THE LOUSE: PRESENT KNOWLEDGE AND FUTURE WORK.

by

P. A. BUXTON, M.R.C.S., L.R.C.P., D.T.M. & H.

Professor of Medical Entomology, London University;
London School of Hygiene and Tropical Medicine.

In the present paper an attempt has been made to take stock of our existing knowledge of populations of the louse, and of methods of controlling it. The paper is brief, because a rather full account of the insect has been recently published (BUXTON, 1939). A full list of references seems unnecessary, and I have only given a few in order to call attention to facts which are not generally known. The paper provides an opportunity for suggesting several points on which further information is desirable.

It is now agreed by most workers that the body louse and head louse are much less distinct than was once thought (FERRIS, 1935). Their status is a matter of opinion rather than of ultimate verity, but it seems best to say that they belong
to a single species, *Pediculus humanus*: as they hardly differ in anatomy, but show greater differences in biology one may call them "biological races," according to present-day zoological practice. In discussing ecology, insecticides, etc., it is more convenient, and probably more true, to regard them as one than as two.

**Collective Biology.**

The applied biologist is interested in the numbers or populations of plants or animals: for instance, he does not only want to know whether locusts or anopheles occur in a certain country, but also whether there are enough locusts to destroy the crops, or enough mosquitoes to transmit malaria. In a similar way those who have to study the louse do not ask whether it occurs in a certain place (a matter on which there is seldom much doubt). They want to know what proportion of people are infested, whether they harbour few or many lice, or what are the chances of transmission of disease: they may also be interested in the constitution of the louse population itself, for instance the proportion of adults to young, or males to females. It must never be forgotten that populations are dynamic not static; they are therefore always increasing or decreasing, irregularly or with the season and other factors. Moreover, as the life cycle of the louse is short, and as it can multiply rapidly, it will very quickly colonize new territory if opportunity occurs. For these reasons, one can feel no doubt of the importance of studies on the collective biology, or biology of populations as it is sometimes called.

An important character of louse populations is simplicity. The louse belongs to an order of insects (the Anoplura) in which metamorphosis is slight, so that the larva is a small edition of its parents; moreover, adults and larvae live in the same place, and feed only on the blood of human beings. There are no parasitic insects which attack lice, and they seem to suffer little from infections and diseases. Head or body lice and the eggs are found on or near the surface of the body; as man's internal temperature is stable, and as he uses clothes partly at least to maintain comfort, it is not surprising that the temperature where the louse lives varies but little. It is more remarkable that the humidity beneath the clothes is also relatively constant (Mellanby, 1932; Mansi and Buxton, 1937). Even if this regulation of temperature and humidity on the surface of the body breaks down after violent exertion, it remains true that the physical environment of *Pediculus humanus* is remarkably constant in most respects.

It is in this stable environment that the louse lives and fluctuates in numbers. There are several ways in which we may study these numbers:—

1. Counts (or estimates) can be made of the number of lice in garments or on the head. One can for instance remove all the hair from the scalp with a razor and dissolve it, leaving the cutaneous skeletons of the lice to be enumerated. This method is valuable for it tells one something of the distribution of parasites among hosts at a particular instant. But it gives no information about the dynamics of the subject, about the rate of growth of the population of lice, or the factors which influence that rate.

2. One may breed lice, in gauze-bottomed containers held against the skin. Such a method gives information about changes in population (daily births, length of life, deaths of eggs, larvae, and adults, etc.) but one cannot say how closely the conditions approach the natural. One could also liberate the lice in an enclosure (for instance under a stocking leg, sealed to the limb at each end). Such methods as these will eventually lead to the completely natural experiment, in which a known number of lice are liberated on a volunteer, left at large, and searched for at intervals. In the meanwhile one should not miss opportunities of observing and recording what happens if lice are accidentally introduced into a small rather isolated community of people, such as those inhabiting a small ship, or a blockhouse.

3. On a basis of facts about births, deaths, etc., general formulæ and curves can be developed, to describe the increase or decrease of populations. This method has been worked out by Thompson and his collaborator, the late H. E. Soper (Thompson, 1931).

These methods are beginning to give some idea of the growth of a population of lice. The basic facts, obtained from lice kept in boxes against the skin, under good experimental conditions are as follows:—

**Adult female** lives 34 days, laying no eggs on the first two, or the last, day; on other days she lays nine eggs (i.e., a total of $31 \times 9 = 279$).

**Eggs** have a mortality of 30 per cent.; stage lasts 9 days.

**Larvae** have a mortality of 40 per cent.; stage lasts 9 days.

**Adult progeny** are assumed to be male and female in equal numbers. Every female is fertile.

From these facts a timetable may be derived, on the assumption that the stem mother or original female was born as an egg on day 0. The course of events is then:—

Day 0, original ♀ (G 1) is born, as an egg.

1. 9, ♀ becomes larva.

2. 18, ♀, adult: is fertilized.

3. 20, ♀ lays first eggs (G 2).

4. 29, first daughter eggs (G 2) hatch to larvae.

5. 38, ♀, daughters become adult.

6. 40, ♀, begin to lay eggs (G 3).

7. 49, G 3 eggs become larvæ.

8. 51, original ♀ (G 1) dies.

Etc., etc.

Using these facts and the simplest arithmetical processes, it is possible to construct a table showing daily births, deaths, total number alive, etc. In
the present instance it is convenient to simplify the work by regarding eggs and larvae together as "offspring," and one may also limit attention to females, as they give rise to the next generation. One may also exclude all those eggs and larvae which are destined to die, and deal only with those which are "viable" (i.e., those which will grow up to non-viable age): it must be remembered that at any moment there are many non-viable eggs and larvae alive, which are excluded from the table.

**Table I.**

**Show ing the Early Stages of the Increase of a Population of *Pediculus humanus* Living Under Good Artificial Conditions.

G1, G2, etc. = First and Second Generations.

