

zeugt; die Läuse in den Haaren überhaupt, besonders. *Ανελπισσιον*, Berlin, 1. 706-715.

den Flecktyphus als Kriegseuche. *Berlin*, 1), 807-809 et seq. [Discusses epidemiology on the "theory of louse-transmission," with obviously unfamiliar. He cites von Hecker, 1915, No. 7), and Hueppe (*Berlin. klin.* in support of his antiquated views.) D. ten von Flecktyphusepidemien in Truppen. *n. klin. Wochenschr.*, III. 1045-8. [i.m.] D. *antation des muqueuses dans la mélanodermie différentiel de cette affection avec la maladie* [i.m.] Pl.

ge der Läusebekämpfung. *München. med.* Fig. [Ova.] (Feldärztl. Beilage, No. 18.)

und ihre Ergebnisse. *Zeitschr. f. Mediz.* Friedmann, 31. 1. 1916, pp. 336-8.] K.

Plattläuse durch Chloroform. *Zeitschr. f.* denburg, VII. 251. [i.c.] Ph.

kämpfung der Kleiderläuse. *Centrabl. f.* Figs. K.

Frage der Läusevertilgung. *Wien. klin.* K.

versuche von Läusen und Nissen. *Wien.* -565, 2 Figs. B.K.

## THE PART PLAYED BY *PEDICULUS HUMANUS* IN THE CAUSATION OF DISEASE.

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(With Plate I.)

CONTENTS.	PAGE.
I. Introduction . . . . .	43
II. Typhus fever and its conveyance by lice . . . . .	44
III. Relapsing fever and its conveyance by lice . . . . .	57
IV. Miscellaneous infective diseases which lice may serve to spread . . . . .	66
V. Some other pathological effects attributed to lice . . . . .	69
VI. Primary effects of louse infestation . . . . .	70
Note on the presence of anticogulins in the salivary glands of <i>P. humanus</i> . . . . .	74
Summary and Conclusions . . . . .	74

### Introduction.

THE following pages give an account of the part played by *P. humanus* in pathology, no summary of the kind having hitherto been published to the writer's knowledge. Most attention is devoted to the part played by the louse in the etiology of typhus and relapsing fever because of their importance and prevalence in certain countries involved in the present war. The most important discoveries relating to these two diseases are of relatively recent date and this accounts, in a measure, for the ignorance of these achievements of science among many members of the medical profession when the war began. As an example I may mention that after the war had lasted about a year, a physician of my acquaintance who was in charge of a large hospital actually scoffed at the statement that lice convey typhus and relapsing fever—we trust that he has grown wiser in the interval.

From the point of view of the historical sequence of the more recent discoveries bearing upon the two diseases mentioned, relapsing fever

should have been considered first, as the investigation of this disease by Sergent preceded and stimulated similar researches into the etiology of typhus by Nicolle and his collaborators. The latter disease, however, is given precedence because of its graver character. The remaining subject-matter is similarly treated in the order of its practical importance.

### I. TYPHUS FEVER AND ITS CONVEYANCE BY LICE.

#### 1. THE GEOGRAPHICAL DISTRIBUTION AND PREVALENCE OF TYPHUS.

Typhus was exceedingly prevalent throughout Europe in former times, but, apparently owing to a general improvement that took place in hygienic conditions lasting up to the outbreak of the present war, the disease had gradually become almost entirely confined to certain endemic areas.

