper deals with a long series of tests performed with various substances, and a detailed method of impregnating underclothing with a solution of an emulsion of crude carbolic acid and soft soap. I have, of course, no personal interest in the newness or otherwise of any remedy. Professor Lefroy indeed says, in reference to "vermijelli," that "there are, doubtless, better specifics now," but he has failed to mention any, and there is no published evidence that he has performed a single test with any substance other than crude mineral oil emulsion; indeed, I cannot find that even with respect to this heavy oil emulsion, Professor Lefroy has made public any controlled experiments similar to those regarded as essential in ordinary biological or pharmacological investigations. One would perhaps have thought that such elementary desiderata as range and period of action, effect of physical conditions, effective concentration or quantity in relation to area, would have been made public by an investigator so solicitous of bringing comfort to the "thousands of men, &c.," and I must regard the other "thousands of men, officers and ladies, &c." as but phantom substitutes for this exact information. It is perhaps possible to be scientific without being in Professor Lefroy's sense of the word academic.

(*c*) Professor Lefroy's eloquence in no way moves me to weaken what he evidently regards as a censure of "vermijelli." I pass over his suggestion, rather than explicit statement, that "vermijelli" derives specific virtues from containing certain hydrocarbons of specific constitution; no one, not even the "thousands of men, officers and ladies," having produced any definite evidence on the point. He opposes to my remark that "vermijelli" is certainly ineffective, &c., the statement that "I have never claimed that clothing impregnated with it will kill lice." By way of commentary on this positive

assertion I will quote a passage from a pamphlet written by Professor Lefroy and widely circulated some months ago.[1]

"The emulsion should be used in the hospital laundry as soap, or in combination with other soaps. The articles, after washing, should be rinsed in water containing from 1 per cent. to 2 per cent. (about 2 oz. to the gallon) of the emulsion, well mixed. They should not be wrung out too tightly, but allowed to dry so that the clothing is impregnated with it. The clothes will then confer protection against lice. Vermin hatching out from the eggs upon cloth that has previously been treated in this manner have been found *incapable of survival.*" [My italics.]

The difference between claiming that a substance will kill lice and claiming that it will render them incapable of survival is so subtle that I think it a little hard to be condemned as unpractical and academic by a writer who lays stress upon it.

To sum up, I think the claims made on behalf of "vermijelli" by its vendors are in excess of its real merits. My reasons for this opinion are set out in the paper just read, and subsequent experiments simply confirm these results. When Professor Lefroy sees fit to make a quantitative series of trials and publish the results I shall willingly reconsider the matter, but not until this is done.

[1] "Measures for Avoidance of Flies, Mosquitoes, Lice and other Vermin." H. Maxwell Lefroy, M.A., F.Z.S.