<table>
<thead>
<tr>
<th>Day</th>
<th>Event</th>
<th>Viable Female Births Daily</th>
<th>Viable Female Births to Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Parent (♀) laid as egg ...</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Egg becomes larva ...</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>Larva becomes adult ♀ (G1)...</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Above ♀ lays eggs (G2)</td>
<td>0</td>
<td>1-9</td>
</tr>
<tr>
<td>21</td>
<td>First larva emerge (G2)</td>
<td>0</td>
<td>1-9</td>
</tr>
<tr>
<td>22</td>
<td>First larva (G2) become adult</td>
<td>0</td>
<td>1-9</td>
</tr>
<tr>
<td>29</td>
<td>Adults (G2) lay eggs (G3)</td>
<td>0</td>
<td>1-9</td>
</tr>
<tr>
<td>39</td>
<td>First G3 eggs become larvae</td>
<td>0</td>
<td>1-9</td>
</tr>
<tr>
<td>49</td>
<td>First G3 eggs become larvae</td>
<td>0</td>
<td>1-9</td>
</tr>
<tr>
<td>50</td>
<td>♀ (G1) dies ...</td>
<td>0</td>
<td>43-3</td>
</tr>
</tbody>
</table>

A table has been made in this way, from the basal data given above, and parts of it are shown as Table I. It gives the growth of a population up to the 51st day. But it would be difficult to carry the work much further by this method, for the arithmetic though simple, becomes more and more tedious and full of pitfalls. For instance, there are births in the fourth generation (G4) from day 60: on that day the 3-6 viable females (G3), born on day 40, each lay 1-9 viable female eggs, so that there are 3-6 × 1-9 births; next day the females born on days 40 and 41 are becoming mothers, so that there are (3-6 + 7-2) × 1-9 births; and so on. There are, moreover, deaths to be taken into account.

Fortunately, simple general formulae are available (Thompson, 1881), from which the curves given in the figure have been constructed. These curves make it clear that if all the circumstances continued to be favourable, as they were at the start, the population would rapidly reach enormous figures. The graph shows that the "viable females" exceed 1,000 on the 61st day. It is true that many of them are then eggs, but it is also to be remembered that all males and many non-viable eggs and larvae have been excluded.

Even if conditions are much less favourable to the insect, as they might be on a person able to achieve a partial control of the insect, lice can multiply to a surprising extent. Suppose, for instance, the average female only lives 20 days, that she only lays six eggs per day, and that 80 per cent. of her offspring die.
without reproducing themselves; even then the descendants of a single female will amount to:—

<table>
<thead>
<tr>
<th>Number of Females</th>
<th>Total Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>62</td>
</tr>
<tr>
<td>100</td>
<td>81</td>
</tr>
<tr>
<td>1,000</td>
<td>89</td>
</tr>
</tbody>
</table>

(Buxton, 1939, Fig. 21.)

We can perhaps feel satisfied that our curves correspond to reality at least so far as they relate to the earlier stages of the growth of a population. But every population of animals tends to be reduced by what is sometimes called the "pressure of the environment": this is generally complex, because some of its component factors (such as competition and the effect of enemies) do not destroy a fixed proportion of the animals, but become more and more effective as the population increases; in other words, deaths due to these factors are a function of the density of the population. The weakness of the reasoning used above, and of Thomson's formulae, is that no allowance is made for the increasing effect of these factors. Now so far as the louse is concerned a number of causes of death are known (Buxton, 1939, p. 37). Two of these appear to be important: wandering from the host with consequent starvation, and human action. It is clear that the second of these is likely to become more and more effective as the population of lice increases; for instance, by people to whom the insect is familiar, a small number might be regarded as normal and tolerable; but when the insects increased beyond a certain limit the host would be stimulated to action. We cannot yet gauge the intensity or effectiveness of this human factor but it is evidently complex; much would depend on the individual's standards and susceptibility, and on various external circumstances which might make control easy or difficult. It is perhaps possible to get an indication of the point at which man begins to take action, if we study large numbers of natural populations of lice. A great many counts have now been made on the numbers of head lice per head and they are summarized in Table II; it is to be understood that the figures relate to adults and larvae but exclude eggs. The table shows that in several different parts of the world very small populations of from 1 to 10 lice are commonest, and that counts beyond 100 are rare, though a few have been recorded beyond 1,000. Counts made on the number of lice per shirt (Peacock, 1916) show a very similar distribution, small populations being much the commonest. These figures appear to indicate either that populations frequently start and are exterminated, or that they are kept at a low level by human interference, or by some other factor which is effective when the number of adults and larvae is much less than 100.

One might, however, think of the matter in another way, taking as our unit, the lice living on a small group of men living together, not on one man. If we suppose that one of these men starts an infestation which spreads through the group, curves such as those shown in the figure have perhaps a greater significance, for the curve may be taken as giving the maximum number of lice which might exist on the group of hosts under certain defined conditions.

The public health worker may look at Table II, and Peacock's data about body lice per shirt, in a different way. As so many natural populations are small (under ten) it must be a difficult matter to discover them all by inspection; on the other hand, among a number of infested people there are a few who harbour several hundred or even thousand lice, and who must be centres from which they may be disseminated.

The original data have been analyzed elsewhere to give information about the distribution of head lice in relation to the human being's age and sex.

### Table II

Showing Number of Complete Crops of Head Examined, and the Percentage Found to be Free of Lice, or to Contain 1 to 10, 11 to 100 Lice, etc.

(Data from Buxton, 1936, 1938, and unpublished data.)