Typhus is essentially a disease of cool and temperate climates. In *Europe*, during recent decades, it had been chiefly recorded from Galicia, Poland, European Russia, Ireland, and Italy, all but the last having been regarded as its chief endemic centres. Typhus occurred to a moderate extent in England, Wales, and Scotland, and to an undeterminable degree in Finland, Spain, Portugal, Bohemia, Austria, Hungary, Bukovina, Roumania, Bulgaria, Montenegro, Serbia, Greece, Turkey, and some of the Mediterranean Islands. The disease had grown rare in Norway and Sweden, Denmark, Holland, Belgium, France (since 1893), and Switzerland, and this may also be said of Germany where the cases that occurred were largely imported from Russia and Galicia. On the continent of *Africa*, it has been recorded from the countries bordering upon the Mediterranean (Morocco, Algeria, Tunisia, Tripoli, Egypt), where it may be regarded as endemic. In *Asia*, typhus occurs in Asia Minor, Armenia, Persia, Mesopotamia, the Caucasus, Siberia, Central Asiatic Russia, India, Northern China, Korea and Japan. In *America*, it is still reported occasionally from Canada and the United States where severe epidemics followed on the track of Irish immigrants in the middle of the last century; it has, moreover, been recorded for a long time from Peru, Chile, Brazil, Bolivia, Nicaragua, and it is endemic in and about the City of Mexico<sup>1</sup>.

The prevalence of typhus in the centres where it occurs most frequently is shown in the following table, the latter requiring but little

<sup>1</sup> These data have been compiled from Hirsch (1881), Clemow (1903), Low (1916) and knowledge personally acquired.

comment. A great decrease in the number of deaths is observable in succeeding decades or groups of years in the case of some countries. No doubt this decrease coincided with a fall in the number of vermin-infested persons in the population, coupled with a better standard of living.

#### Deaths from Typhus Fever recorded in Various Countries

Condensed from Low (1916, pp. 32-86).

England and Wales ...	1869-83 (15 yrs)	1884-98 (15 yrs)	1899-1913 (15 yrs)	
	23,702	2,249	390	
Scotland ...	1865-74 (10 yrs)	1875-84 (10 yrs)	1885-94 (10 yrs)	1895-1904 (10 yrs)
	5,547	2,693	818	308
Ireland ...	1869-83 (15 yrs)	1884-98 (15 yrs)	1899-1913 (15 yrs)	
	11,544	4,703	1,043	
Italy ...	1887-1900 (14 yrs)	1901-14 (14 yrs)		
	13,909	1,514		
Galicia ...	1895-1904 (10 yrs)	1905-12 (8 yrs only)		
	5,592	2,181		
Germany ...	1886-95 (10 yrs)	1896-1905 (10 yrs)	1906-10 (5 yrs only)	
	302	81	19	
Russian Empire ...	1905-11 (7 yrs)			
	45,533			
European Russia ...				
Poland ...		1,126		
The Caucasus ...		1,546		
Siberia ...		681		
Rest of Asiatic Russia ...		327		
Total ...		49,213		
Mexico City ...		1893-1913 (21 yrs)		
				14,758

With the advent of the war, history repeats itself, classical examples being afforded by experiences in Serbia and *Germany*. German authors are unanimous in attributing epidemic typhus in their country to the entry of Russian prisoners who were largely verminous, and when they were mercilessly herded together with prisoners from other



countries and "isolated" not from each other but from the Germans, severe epidemics broke out amongst them. The disease nevertheless occurred among the civil population, but we do not know to what extent. Low (1916, p. 57) has compiled a list of six towns, beginning with Berlin, in which typhus occurred in 1915, besides which epidemics occurred in prisoners' camps in 16 districts; he names 10 camps in which British soldiers were confined and where typhus broke out. It is doubtful if statistics relating to these outbreaks among prisoners will ever be made available in the future. In *Serbia*, the deaths from typhus were reckoned at 500 a day in February 1915.

## 2. THE EPIDEMIOLOGY OF TYPHUS. EARLIER OBSERVATIONS.

Before describing more recent researches into the etiology of typhus fever, it is necessary to dwell briefly upon some of the evidence that was gathered by earlier investigators concerning the epidemiology of the disease, especially as much of the evidence applies equally to relapsing fever (see Section II).

