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RECENT WORK ON THE LOUSE (*Pediculus humanus L.*)

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The two varieties of the human louse, *capitis* and *corporis*, are very similar in their anatomy and physiology. But the difference in their habits, which induces one form to inhabit the scalp and the other to live amongst the underwear, results in two quite separate problems of public health. These problems are most distinct in the more modern countries, where improved standards of hygiene (especially the regular laundering of underwear) have relegated the body-lice to a minor problem in peace time. The people infested by it are mainly vagrants; transitory inhabitants of the casual ward or common lodging-house. They are often elderly and sometimes infirm.

The head-lice, on the other hand, is disturbingly common in some industrial areas. It attacks quite a different section of the population, mainly girls and young women, often of quite cleanly habits. Sometimes, indeed, the parasite has benefited from a misguided vanity, when regular combing of the hair has been neglected in order to preserve the set of a "permanent wave"!

With the advent of war, the status of the two problems was changed. The destruction of towns, the disturbance of amenities, famines and mass movements of people caused by war have always given the body-lice a chance to spread rapidly and cause epidemics of typhus and other rickettsial diseases. It appears that, under experimental conditions, both races of louse can transmit typhus; but the major epidemics of the past have all been associated with widespread *corporis* infestation. The almost complete absence of typhus from north-western Europe, where *capitis* is still comparatively frequent, is another ground for assigning to *corporis* the major role in the spread of the disease.

A. CONTROL OF THE BODY-LOUSE: PREVENTION OF TYPHUS

Since the danger of typhus is greatly increased by war, much of the research on the subject has been done during the two great wars of this century. During the war of 1914-1918, the researches of Bacot, Kellin, Nuttall and others, largely elucidated the biology of the louse; during the recent conflict, most of the progress has been towards securing effective control of the parasite. Recent papers on the biology of lice include an account of their sensory physiology and behaviour (Wigglesworth, 1941) and studies on the influence of nutrition and temperature on their longevity and oviposition (Leeson, 1941a; 1941b; Haddow, 1941). The advances in control-measures will concern us for the rest of this article.

One of the most valuable innovations is the development of anti-typhus inoculation on a mass scale. The various vaccines have given evidence of protection from the disease and they certainly make it much less severe. It is, therefore, much safer to attack a typhus epidemic, because all medical and sanitary staff can be immunized. Even whole armies

exposed to special risk can be treated; the Allied soldiers in Naples escaped the disease partly for this reason. Inoculation, however, is too slow to check a really large epidemic and, so far, there appear to be no drugs of therapeutic benefit by the time that a patient shows symptoms of typhus (Andrewes, King, van den Ende & Walker, 1944). Therefore, we must still rely, to a large extent, on attacking lousiness to quell an epidemic.

In all the great wars of the past, the soldiers became chronically lousy and were usually the victims of terrible typhus epidemics which sometimes paralysed whole armies. But now that the strategic importance of disease is realized, the hygiene of troops has been greatly improved and military epidemics are much less likely. So the advances in methods of controlling the louse are most likely to benefit civilians in areas devastated by war. The halting of the Naples epidemic was the first example of this.

Experimental Methods

To find new methods of controlling the louse, it is almost essential to keep a culture for laboratory experiments. Body-lice can be bred satisfactorily only by allowing them to feed regularly on man; though a recent American paper proves that they can be reared, with difficulty, on rabbits (Davis & Hansens, 1945). In England we employ the method of breeding them in small boxes with gauze bottoms through which the lice can feed. These are firmly attached to the skin of the leg during the day, which gives the lice opportunity to feed at will during 12 to 16 hours out of the 24 (Buxton, 1940c). Similar boxes, but made of metal so that they can be thoroughly cleansed, are used for experiments. In a method employed in America, the lice are kept in an incubator at 30° C. and fed twice daily on men employed for the purpose. This procedure is slightly more artificial than ours, but a very large culture of lice can be maintained by it, for it is stated that as many as 40,000 lice can be fed on the back of one man without great discomfort (Culpepper, 1944).