<table>
<thead>
<tr>
<th>Percentage of Heads.</th>
<th>Number of Crops of Hair.</th>
<th>No lice</th>
<th>1–10 lice</th>
<th>11–100 lice</th>
<th>101–1,000 lice</th>
<th>Over 1,000 lice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagos, Nigeria</td>
<td>102</td>
<td>79–4</td>
<td>6–9</td>
<td>8–8</td>
<td>3–9</td>
<td>0–9</td>
</tr>
<tr>
<td>Sokoto, Nigeria</td>
<td>409</td>
<td>88–6</td>
<td>7–6</td>
<td>2–2</td>
<td>0–5</td>
<td>0</td>
</tr>
<tr>
<td>Nairobi, Kenya</td>
<td>418</td>
<td>91–1</td>
<td>3–4</td>
<td>2–9</td>
<td>2–2</td>
<td>0</td>
</tr>
<tr>
<td>Kotonu, Nigeria</td>
<td>329</td>
<td>74–9</td>
<td>10–9</td>
<td>11–7</td>
<td>2–2</td>
<td>0</td>
</tr>
<tr>
<td>Comarana, Malabar</td>
<td>1,422</td>
<td>62–0</td>
<td>24–9</td>
<td>12–1</td>
<td>0–5</td>
<td>0</td>
</tr>
<tr>
<td>Colombo, Ceylon*</td>
<td>240</td>
<td>47–9</td>
<td>33–8</td>
<td>14–6</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Figures from Ceylon relate to adult lice only; from other places adult and larval lice are included.

It seems important to study seasonal changes in the distribution of lice in a human population, particularly because these changes seem to be related to the seasonal incidence of louse-carried diseases. One must not forget that when lice are said to be more abundant, two distinct things may be involved: the insects may be more widely distributed among the hosts, or more abundant per infested host; very generally the two things go together. It seems to be established that in the Mediterranean, head and body lice are rarer and less generally distributed in the hot dry summer than in the cold winter; and in such countries as northern India and the north of Nigeria, lice are rarer in the hot dry weather before the rains, than at other times of the year (Buxton, 1939, p. 50). For most parts of the world, including Britain, no large body of fact is available. Though one cannot obtain samples of the population as a whole, one could do so for particular classes, and it would be most valuable if information could be accumulated. A medical man might be able to examine elementary school
children, or out-patients, or prisoners on admission to jail; he should record the incidence of head and body lice separately, with an indication of whether there were none, few or many, and the host's age and sex, for one year at least.

Control.

An enormous number of substances, formulae and methods have been recommended or used for destroying lice, as one may see from the review of the subject published by Nuttall (1918). Some of them are unnecessarily cumbersome and elaborate; not a few are also ineffective. On the other hand several new insecticides, known to be of value against other insects, have never been tested on Pediculosis, because the subject of controlling it has remained untouched for about 20 years.

In the present paper an attempt is made to provide a "short list" of methods of proved value, preference being given to those which are simpler. Many details about application have been omitted; some may regret this, but in practice each man develops his own technique, and then becomes dogmatic about it. The important matter of organizing campaigns against the louse is also omitted.

In discussing the subject of control it is probably best to consider head and body lice, and crab lice (Phthirius) together, for what kills one will kill another, so far as we know. The subject is better divided into two headings, the destruction of lice and eggs on the surface of human beings (especially on the hair and parts), and their destruction on garments and blankets; the articles in the second group are made of a great variety of materials: cotton, wool, leather, metal, etc. It should also be clear that the objective may be a radical cure, but as this may demand having complete control of a body of men for several hours it is often impracticable; one may therefore have to use palliatives. But palliatives may sometimes be of great value; if one could send troops up the line in garments which would remain nearly louse-proof for a good many days, one would very greatly reduce the number of lice, even if they were never abolished.

There is urgent need to discover and bring into use better methods of controlling lice. In the civil population, a considerable proportion of school children are infested with head lice. As to the military, experience in the war of 1914-1918 showed that one could thoroughly "de-louse" a large body of men, but that they became re-infested as soon as they went up the line again; trench fever, and skin complaints associated with Pediculosis remained major causes of admission to hospital up to the end of the war. It seems to follow that the most important problem, on the military side, is to find a means of disinfesting a soldier, without undressing him or taking him away from work; or, as an alternative, to "proof" him and his clothes so that they will not become infested.

If improved methods of controlling lice are required the most promising things to investigate are:—

1. The effect of the newer organic fumigants on lice in clothing and blankets.

2. The possibility of controlling body and head lice with powders or liquids containing rotenone and substances which occur with it; these are found in certain plants (Derris, Lonchocarpus, etc.).

3. The possibility of "proofing" garments, at least for some days, with the halogenated cresols.

The following methods of controlling lice appear to be the most efficient.

Mechanical Methods.

The use of an ordinary brush and comb probably crushes a considerable number of eggs of the head louse. But it is far more efficient to use a very fine metal comb, such as that specially made for the purpose by Messrs. Sacker: the teeth are so close together that the nits are always crushed as the hairs pass through the comb, and lice including small larvae are combed out. An objection to this method is that it is necessary to work over the whole head with great care, and to give particular attention to the base of the hair close to the scalp. But in careful hands the method is excellent; a good point is that no liquid application is required.

An ordinary comb is also useful as a means of applying a liquid insecticide to all parts of the scalp.

People continue to use vinegar, or dilute acetic acid, believing that they loosen the attachment of the nit to the hair, and render it easy to comb them out. It is now more than 20 years since Nuttall showed that this is not so.

Effects of Temperature.

The following high temperatures are the lowest that are fatal, on exposures for the periods stated.

\[
\begin{array}{ccc}
\text{Eggs} & 60 & 140 \text{ min.} \\
\text{Lice} & 52 & 125 \text{ min.} \\
55 & 131 & 10 \\
50 & 122 & 20 \\
49 & 120 & 25 \\
\end{array}
\]

\[
\begin{array}{ccc}
\text{Nuttall, 1918}. \\
\text{Buxton, unpublished; and Millar, 1932.}
\end{array}
\]

For short exposures such as those it is not necessary to take account of humidity, for the evaporation from lice or eggs is insufficient to have any effect on the thermal data point. The above figures are determined precisely in the laboratory. In practice it is essential that all parts of the garments treated should reach the lethal temperature. In many types of disinfectors, heat is not evenly or quickly distributed through the load.

As the thermal death point is relatively low, lice and eggs can be killed if garments or blankets are spread out in the sun in hot bright climates; in the tropics and subtropics the surface of bare earth rises to 60° C. (140° F.), and...
occasionally 70° C. (158° F.) at and after noon. The conditions to which cotton garments are exposed in ordinary laundry practice are sufficient to kill lice and eggs, but woollens are not generally exposed to temperatures high enough to ensure this.