The older authors all lay stress upon the occurrence of typhus epidemics in times of calamity, during periods of famine when the crops failed, whilst war raged, or when there were commercial crises leading to general impoverishment. The influence of filth and overcrowding, and unhygienic conditions generally, were recognized as potent factors in the epidemiology of typhus. Many records relate to outbreaks of typhus in crowded or ill-ventilated workmen's quarters, in overfilled prisons and poor-houses, on shipboard, in armies in the field, but especially among the besieged and besiegers. The seasonal incidence during winter (November to April) was attributed to overcrowding indoors during this season.

A suggestive observation, in the light of our present knowledge, is recorded by Bernhardt<sup>1</sup> who states that the prevalence of *louse infestation* was observed in the 17th century in connection with typhus and relapsing fever. Moreover, Low (1916, p. 61), writing of typhus in Hungary, mentions that "at the beginning of the 17th century, Tobias Coberus expressed his belief that the louse had a psychic effect upon the human subject; he therefore recommended garlic applied as a prophylactic against war-typhus" ... "which he seems to have asso-

<sup>1</sup> Cited by Landois (1865b, pp. 499-503) from Hecker's *Kunst die Krankheiten des Menschen zu heilen*, 6th ed., II, 671. [I have been unable to gain access to this work. Hecker was born in 1763 and died in 1811; the 2nd ed. of the work appeared in 1805.]

ciated with the presence of lice upon the person attacked." [Low gives no reference.]

That the clothing of typhus patients is a source of infection, was soon recognized. Lind (1833)<sup>1</sup> pointed out the high incidence of typhus among laundresses, and Perry (1836)<sup>1</sup> noted its spread through convalescents transferred to clean wards with the clothes they had worn when ill.

Passing over older authors, we find that Hirsch (1881, vol. I, p. 405) points out the great similarity between the epidemiology of typhus and relapsing fever, the world-wide distribution of the two diseases, and the fact that in neither is any racial immunity observable.

Of fundamental importance, however, is the work of Murchison (1884) on the epidemiology of typhus. There is practically nothing to add to-day to the epidemiology of the disease as outlined by this author, if we except the most recent discoveries regarding the part played by lice as vectors. Murchison found: (1) That when typhus appears in a locality or house, it usually spreads very fast. (2) That the number of cases stands in direct relation to the degree of contact between individuals. (3) That persons visiting the sick are prone to catch typhus. (4) That the sick convey the disease to clean quarters. (5) That typhus is checked by isolation of the affected. (6) That it is acquired by contact with the sick, by contact with objects contaminated by the sick, and by sojourning in places previously occupied by typhus cases.

Murchison referred outbreaks to clothes "saturated with typhus poison." He indicated the need of personal cleanliness, warm baths, change of garment, and the disinfection of clothing for those in attendance on the sick. The convalescent should receive the like treatment. Visitors should not sit on the beds occupied by the sick, and in hospitals "the same bed and bedding ought always to be reserved for typhus cases." He considered that there was much evidence which proved the efficacy of these simple prophylactic measures.

The period of incubation, under natural conditions, would appear to vary between 9 and 20 days. (Jacquot, in the Crimean war, recorded 9-13 days; Barallier gives 12-15 days; Murchison gives 12 days, basing the figure on 31 cases observed by him in practice; Thoinot and Dubief (1893), in Paris, give the period as 10 or more days; Doral (1915) and other recent writers record an incubation period lasting 10 to 20 days.)

<sup>1</sup> Cited by Murchison (1884).



3. THE DISCOVERY THAT THE VIRUS OF TYPHUS OCCURS IN THE BLOOD OF THE AFFECTED AND THAT THE DISEASE IS COMMUNICABLE TO MAN AND ANIMALS BY INOCULATION.

That the blood of typhus cases is infective for man was first demonstrated by Mocutovski (1900)<sup>1</sup>, who inoculated himself therewith and suffered from an attack of typhus fever after an incubation period of 18 days. His heart never recovered from the effects of the disease and he died, a hero of science, in 1903<sup>2</sup>. Yersin and Vassal<sup>1</sup> confirmed Mocutovski's observation by inoculating two men who developed typhus after 14 and 21 days respectively.