Before new insecticides can be recommended, practical trials are necessary. In Britain we have done tests on naturally-infested men, living their normal lives, and only coming at intervals for inspection. Usually only one garment would be treated, which implies a fairly severe test, for the men were constantly exposed to re-infestation from other garments and from their associates and surroundings (Craufurd-Benson & MacLeod, 1946; Busvine, 1945). Similar field-trials were done under semi-tropical conditions with native labour gangs in Egypt (Buxton, unpublished) and in jails in Algiers (Craufurd-Benson, unpublished).

In the course of these trials, opportunities arose for studies of body-lice populations under natural conditions. A great deal was learnt about the distribution of lice among the undergarments, the proportions of the different stages present, and the fluctuations of numbers of lice which may occur on

individual hosts over short periods (MacLeod & Craufurd-Benson, 1941b). Examinations of beds in common lodging-houses revealed the numbers of lice to be expected in the beds after infested men had slept in them (MacLeod & Craufurd-Benson, 1941a), and some simple experiments were made to trace the meanderings of lice among the clothes (Busvine, 1944a).

Much of the American fieldwork was less naturalistic, since it was done with artificially-infested men (Davis & Wheeler, 1944; Jones, McAlister, Bushland & Knippling, 1944). This has certainly the advantage of convenience, for much time and trouble are wasted with naturally-infested vagrants by frequent disappearances during the course of the experiment. One group of Americans, however, studied the difficulties of control under entirely natural conditions by attempting to eradicate lice completely from village communities in Mexico (Davis, Juvera & Lira, 1944).

The final testing-grounds for anti-lice measures are, of course, the sites of actual epidemics of lousiness, especially with typhus present. Most publicized of these practical demonstrations of modern delousing methods was the attack on the outbreak of typhus in Naples in 1943-44. Other successful campaigns have been accomplished by the Russians in Moscow (winters 1942 and 1943), and in Bessarabia, and by the French in Algeria (Sergeant & Beguet, 1944).

Advances in Control Methods

Hot-air Disinfestors

Disinfestation of garments by hot air is a convenient method which was widely employed during the previous war. Its advantages are ease, cheapness and safety, and simple hot-air disinfestors (such as the Orr Hut and the Serbian Barrel) can easily be improvised in the field. A recent Russian paper describes further easily-constructed disinfestors of this type (Amchislavski, 1942). By bacteriological standards, lice are fairly easy to kill by heat, for the most resistant stage (the egg) is destroyed by 5 minutes at 55° C. or 45 minutes at 50° C. (Buxton, 1940c). However, the penetration of heat through thick garments is slow, and the method is unreliable unless rather a long exposure is used. In practice it is necessary to hang up garments in a room with an air-temperature of 70° C. for an hour (Busvine, 1944b).

Moving hot air is much more efficient in heating fabrics than still air; also it prevents the hot air from accumulating at the top of the chamber. Early in the war a portable disinfestor with an air circulatory system was designed for the army, which disinfests a large load of clothes or bedding in half an hour (Richmond, 1940). The civil authorities, no less than the army, were alive to the greater efficiency of circulating hot-air disinfestors, and some very large plants were built to disinfest bedding from air-raid shelters (*Municipal Engineering*, 1945).

Fumigation

In the epidemics in eastern Europe after the 1914-18 war, the fumigant most commonly used for delousing was hydrogen cyanide. This is, indeed, a highly toxic gas with good penetrating powers. It has been used extensively for house-fumigation against bed-bugs in recent years, and the same procedure has been shown to be effective for destroying lice in a building (e.g. after removal of a typhus patient) (Busvine, 1943a). But, for the general delousing of clothing, cyanide is very dangerous, owing to the readiness with which it is absorbed by fabric and subsequently driven off by the warmth of the body. Therefore, a number of other possible fumigants have been examined for effectiveness and freedom from residue (David, 1944a; 1944b). Some new substances have been recommended which can safely be used for disinfesting garments: methyl allyl chloride and ethyl formate in England (David, 1943); methyl bromide in America (Latta & Yeomans, 1943); methyl formate in Russia (Evreinova, Pozin, Sobolev, Tregubov, Khovanskaya & Fedder, 1942) and trichloroacetonitrile in Germany (Rose, 1943). Simple methods were developed for use in the field; clothing is put into a metal bin or a reasonably gas-proof bag and sprinkled with liquid fumigant. It was found that solid fumigants such as naphthalene and paradichlorobenzene were too slow in action to be effective by this method; they required very long exposures (over 24 hours) to destroy lice and nits (Busvine, 1943a).