For practical reasons one occasionally wants to know the effect of moderate temperatures on the eggs or the fasting louse. The available facts about exposure to constant temperatures are as follows:

<table>
<thead>
<tr>
<th>° C.</th>
<th>° F.</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>102</td>
<td>fatal in 24 hours.</td>
</tr>
<tr>
<td>30</td>
<td>86</td>
<td>2 days, or less.</td>
</tr>
<tr>
<td>20-30</td>
<td>68-86</td>
<td>4-5</td>
</tr>
<tr>
<td>10-20</td>
<td>50-68</td>
<td>7</td>
</tr>
<tr>
<td>0-10</td>
<td>32-50</td>
<td>9</td>
</tr>
</tbody>
</table>

**Eggs.**

<table>
<thead>
<tr>
<th>° C.</th>
<th>° F.</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>104</td>
<td>none hatch.</td>
</tr>
<tr>
<td>37</td>
<td>98</td>
<td>hatch in 6 days (rarely 5 or 7).</td>
</tr>
<tr>
<td>30</td>
<td>86</td>
<td>8-9 days (rarely 7-11).</td>
</tr>
<tr>
<td>25</td>
<td>77</td>
<td>16 days.</td>
</tr>
<tr>
<td>22</td>
<td>71</td>
<td>cannot hatch, but not killed.</td>
</tr>
</tbody>
</table>

From the above it appears that one could give 10 days as the outside limit for survival of fasting lice or larvae. Eggs kept at or below 22° C. (71° F.) cannot hatch, but they live at much lower temperatures: for instance, a small proportion survive 7 days at 5° C. (41° F.), and if the temperature rises above 22° C. (71° F.) such eggs will hatch. We do not yet know how long eggs can survive at temperatures below the hatching threshold. I have had larvae emerge as late as the 24th day from a garment which was kept at laboratory temperature and warmed daily. Had we kept it at a slightly lower temperature and warmed it less often we might perhaps have had hatchings up to a month, which is generally regarded as the outside limit. It is a matter of some practical importance to realize that the storage of garments in itself rids them of lice at all stages, and that in hot countries this will be successful in a couple of weeks, because the rate of metabolism of the fasting lice and the rate of development of the eggs is greater at the high temperatures prevailing.

Unusually low temperatures are sometimes used (for instance in the winter of Russia or North China) to kill lice. As to the lice, it seems that 5° to 8° C. (41° to 46° F.) is not harmful, and that they survive —° C. (19° F.) for 36 hours, and —10° C. (14° F.) for 10 hours. But they are killed by —10° C. (14° F.) to —14° C. (6° F.) in about 12 hours, by —17° C. (1° F.) in 2 hours, and —23° C. (—13° F.) in 1 hour. As to eggs, —17° C. (1° F.) is fatal in 2 hours (Chung, 1907).

**Contact insecticides.**

The phrase "contact insecticide" is convenient: it implies a substance (liquid or occasionally solid) which kills an insect after coming in actual contact with it. As we have little precise knowledge about the mode of action of these substances, it is sometimes difficult to know what may be included in the term. The contact insecticides may be used against head or body lice. When they are used on the head it is generally advisable to cover it with a bathing cap (or towel) for an hour, and then wash the hair.

(a) **Cresols and Phenols.**

Two per cent. cresol in water kills head or body lice and their nits. It may be applied to the scalp, but not for longer than 20 minutes. Infested undergarments may also be dropped into it, and it may be used for lathering the body: for this purpose a convenient formula is Jeyes' fluid 1 ½ oz. (50 c.c.), soft soap 1 ½ lb. (700 grammes), water 10 gallons (45 litres).

It is probable that some commercial cresols are more efficient, or more readily saponified, than others.

It seems that certain substitution-products of cresol have great value. They are toxic to lice, hardly irritating to the skin (though the smell is unpleasant), and they may be used to impregnate underclothing, which will kill lice introduced into it even after it has been worn several days: for instance, a garment impregnated with dibromometacresol killed all lice introduced into it up to 5 days later, and killed some as much as 10 days later. (Moore and Herschfield, 1919).

A powder made of talc 20 grammes, cresoite 1 c.c. and sulphar 0-5 gramme is recommended for application inside garments of those exposed to body lice. As sulphur has sometimes proved disappointing, one wonders whether it is a necessary constituent.

Phenol (carbolic acid) diluted 1:40 in water is also recommended against head lice. The patient lies on the back, with the head over the edge of a table, and the liquid is poured through the hair, caught in a basin, and poured through again till all the hair is saturated. It is then lightly squeezed, tied up in a towel for 1 to 2 hours, and then washed. The treatment kills eggs as well as lice.

(b) **Simple organic poisons.**

Ordinary paraffin or kerosene (as burnt in lamps) will kill lice and their eggs. It can hardly be used on the scalp for it may irritate the skin. If it is diluted with an equal quantity of olive oil, cottonseed oil, etc., kerosene remains efficient and is much less irritating; the minimum concentration of kerosene which is
necessary has not yet been worked out. One does not know which of the innumerable substances present in kerosene is insecticidal, and it is certain that their proportions differ greatly in different types of oil; it is therefore not surprising that one or two failures with particular types of kerosene have been recorded. A modified paraffin method is used in several London boroughs against head lice. A mixture is made of paraffin (kerosene) 74 per cent., cottonseed oil 20 per cent., tar oil (wood tar) 5 per cent., oil of lemon grass 1 per cent. It appears that the tar oil materially increases the insecticidal power of the application. Those who use this formula emphasize the necessity for very thorough combing after application, which should not be necessary if the liquid is a satisfactory insecticide. One could probably increase the efficiency of any of these applications by substituting petrol for some of the paraffin.