The discovery that typhus is communicable to apes and monkeys, made by Nicolle (12. vii. 1909, pp. 157-160), was of great importance since it enabled experimental investigation to be conducted in the laboratory<sup>3</sup>. Nicolle, working in Tunis, transmitted typhus to a chimpanzee by the inoculation of 1 c.c. of human blood taken from a patient on the third day of the attack of fever, after the eruption had appeared. The chimpanzee, a young animal, after an incubation period of 24 days, developed a succession of typical symptoms of typhus: fever, eruption, prostration, diarrhoea, dark red plaques on the trunk followed by the disappearance of the eruption, desquamation on the hands, progressive emaciation, and a subnormal temperature.\* Two days before the rash appeared, when the chimpanzee's temperature registered 40.2° C., some blood was drawn from the animal and 1 c.c. thereof was injected into a monkey, *Macacus sylvaticus*, which, after an incubation period of 13 days, in turn developed typical typhus.

The work of Nicolle and his collaborators appeared to indicate that typhus was not directly communicable by inoculation from man to monkey, although they succeeded in infecting monkeys after passing the virus through the chimpanzee. Monkeys, however, frequently react atypically, as Anderson and Goldberger (18. ii. 1910, pp. 177-185) found in Mexico, when experimenting with *Macacus rhesus* and *Cebus capucinus* which they inoculated with 20 c.c. and 8 c.c. of human "tabardillo" (= typhus) blood in two or three successive doses<sup>4</sup>.

<sup>1</sup> Cited by Thoinot (1916).

<sup>2</sup> For biography see *Ueber. perichit., neurop.*, etc., Petrograd, 1903, viii. 320.

<sup>3</sup> The dog, cat, and rabbit are definitely stated to be immune (Nicolle, Blanc and Conseil, I. xii. 1914, p. 103).

<sup>4</sup> It was only at a subsequent date that the identity of Mexican "tabardillo" and European typhus was established to the satisfaction of the authors. I would note, however, that Hirsch (1881, p. 402) said they were identical.

Anderson and Goldberger (*loc. cit.*) found that monkeys which had recovered from typhus inoculation became immune against reinoculation with typhus virus; that human blood was infective for eight days, and monkey blood for 5-6 days after the onset of the attack. On epidemiological grounds they believed that lice, but not bugs and fleas, served as carriers. They did not convey typhus to monkeys by means of lice<sup>1</sup>. In a paper published a few days previously, Ricketts and Wilder (5. ii. 1910, pp. 463-467) reported that they had communicated Mexican typhus to *Macacus rhesus* by an injection of blood drawn from a man on the eighth day of the disease; the monkey showed no eruption like that observed in man.

Ricketts and Wilder (16. iv. 1910, pp. 1304-1307) next inoculated rabbits and observed a rise of temperature in these animals after 5-12 days, no eruption occurring and the bacteriological examination being negative. The authors lay stress upon the need of *immunity tests* being carried out with animals that have merely shown fever followed by recovery. This test consists in inoculating the recovered animals a second time with virulent typhus blood—a negative result indicating that they have been rendered immune by the first (masked) attack. This test is especially necessary when dealing with animals which do not develop typical symptoms. They reported that they could not maintain the virus by passage through more than 2-3 monkeys, and in these animals the disease proved to be mild or abortive, so that they could reach no conclusions without resorting to the immunity test. They found human typhus blood to be infective for monkeys on the 8-10th day of the attack. Gavino and Girard (1910, pp. 1-32), working independently, were able to transmit Mexican typhus from man to *Ateles vellerosus* by the inoculation of 3-5 c.c. of blood. The animals showed fever after an incubative period of 11-14 days, and, after recovery, were found to be immune to reinfection. The virus persists in human typhus blood up to the tenth day of the attack. They found that *the guinea-pig is susceptible to typhus*.