Low Temperature

Insects are generally rather resistant to low temperature, so that disinfestation by refrigeration is scarcely ever considered feasible. However, epidemics of louse-borne typhus are quite liable to occur in parts of Europe and Asia where the outdoor winter temperature at night drops to very low levels. Accordingly, the possibility of utilizing these natural low temperatures for delousing was investigated (Busvine, 1944b). It was found that exposure overnight to a temperature of -15° C. or lower could be relied upon to destroy all lice and nits even in a thick fur garment.

The Use of Insecticides

The measures described so far are adequate for destroying lice in garments but they give no protection from re-infestation. During the war of 1914-18 troops of all the belligerents became and remained chronically lousy, in spite of widespread use of hot-air disinfestors and fumigation plants. The foci of infestation were in the fighting line, remote from the field-laundries and delousing stations. Men newly arrived were soon infested from billets, dug-outs, or from their lousy comrades.

Very early in the recent European war it was realized that some chemical treatment was required which would persist in the underwear and give protection from lice for as long as possible. In general, two methods were favoured: (a) a finely-ground powder-insecticide, which would cling in the fabric, protect for as many days as possible, and then could be reapplied by the individual soldier; (b) a method of impregnating the underwear so that it would remain toxic to lice for several weeks. Work on these two lines was started in various countries independently, but later in the war there was the fullest interchange of information on the results of research in Britain, America and Russia.

a. Anti-lice powders: The original method of using a powder-insecticide against lice was to rub the dust over the inner surface of the undergarments with particular attention to the seams. About an ounce [about 28 g.] of powder was required to treat a man. When more powerful insecticides became available, it was found sufficient to blow the dust up the arms, down the neck, and under the trousers or skirt, without undressing the infested person. The whole process could be done in about two minutes, which was a most valuable economy of time, since it enabled huge numbers of civilians to be deloused within a short period. During the height of the Naples epidemic, about forty delousing stations set up by the American Typhus Commission treated a maximum of 70,000 people in a single day. The simplicity and general applicability of the method to all members of the community contributed greatly to the successful quelling of the epidemic.

The earliest efficient powder-insecticide to be used against lice was the British "AL 63" formula, of which the principal active ingredients were derris and naphthalene (Craufurd-Benson & MacLeod, 1946). This was evolved early in 1940 and was widely distributed to the Armed Forces and to medical aid-posts in air-raid shelters. In Russia, a dust containing diphenylamine was prepared and used in the same way. In Moscow, in the winters of 1941 and 1942, two large hotels were commandeered, the staffs instructed on methods of treatment, and infested people were sent to them to be treated (Fedder, 1942). Another Russian dust of this type which gave very good results was the "SK" formula, of which the active principle was chlorinated turpentine (Ivanova, 1942; Khanenia & Juravlev, 1944; Soboleva, 1944).

When the Americans entered the war, they set several large teams of biologists, chemists, and medical men to study delousing methods. The anti-lice dust first adopted for the U.S. Army was the so-called "MYL" formula, a mixture of pyrethrum, isobutyl undecyleneamide and dimitro anisole (Soapp, 1942; Davis & Wheeler, 1944). This was a very good insecticide, but the inclusion of the pyrethrum was a disadvantage, because all the available supplies of that material were urgently needed for other purposes.

All the anti-lice dusts which have been described were superseded when DDT became known to the Allied Nations. Originally a Swiss discovery, DDT has been the subject of intensive researches in Britain and America, which have extended its uses, defined possible hazards and improved the methods of manufacture. (For a full account of this new insecticide, see Buxton, 1945.) For use against lice in powder form, DDT is used at 10 per cent. in any inert

mineral dust. An ounce of this dust rubbed into the underwear prevents infestation by lice for 2-3 weeks (Bushland, McAlister, Jones & Culpepper, 1945).