An emulsion of kerosene in soap and water is sometimes valuable, for killing lice in garments, or for the treatment of floors and walls after a room has been occupied by very heavily infested men (for instance under such conditions as prevailed in Serbia in 1915). This emulsion is made by dissolving 3 parts by weight of soft soap in 15 parts of water. Kerosene (paraffin) such as is burnt in lamps is then added slowly with constant stirring, until no more will emulsify; the total quantity depends on the particular type of paraffin employed, but it may greatly exceed the quantity of soap and water. This concentrated emulsion, which keeps for long periods, should be stored in bottles, and diluted 1 : 20 for use. It is a good general insecticide, cheap and harmless to man and domestic animals.

"Vermijeli," used in the war of 1914-18, was an emulsion of mineral oils in soft soap. It was stated to kill lice and eggs by contact, and to prevent infestation. The results were inconsistent, and some authorities regarded it as useless. It should not be difficult to produce a similar emulsion, of more certain insecticidal powers, if there is a need for it.

Xylol (xylo) is valuable: an ointment containing 25 per cent. commercial xylol in vaseline and lanoline has been recommended and is said not to burn the skin. It must be well rubbed into all hairy parts. 25 per cent. petrol in vaseline is also used. The risk of fire is evident.

It seems almost certain that the liquids used in dry cleaning garments (benzene, carbon tetrachloride, volatile cuts of paraffin) would destroy all lice and eggs.

(c) Vegetable Oils.

Many essential oils (sassafras, eucalyptus, etc., and also rectified oil of turpentine) have been recommended for use on the head, partly owing to an indefinite idea that their smells are healthy and may act as repellents. It appears that essential oils act as stupefying agents, so that lice capable of recovery are apt to be regarded as dead; but it seems that many of them are undoubtedly valuable provided they come into actual contact with louse or egg. (Nuttall, 1918, p. 504). One may advantageously emulsify one of these oils in water containing bile salts, so as to increase the wetting power of the emulsion, and therefore its power of killing eggs, and lice. After trying a number of formulae, Perrins (1922) recommends sodium taurocholate 10 grammes, oil of eucalyptus 50 c.c., water 1 litre. The salt is dissolved first, the oil is added and the whole shaken. This formula only gave 23 per cent. of cures on a single application. In general, essential oils are not cheap; a further objection is that they soil clothes and bedding.

In many parts of the tropics people anoint the head with coconut oil, which has no unfavourable effect on the lice, though it frequently prevents the eggs from hatching by gumming the cap down, so that the larva never escapes from the shell. But in spite of this a number hatch sufficient to maintain an infestation, which is often heavy where men wear the hair long, even though they frequently wash it and apply coconut oil. It seems probable that the addition of a small proportion of kerosene would increase the insecticidal power of the coconut oil.

(d) Other Vegetable Insecticides.

It seems that Derris and other plants containing rozenone have never been tested on Pediculus, which is not to our credit. They might prove to be of great value as washes: a few recent tests with a proprietary powder in which the active material is powdered Derris root, have been disappointing. These materials are already extensively used in veterinary practice against the lice of domestic animals (Haematopinus, etc.); a proprietary powder of which the active ingredient is Derris root kills lice (Polyplax) on laboratory mice.

Pyrethrum powder has been tested and found unsatisfactory (Nuttall, 1918).

A fresh watery infusion of quassia chips is often used, and reputed to be satisfactory. Many other plant compounds are in use, but their value cannot be assessed. Many authors recommend alcoholic extracts and tinctures (including such poisonous plants as Aconitum) without enquiring whether the alcohol alone would not be effective.

Fumigants.

(a) Sulphur Dioxide.

Sulphur dioxide is not generally a good insecticide and should not be used on damp clothes or blankets because of its bleaching qualities. It was widely used in the early years of the last war, an error which need not be repeated. But it is a valuable and cheap means of controlling the head louse, and it has been in use for 20 years in certain German cities. The scalp is covered with a tightly fitting rubber cap, provided with inlet and outlet pipes through which the gas is passed; 4 per cent. by volume in air is used, and lower concentrations are not efficient. After 12 to 15 minutes the gas is sucked out, and it is found that all lice and eggs are dead. As the cap includes the ears it is well to block them with oiled cotton wool, otherwise a person with a perforation of the drum
will cough violently (LENZ, 1921). The gas has also a curative effect on the eczema which so often accompanies head lice.

(b) Hydrocyanic Acid.

There is no doubt of the value of HCN against lice and their eggs in blankets or garments, but authorities differ about dosage. Lustin found an initial concentration of 0.1 per cent. HCN, which fell to a third at the end of the 2 hours exposure, to be sufficient to kill lice and eggs. Other authorities (for instance, NEWSTEAD and his colleagues) have reported inconsistent results with twice the above concentration and the same period of exposure. The differences are probably due mainly to differences in temperature; at higher temperatures fumigants are more efficient, for the respiratory rate of insects and eggs is higher and adsorption of gas on the surface of the textiles is less. It seems therefore that the necessary concentration should be determined on the spot and with the actual apparatus which is to be used.

(c) Organic Fumigants.

Many organic fumigants are now in use, against domestic insects and those which infest grain, and much is known about some of them. Very few of them have been tested on Pediculus; they might be valuable agents for controlling body lice in garments.

Carbon bisulphide and carbon tetrachloride have been used against body lice in garments under field conditions. The lethal concentrations are not yet defined but both are reported to give valuable results. Chlordane is apparently very toxic to lice and eggs. It is not very volatile, and at ordinary temperatures must be sprayed on a hot plate, or poured on hot bricks, to secure vaporisation. It is extremely irritating and dangerous to man, and the operator must use a gas mask. Eggs, which are more resistant than lice, are killed by 10 c.c. in 2-5 cu. ft. in 30 minutes (MOORE and HIRSCHFELDER, 1919).

(d) Naphthalene.