Anderson and Goldberger (2. ii. 1912, pp. 149-160) demonstrated experimentally that "Brill's disease" occurring in New York, is identical with "tabardillo" of Mexico and European typhus fever. They successfully infected monkeys (*Macacus rhesus*) with the blood

<sup>1</sup> Their suggestive observations on the distribution of lice and typhus in Mexico will receive mention in the following paper on the Biology of *Pediculus humanus*.

<sup>2</sup> Vide Brill, N. E. (1898), *New York Med. Journ.*, Lxvii. 48, 77; (r. 1910) *Am. Journ. Med. Sci.*



Immunity tests were applied in each instance to the animals which had recovered. The author concludes that typhus may be transmitted both by lice being crushed upon the skin or through the bites of the infected insects.

These experiments of Goldberger's do not appear entirely convincing, and a statement by Anderson and Goldberger (x. 1912, pp. 101-130) rather bears out this contention. They mention, namely, that about 22% of the monkeys used for experiment possess transient or permanent immunity against typhus inoculation. They failed (p. 130) to confirm Wilder's opinion that the virus of typhus is hereditarily transmitted in the louse.

*The period of infectivity of lice.* Nicolle, Comte and Conseil (1909, vide supra) found lice infective 1-7 days after they had fed on typhus blood; Nicolle and Conseil (1911) subsequently infected two monkeys with lice after a period of 5-7 days. Wilder (1911) thought he had infected a monkey through louse bites after an interval of 7-11 days. Anderson and Goldberger (x. 1912, p. 129) thought that in one of their experiments they had infected a monkey through louse bites after a period of 1-4 days. These conclusions appear difficult to harmonize. [See the results of further experiments by Nicolle and his colleagues, on p. 53.]

Prowazek (3. xi. 1913, pp. 2037-2040) infected a monkey by injecting the contents of a single crushed louse that had fed two days before upon a typhus patient and had been afterwards fed twice upon a monkey. The test monkey showed fever on the 12th day after inoculation; the blood changes, as also the lesions, agreed with those observed in man, there being no other apparent reason why the animal died. He found no organisms in the lice. Though much has been made of this observation of Prowazek's in Germany, there was practically nothing new in it.<sup>1</sup>

Sergent, Foley and Vialatte (3. iii. 1914, pp. 964-965) note that epidemics have occurred frequently in which typhus and relapsing fever have been observed side by side. The explanation of this is rendered obvious by an experiment wherein the authors fed lice from a relapsing fever patient upon a man, and unintentionally gave him typhus.<sup>2</sup> They

<sup>1</sup> It may be stated incidentally that immunity cross-tests, in the hands of the authors and also of Ricketts and Wilder, established the non-identity of experimentally induced typhus and Rocky Mountain fever in monkeys.

<sup>2</sup> S. von Prowazek died 17. ii. 1915 from typhus contracted whilst studying the disease among Russian prisoners of war at Kottbus (*Méat. Klinik*, xi. 264).

confirmed the observations of Nicolle and his collaborators in that they transmitted typhus to a man and monkey by inoculation with crushed infective lice. They state that typhus virus is transmitted hereditarily in lice. The incubation period in monkeys inoculated with the contents of infected lice or their eggs, lasted eight and five days respectively.

Usher (19. ix. 1914, pp. 509-510) in Van, Turkey, records that a male nurse "subjected himself to infected lice, and promptly contracted the disease," after an incubation period of five days, according to the author's recollection, which would appear to have been untrustworthy or else the man was infected before. A five day incubative period is too short.