The use of DDT dust applied beneath the clothing of dressed people with a hand dusting-gun has become the standard method of treating large numbers of infested people. It has been used with success in bombed cities and on refugees and prisoners of war, and has become the principal weapon for attacking a typhus epidemic.

b. Impregnated clothing: The use of impregnated underwear against lice fulfils a different role from that of powder. Impregnation is feasible only for people in uniform who can be issued with treated underwear and their discarded sets cleaned and re-treated. It is, therefore, a means of protecting soldiers and medical personnel from infestation for relatively long periods spent in areas where infestation is common.

One of the first treatments which gave protection from reinfestation for about a month was the thiocyanate applications developed in this country in 1940-42 (Busvine, 1945). A similar idea was developed independently in Russia, where bis-ethyl xanthogen was used for impregnating underwear (Soboleva, 1942; 1944; Juravlev, 1944). In America the same line was followed in the use of strong pyrethrum preparations to treat sets of underwear (Jones *et al.*, 1944). Some tests of pyrethrum-impregnation were also made in Russia (Kalabukhov, 1943). But all these processes suffered from more or less serious disadvantages. The thiocyanates were liable on occasions to produce smarting of the skin; bis-ethyl xanthogen has a strong unpleasant smell; pyrethrum is effective only at high rates which are scarcely practical; and all three are, to a large extent, removed by laundering.

Once again DDT superseded all the other compounds for this particular use. Its advantages are that it is imperceptible to the wearer; it is entirely harmless in this form; very little is removed by ordinary washing and it persists for about six weeks before re-treatment is necessary (Jones, Fluno & Hendrick, 1945; Musgrave, 1946). Large numbers of DDT-treated shirts were prepared for the Allied armies before D-day, with the result that during the subsequent campaigns the troops were virtually free from lice. This was the first time that troops in active warfare under difficult conditions had been protected from general lousiness.

B. NEW WORK ON THE HEAD-LOUSE PROBLEM

Statistical Information

We owe a great deal of our knowledge of the bionomics of head-lice to the studies by Buxton in recent years (1936, 1937, 1938a, 1938b, 1940a, 1940b, 1941). These papers describe the populations of lice found in crops of hair taken from the occupants of hospitals and jails, mostly in Africa and India, but including men of several races. Irrespective of locality or race, the general trends were consistent, and later Mellanby (1942a) and Le Noury (1945) showed that they held good in Britain. Very briefly, the conclusions were these: there is a strong positive correlation between weight of hair (which is the best measure we have of length of hair) and infestation. On account of their generally longer hair, women and girls are more liable to infestation than men and boys. There is a negative correlation with age, children being more infested than adolescents, who are more infested than adults. The heaviest rates of infestation are to be found in groups showing the highest proportion of infested people.

Mellanby (1941) tried to obtain an estimate of the general level of head-lice infestation in Britain, taking as a reasonably unbiased sample records of examinations on entry into fever hospitals. The results (based on pre-war years) were very disturbing, for it appeared that nearly 50% of girls of school age and 30-40% of boys showed evidence of infestation. These figures were for urban districts; children in rural areas were much less badly infested. A later survey (Mellanby, 1943) showed that the situation was not much changed after four years of war.

Comparing the proportions of children infested in families of different size, it was found that the percentage increased with the number in family (Mellanby 1942b). An examination of the figures for recruits to one of the Women's Services revealed that infestation was most common among less-intelligent groups, as shown by intelligence tests (Rollin,

1943). These two accounts illustrate the association of head-lice infestation with poverty and ignorance.

Advances in Control Methods

In a review of methods of controlling the louse, Buxton (1940d) describes the standards method for treating pediculosis capitis. The most usual methods were: shortening the hair if possible, and combing thoroughly with a fine-toothed metal comb; or the application of paraffin, phenol, cresol or sassafras oil. All these methods, which were in vogue up to the beginning of the war, suffered from some disadvantage; they were either tediously slow, or else they were liable to be inefficient; none of them conferred any degree of protection from re-infestation.