As it is established that the vapour of naphthalene will kill lice we should regard it as a fumigant, though it is possible that the solid may also act as a contact poison and the vapour as a repellent. Use has been made of naphthalene by sprinkling it on infested garments which were placed in a dust-bin with a good lid and found next day to be free of lice. It has also been used to kill lice on the body, a small bog being hung under the clothes. The experiments reported by NUTTALL (1918, p. 538) show that, when used in this way, it does not invariably kill all lice; but it is certainly a useful palliative when men cannot be more radically treated. Considerations brought forward by MOORE and HIRSCHFELDER (1919) point to the conclusion that the atmosphere beneath the clothes is unlikely to be more than 15 to 20 per cent. saturated with the vapour.

Naphthalene is a distillation product of coke and crystallizes out from some of the higher cuts; it is then separated from the accompanying liquids by "whizing" (centrifuging). It is known that the unwhized product has greater insecticidal powers than pure naphthalene; the matter clearly demands fuller study.

One way of employing naphthalene is as a powder rubbed on the inner surface of garments. A common preparation is NCI powder (naphthalene 96 parts, creosote 2, isoform 2), which is more lethal than naphthalene, but rather moist to apply; 2 ounces per man should be rubbed into the shirt and undergarments once a week. According to MOORE and HIRSCHFELDER (1919), an equally effective, drier and cheaper powder is made from tale 20 grammes, naphthalene 0.5 gramme, isoform 0.5 gramme, creosote 1 c.c. Naphthalene is irritating to some skins, particularly if it accumulates in folds. For this reason the powder containing a high proportion of tale might well be preferable.

REPELLENTS.

An effective repellent would be extremely valuable; it would tend to reduce lousiness among men on active service, and lessen the risks to which nursing and medical staffs are exposed when they deal with louse-carried epidemics. Certain vapours (essential oils, naphthalene) appear to have a repellent action, though they do not debar a hungry louse from feeding.

It seems unlikely that we shall be able to make much use of repellents till a full study has been made of the behaviour of the louse, and in particular of the factors which guide it towards man, and cause it to commence to feed. When these have been defined, and their relative importance assessed, it may become possible to make good use of repellents.

REFERENCES.


MELLANDER, K. (1922). The conditions of temperature and humidity of the air between the skin and shirt of man. Ibid., 32, 200-274.


**Discussion.**

**The President (Sir Rickard Christopher):** I am sure you will wish me to thank Professor Buxton for the very instructive and clearly set out paper he has given us to-night, with just the kind of data necessary as a basis for preventive measures against lice. He has not read us the whole paper, but most of you will have had advance copies and will have been able to judge the kind of work that has been done. What Professor Buxton has given us is much more than merely an account of what is known about lice, because he has himself been working for some time on the subject and has been able to add to existing knowledge many concise and definite data on the length of life, duration of the different stages, reaction to temperature and so on. All this makes the putting into practice of actual measures of prevention much simpler. When speaking he has not gone into great detail about the second part of the paper; but it seems to me that a part that a number of you may quite well be interested in, namely the actual measures of prevention. I hope that in the discussion some you will be able to add something on that side of the question.

For instance, Professor Buxton refers to the use of kerosene emulsion: that is dismissed in one small paragraph but it is quite an important method, and there is much more that might be said about it than could appear in such a brief summary as the one Professor Buxton has given us.

**Dr. V. B. Wigglesworth (in opening the Discussion):** Professor Buxton has said that what we most need at the present time is more information about the factors which determine the fluctuations in louse populations and some simple improved methods of louse control. But there is another important aspect of the louse problem and that is the psychology of the louse. At the suggestion of Professor Buxton I have recently started an investigation on the behaviour of the louse. It is perfectly true of course that such an investigation will not help us directly to control the louse. But everyone who has to deal with lice, whether from the standpoint of control or as vectors of disease, is continually asking himself questions on this subject—questions which as a rule he is unable to answer. For example, it is often said—and there seems to be a good deal of evidence in support of the belief—that lice leave a patient with fever. Now, is that true? And if that is so is it the high temperature which repels them, or does it only happen when the skin is moist with sweat or when the sweat is fermenting? In a classic communication before this Society,* with which I am sure everyone here must be already familiar, Sir William Mac Arthur, the present Director-General of the A.M.S., described in vivid terms the finding of the mortal remains of St. Thomas à Becket in December, 1170. He recalled, as you will remember, how the body of the Archbishop lay all night in the Cathedral, and how in the morning, when it was being piously

The figures I have given are very disturbing. If at one time 48 per cent. of children are lousy (June) then during the year the majority must at one time or another be infested.

These results were obtained in a hospital. Every child on admission is examined carefully and treated immediately to remove any possibility of spread of the insects. The results differ considerably from the findings of the school medical service. Among children of elementary school age they find only 1-3 per cent. of the boys and 4.7 per cent. of the girls were "unclean," and of these children only 0.1 per cent. bore actual live lice. These figures are so much lower than those obtained in the hospital that it appears certain that in the school examinations the majority of the infestations must be missed. The degree of infestation observed in many hospital cases shows that it is long established and has not developed on a sick child unable to take care of itself.

I find that head lice may be treated very simply with a mixture of three parts of spirit with one of water. This fluid, which is practically 70 per cent. alcohol, does not harm the skin, is not readily inflammable, but kills both lice and nits. It has been successfully used on sick children in hospital, where more drastic methods are not always practicable, and could be extended for use on other children. The head is wetted thoroughly with the liquid (it should be kept out of the eyes), a cloth wetted with the same mixture is put over the hair and the head covered with a rubber cap. After an hour the coverings can be removed and the head allowed to dry. Washing and combing is desirable but not essential. At the temperature of the head the alcohol kills all stages in 1 hour, including the resistant nits. If clothes at room temperature are treated with alcohol a longer exposure (say 3 hours) should be given.

Dr. E. Muir: I have only a short remark to make. Professor Buxton, in his paper (page 377) mentions among vegetable oils the use of cocoa nut oil in some parts of India. He does not mention mustard oil which is used, I think, almost exclusively in Bengal. Now in Bengal lice are, in my experience, exceedingly uncommon among healthy people, who invariably bathe daily and rub mustard oil into the scalp and all over the body. When, however, they are ill for a considerable time with malaria or other diseases, lice become common, and it is said that this is the result of refraining from the use of mustard oil. I suggest that the insecticidal value of this substance be tested.