Nicolle, Blanc and Conseil (3. xi. 1914, pp. 661-664; 1. xii. 1914, pp. 84-121) record two interesting cases of louse transmission of typhus: (1) a guardian of a Tunisian penitentiary, since deceased, having doubts as to the part played by lice as vectors, and being of an independent and experimental turn of mind, surreptitiously placed some lice, taken from a typhus patient, upon the neck of one of two workmen who came from the outside and lodged in an outhouse apart from the infected inmates. The experimentally infested man developed typhus on the ninth day, whereas the "control" remained well. (2) A laboratory assistant was accidentally bitten by an infected louse and developed typhus on the 10th day.

In view of the conflicting results obtained by various investigators (see p. 52), the authors sought to determine when the lice become infective. For this purpose they fed lice to reptiles upon infected monkeys, and, at stated intervals, they crushed 10-40 or more of these lice and injected their substance intraperitoneally into test animals as follows: (1) eight monkeys and two guinea-pigs were inoculated with lice crushed after 1-8 days with negative result. (2) Four monkeys and one guinea-pig were inoculated with lice crushed after 9-10 days and all developed typhus. The periods of incubation observed in the case of the last four monkeys were respectively 10, 22, 26 and 41 days. The authors note that it was a mistake of the American observers to discard their non-reacting monkeys as early as the 15th to 20th day after inoculation since the incubation period may be longer.

The faeces of lice fed on typhus blood were found infective by the inoculation of animals:

Faeces collected		Result of inoculation
2-10 days after the lice were infected	...	1 positive
6-10	"	1 positive
3-6	"	2 positive
7-9	"	1 doubtful and 1 negative



These results are similar to those obtained with plague and fleas, where infection may be caused through the bites of insects or through their dejecta, the act of scratching by the subject bitten affording a means of entry of the virus into the system.

Contrary to Wilder (1911), and Sergeant, Foley and Vialatte (1914), and in agreement with Anderson and Goldberger (1912), Nicolle and his colleagues (1914) find that there is no proof of hereditary transmission of typhus virus in lice, they consider that such transmission is improbable on epidemiological grounds<sup>1</sup>. I cannot see why, on epidemiological grounds, hereditary transmission of the virus should be improbable, for in relapsing fever whose epidemiology is similar to typhus, the spirochaetes are transmitted hereditarily.

6. SOME CONFIRMATORY EXPERIENCES IN PRACTICE.

Usher (19. ix. 1914, pp. 509-510), who observed an extensive typhus epidemic in Van, Turkey, gives a short but interesting account of his experiences under difficult circumstances. He was the first to recognize the nature of the malady which caused the death of 2,500 soldiers. Although the preventive measures he instituted were somewhat primitive, no cases occurred in the hospital when precautions were taken to exclude lice. When this was done, the typhus cases could be placed in beds beside other patients with impunity. As soon as it was possible to do so, both infected clothing and bedding were boiled to destroy the lice they might harbour.

According to an abstract of their paper, Klemperer and Zinn (ii. 1915, p. 325) describe the case of Dr Jochmann who died of typhus contracted in attendance on typhus patients. He died on the 11th day after an incubation period of 10 days. Jochmann was convinced that typhus is only conveyed by lice, and, in a book he published (no reference) he cites cases, as do also Klemperer and Zinn, to prove that louse-free patients are not a source of danger. Jochmann had ten people about him when he was ill, including his wife and children, but none caught typhus. Uhlenhuth (9. v. 1915, p. 531) shares the opinion of Jochmann and cites Jürgens and Gottschlich (1915, Med. Klinik, No. 13) in confirmation.

Kirchner, the Chief of the Imperial Bureau of Health of the German Empire, is cited in a German Editorial (28. ii. 1915, p. 263) as having

<sup>1</sup> The authors had previously laid stress on the similarity in the epidemiology of typhus and relapsing fever (v. infra p. 61).

presented a report on typhus to the House of Representatives in Berlin. He stated that typhus was more prevalent in Russia than in Germany into which it was introduced by Russian prisoners. Typhus was checked by the isolation of these prisoners (perhaps by the Wittenberg method!). An investigation conducted at the instance of the Government, confirmed the view that typhus is "almost" exclusively conveyed by lice.