The general mobilization and the evacuations of towns during the war were accompanied by more frequent medical inspections of our population. Among other things, much more attention was paid to methods of eradicating head-lice. The RAMC doctors, responsible for disinfection of large numbers of recruits, called for a treatment that was *rapid* as well as being efficient. Industrial medical officers, who had to deal with factory girls, needed some treatment which would not be resented by the patients. But, above all, there was the perennial difficulty of the school medical officer and the medical officer of health which can be summed up in one word: re-infestation. The common focus of infestation is the family group. In a recent American drive against pediculosis (Murphy, 1943), the home contacts of infested children were urged to come for inspection. Nearly 50% of them came and, of these, 80% were found to be lousy.

In order to overcome some of the deficiencies of the older methods of treatment, there have been a number of proposals for utilizing modern powerful insecticides against the head-lice. Busvine & Buxton (1942) tried out in clinical tests two different thiocyanates diluted in oil and rotenone made up in a cream and in a lotion. The advantage of preparing the drugs in this way was that they could be simply applied in the manner of an ordinary hair-dressing. Being hardly noticeable, they were not resented by the patient, and so would be left undisturbed for a week as a protection against re-infestation. These substances were widely tested (on some 10,000 heads) under the auspices of the Ministry of Health, and one of the thiocyanate formulae, the lethane-special hair oil, was recommended for general use (Ministry of Health, 1943; Busvine, 1943b). The same preparations and, in addition, pyrethrum were successfully used at somewhat lower dilutions in Canada (Twinn & MacNay, 1943).

The use of derris dust as a powder-dressing has sometimes been advocated (Buxton, 1940d; Murphy, 1943). But it is not effective unless the dust is left on the head for several days, which is usually resented by the patient, for it gives a chalky powdered effect to the hair. A way of employing derris which seems more promising is in the form of a shampoo (Trembley, 1943).

Benzyl benzoate emulsion, as used for the treatment of scabies, has some value in the treatment of pediculosis (Blackstock, 1944), though it is not perhaps as efficient as originally claimed. Certainly the compound has no solvent action on lice or nits (Smith, 1944).

According to the results of American work, an effective lotion can be made up with phenyl cellosolve (Davis, 1943; Hansens, 1945). The cellosolves are commonly employed as bases in perfumery, so that they are almost certainly harmless; phenyl cellosolve, however, is rather like glycerine and might give a slightly sticky appearance to the hair. The material appears to remain effective in the hair for about 4 days. Another lotion, recommended by other American workers, contains isobornyl thiocyanate as its active ingredient (Shelanski, Smyth, Clark, Zeller, Pious, Frank & Kramer, 1945). Like the phenyl cellosolve it is said to be easy to apply, and it leaves no grease, stain or odour; but as it is washed off on the day after treatment, it can have no protective effect.

In India, Roy & Ghosh (1942, 1944) claim to have obtained very satisfactory results by spraying infested heads with preparations of pyrethrum in kerosene.

Recently a number of these new anti-lice treatments were re-examined and compared with the older methods by Scobbie (1945). Among the interesting results of laboratory tests was the high ovicidal action of phenol and lysol, also noted by Gamlin (1943). Scobbie tested the new insecticide DDT in the form of an emulsion, and her general conclusions were

that DDT emulsion and lethane-special oil stood out as the two insecticides of value in the treatment of pediculosis capitis. DDT was preferable to lethane, because one treatment with it secured a cure in every case, and because the period of protection after DDT treatment was 14 to 18 days as opposed to 4 to 6 days with lethane.

DDT treatment appears to be very promising, but it would seem desirable for results to be confirmed by larger trials.

C. CONTROL OF CRAB-LICE

Some of the materials used for treating pediculosis have also been employed against the crab-louse, *Phthirus pubis*. Owing to the sensitivity of the skin of the genital region, caution must be exercised to avoid dermatitis. Twinn & MacNay (1943) used ointments and lotions containing thiocyanates, rotenone, or pyrethrum. The results were good,

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