Major H. C. Brown: I would like to ask Professor Buxton what his views are regarding the possibility of using deterrents by the mouth. When I was investigating an epidemic of relapsing fever in the United Provinces in India in 1913, I observed 132 contacts in a heavily infected village for a period of
2 months; 18 per cent. of these became infected with relapsing fever. To forty-nine other unselected contacts I gave sulphur, 5 grains in pill form every day, and during the same period only 8 per cent. became infected.

I am perfectly aware that these results are not significant from a statistical standpoint, but I claim that they are suggestive.

It might be argued that because men do not get so much malaria after the administration of prophylactic quinine the mosquitoes have not bitten the individuals, but it is well known that sulphur, taken by the mouth, is excreted by the skin, whereas there is no evidence that quinine is excreted in this way.

I should, therefore, like to ask Professor Buxton whether he thinks that further work on these lines is indicated.

Dr. G. Macdonald: May I thank Professor Buxton for his fascinating account of the bionomics of the louse community, and for his construction of a life table, which is not only of interest but of supreme importance if their control is to be achieved. I am sorry that he was not able to include an account of the relationship of their numerical prevalence and their control.

It is apparent from the first part of his paper that there are great variations in the numbers of lice on individuals, and therefore in the chance of their transference to others. In the presence of low infestations transference from man to man is relatively rare, the majority of the population can keep themselves free from lice, and louse-borne diseases are rare. Once a certain threshold value in the infestation rate is passed, transference from man to man becomes very common, with associated lousiness of the entire population and the risk of such diseases. It seems probable to me that this threshold is reached when a certain, possibly small, proportion of the population have a high infestation rate, and conversely that the prevention of louse-borne diseases does not demand the absolute control of all lice, but the prevention of heavy infestations.

I would be grateful if Professor Buxton could give us some indication, if he agrees, of what this threshold is, either in terms of the population infested or the number of lice on individuals.

Dr. Llewellyn Lloyd (Leeds): There are one or two points to which I should like to refer. The first is the importance of temperature in treatment. I do not mean temperature when used as a killing agent but when gases and solutions are used. In his paper Professor Buxton remarks on the very different accounts that have been given of the effects when hydrocyanic acid gas is used as a toxic agent, and suggests this may be due to different temperatures being employed. That is probably the case. When A. W. Baco and I were investigating the effects of solutions of lye and cresol on lice, we found that at temperatures below 100° F. a 2 per cent. solution gave a complete kill with the eggs but not a complete kill with the lice, if the garments were immersed for about half an hour and then drained off. If the lice were left in the undrained garment and the substance allowed to dry on the cloth, a complete kill was effected. If the temperature was raised to 100° F. with the same exposure there was a complete kill of the lice in either case.* There seems to be something critical to the louse in the temperature of 100° F. It is shown in the case of solutions and probably in the case of gases and in the very marked activity which they develop on the fevered skin.

Dr. Wigglesworth is investigating that matter and is going to give us some more scientific information about it; but it is a revelation to see the movements of lice when they are transferred on to the fevered skin as opposed to their movements on the normal cool skin. They get exceedingly uncomfortable when the temperature is two or three degrees above 100° F. and I think that is a very important point to remember when treating with either gases or solutions. In lecturing to my students about the bedbug and its control by gassing, I suggest trying to get the bed bug painted before gassing it, and that is a good principle with the louse.

The second point is the treatment with an ointment composed of soft soap and naphthalene. It is too irritating for most skins. Professor Buxton remarks that the effect of this substance needs further investigation. Naphthalene is sold in four grades: (1) the pure sublimed substance, (2) crude naphthalene, dark in colour owing to the presence of carbon but with very little of the tarry acids present, (3) the drained salts, or whizzed naphthalene, which is damp and pink and rather oily to the feel and contains a small quantity of cresol and phenol and (4) the undrained salts, or unwizzed naphthalene, which contains a considerable amount of phenol. The vendors will not guarantee the strength of any except the sublimed grade. Shortly after the last war, with the question of whizzed and unwizzed naphthalene very much in mind, I was working on the greenhouse white fly. Naphthalene was being sold as a fumigant for this insect. I tested the pure naphthalene as a fumigant for the fly and got hardly any killing at all. Then I tested the whizzed variety containing a certain amount of tarry acids and got a fairly good kill. Cresol and phenol separately, and together, were then tried and these gave about a 75 per cent. kill. But when a little pure naphthalene was added to either cresol or phenol the kill was about 100 per cent.† That seems to show a very complicated problem in the effect of the various grades of naphthalene when used as fumigants or deterrents for insects. It may be that in some way the vapour of the very volatile naphthalene enables the vapours of the more toxic substances to diffuse more readily in the fumigating chamber than if they are present alone.

Sir Aldo Castellani: First of all I should like to congratulate Professor Buxton on his most interesting paper. It is always a great pleasure to listen to an expert. I have had experience of lice in two wars—in the Great War * Baco, A. W. & Lloyd, LL. (1918). Brit. med. J., 1, 479.
(1919). Ibid., 2, 704.
from 1915-18 and in the recent Ethiopian Campaign. During the Great War lice gave a tremendous lot of trouble in the Balkans where I was. During the Ethiopian Campaign lice gave practically no trouble whatever. What was the reason? With regard to Somalia I think the reason was that the uniform worn by the Italian troops consisted of only a pair of shorts and a big topee: there was therefore no room for lice; while the Abyssinian troops were wearing all sorts of garments and were swarming with lice. Hence a very large number of cases of typhus and relapsing fever in the Abyssinian Army, and no typhus and practically no relapsing fever in the Italian Army. On the Northern Front, while it was very hot during the day it was rather cold in the late afternoon and at night, and the troops had therefore to wear ordinary khaki uniform and some cases of louse infestation occurred, although very few. The psychological lastic measures were the shower bath every other day and the use of a powder somewhat similar to one introduced years ago with good results in other armies, consisting of naphthalene and pyrethrum. Of course, naphthalene has a less deleterious effect on lice than certain other substances, but it is cheap and it does not usually irritate the skin. With regard to pyrethrum, it has practically no effect on lice but it has, as we all know, a lethal effect on bed bugs and ticks.

Professor Buxton very rightly, I think, called attention to the fact that we medical men still go on using in our fight against lice certain drugs and certain chemicals which were introduced into the practice of medicine hundreds of years ago, and which are really dangerous drugs. I quite agree with him. After all, we are now in possession of simple and efficacious methods. We have just heard that the application of simple 70 per cent. alcohol to the scalp kills lice. May I remind you of another method which is extremely simple. Just rub plenty of plain vaseline into the scalp, and you will get practically the same effect as by rubbing in ointments containing mercury or other powerful drugs. As impetiginous lesions, however, are very common it is advisable to add to the vaseline 1 per cent. white precipitate or yellow precipitate, or 1 per cent. carbolic acid.

Colonel W. Byam: I would like to ask Professor Buxton whether when working with these substances for the destruction of lice he is also taking into account the effects on the excreta of lice, because it has been shown with regard to the louse-borne disease which was most important in the last war, namely trench fever, that the excreta were infinitely more important in the spread of the disease than the insect itself, and that the excreta remained dangerous and capable of spreading infection for long periods after the lice had disappeared from garments and blankets. Minute quantities of the excreta were sufficient to cause infection, and what was a suitable measure for the removal of lice was not necessarily effective when it came to making blankets and garments safe for future use. I think that when work is done on fumigation and destruction of lice, it is important the whole time to take that matter into consideration.

Excreta infect the body through the eyes as well as through abrasions of the skin, and it is possible for people to suffer from louse-borne diseases who have never actually had a louse upon them at all. If there are lice to be destroyed there must be excreta to disinfect.

Mr. G. H. Stuart-Bunyan: I rise with great trepidation because I am a layman, but I have been a magistrate for 25 years and have had to deal with lousy children. When first a magistrate I came to the conclusion that the working classes regarded the louse as a friend who sticketh closer than a brother. Since then with more experience I have come to the conclusion that among the reasons why we are troubled with lice in this country is the lack of education among local authorities, parents and children. Time after time I have had cases before me where the parents have been warned nine or ten times before being brought to Court, and have pointed out that it is far too long. Parents do not seem to know very much about these things, so may I repeat with great respect that the best way to kill lice is to educate local authorities, parents and children.

The President: Professor Buxton has now to close the discussion. Before he does so I would like to ask him—I do not want him to go into any lengthy details—whether in the course of his work with the louse he has arrived at any general indication of the best measures for controlling lice, especially in clothing, which I suppose is the most important thing of all. Lice are known to be very susceptible to heat and also to disinfectants such as cresol. Has he any particular method, however, which he considers is the line the practical worker should endeavour mainly to follow up? At present we are faced with a large number of remedies, including mercurial ointment etc., which all seem to be given equal importance, but probably there are one or two things which are really the most suitable.

Professor Buxton (in reply): We may congratulate ourselves on the discussion we have had, which has provoked a number of interesting things. They will appear in print in our Transactions and I need not deal with most of them now.

The communication from Dr. Kenneth Mellanby about his northern city was very disturbing, and I don't think it is exceptional; the official figure for lice in children was 1 per cent., but the actual figure on admission to hospital was about 20 per cent. During the last three months general experience with evaucities has given ground for thinking that some such figure may be common in many parts of the community, so that there seems to be urgent need on the civil side, as well as the military, to devise better methods of control and bring those methods into use.
As to mustard oil in Bengal, and the heavy infestation of those who were sick: the facts are possibly to be explained in a different way. It may be that people who are chronically sick and in a bad state of nutrition are more readily attacked by lice, irrespective of the mustard oil. There is a recent American paper* on the louse (Polyplax) that attacks laboratory mice. It is shown that mice brought up with a reduced ration of vitamin A can be readily infested by Polyplax on them and the infestation maintains itself; but if you give a full diet the mice do not acquire a natural infestation and you cannot establish an infestation by putting the lice on them. So that in human infestations with Pediculus, there may be a large nutritional factor about which we know nothing.

As to Dr. MacGonigal's question about the threshold beyond which a clean person runs a serious risk of becoming infected, I do not think we have any information; but it would not be difficult to find out, if a number of people would collect fairly precise numerical facts. It does not seem to be an inherently difficult problem.

Dr. Lloyd mentioned the matter of skin temperature of fever patients and spoke of the louse dashing about on the skin of the sufferer. We should remember that although a man's temperature as taken by the clinical thermometer may be up by only three or four Fahrenheit degrees, possibly the skin temperature is up a great deal more, because the patient may be getting rid of the heat through his skin.

As to Colonel Byam's point about excreta: it is certainly true that we must not forget the importance of the faeces of lice as the channel of transmission of the Rickettsia of trench fever and typhus. But I doubt whether we should be wise to give it attention when trying to find ways of killing the insect. It seems highly improbable that methods successful with the insect would disinfect the faeces. Cresols might do both, but it is improbable that most insecticides would be effective against the organisms in the dried faeces. Personally, I think that the attack on typhus and trench fever is best conducted by controlling the lice rather than by attempting to disinfect their faeces.

As to the importance of propaganda, information and teaching, we are all heartily in agreement: it is most unfortunate that infestations of lice and bed bugs are hardly allowed to be mentioned in this country.

As to which is the best way of controlling the louse, it depends on a number of circumstances. The text gives a short account of several methods which are reliable. But there are two very promising things which should be investigated. The halogenated cresols might well make a person uninfestable for a period, though these substances have an unpleasant smell. They could be used in the open air on active service, even if they proved unacceptable in civil life. The other thing to look into is the possibility of dealing with clothes and blankets in bulk by organic fumigants. The whole subject of insecticides capable of killing the louse should have been taken in hand some years ago.


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