The Professor of Hygiene at Berlin, Flügge (9. v. 1915, p. 531) reports that experience covering several months in German prison camps, confirms the belief that typhus is solely conveyed by lice.

Boral (17. vi. 1915, p. 641) concludes from epidemiological observations upon Austrian troops, that man is not infective for lice during the incubative period of typhus, and that in the absence of lice the disease is not conveyed from man to man at any stage of its evolution.

Blumberg (vii. 1915, p. 837) observed a large epidemic among prisoners of war at Brandenburg, lice having been brought to the camp by Russians nearly all of whom were verminous.

Neukirch and Zlocisti (5. iii. 1916, p. 259) record their experiences with typhus in Anatolia. They state that fleas abounded so that everybody was bitten by them, nevertheless very few of those who attended upon typhus cases acquired the disease. Bugs (*Cimex*) could also be excluded as carriers, for they swarmed in a typhus ward whence the patients had to be cleared for the reception of wounded; none of the latter caught typhus. All of the Turks, who suffered from typhus, were verminous.

Deléarde and d'Halluin (20. iv. 1916, pp. 310-320), ex-prisoners of war in Germany, report upon their experiences with typhus in the camps at Langensalza, Saxony, and at Niederwehren, near Cassel. Russian and French prisoners, numbering 20,000 cases of typhus, and these two camps. The authors observed 2,000 cases of typhus, and estimate that the number totalled 5,000. Of 7,131 French prisoners, 187 died of typhus; they were all verminous. The authors believe that lice play the chief part in the spread of typhus.

<sup>1</sup> The authors think, however, that typhus may also be conveyed, although to a lesser degree, by coughing, and, in support of their contention, cite the case of a physician who caught typhus although no lice were found on him: a typhus patient had previously coughed in his face. They mention plague as possibly a parallel instance, where we know that infection may be conveyed by ectoparasites (fleas) and also by the inhalation of plague bacilli from sputum sprayed into the atmosphere in droplet form. The authors do not take into account that the small larval stages of lice may well escape notice. That

See  
July

See Kirchner's paper  
in the German  
Editorial  
of the 28. ii. 1915  
p. 263  
and also  
Uhlenhuth's  
paper in  
Med. Klinik  
No. 13  
of 1915  
p. 531



The foregoing instances, illustrating the part played by lice in relation to typhus epidemics, will suffice for our purpose. Similar experiences have been reported from Russia and Serbia.

#### 7. DEMONSTRATION OF THE PRACTICAL RESULTS OF PROPHYLACTIC MEASURES BASED ON THE KNOWLEDGE THAT LICE CONVEY TYPHUS.

The knowledge gained regarding the part played by lice in the propagation of typhus, led naturally to the institution of prophylactic measures directed against lice. The results have been most striking in Tunis, as is shown by the published figures given by Nicolle and Conseil (20. I. 1915, pp. 18-20; also referred to by Nicolle, 14. IV. 1915, p. 160). The preventive measures produced a great fall in the number of cases following on the year 1911, as follows:

##### *Typhus fever incidence in Tunis.*

Year	Number of cases
1909	856 all indigenous
1910	148 " "
1911	180 " "
1912	22 " "
1913	6 " "
1914	3 all imported
1915	0

Owing to the war, no evidence as striking as that tabulated above is at present available from any other part of the world. The evidence affords a complete demonstration of the efficacy of measures directed against lice which are the only known vectors of typhus.

#### 8. NOTE ON THE VIRUS OF TYPHUS.

A perusal of the literature on typhus shows that there is no general agreement as to the nature of the virus. Typhus is one of those diseases in which the supposed cause has been repeatedly discovered in the course of many years. Of recent writers some claim that the causative agent is a cultivatable bacterium, others that it is an undeterminable microorganism which cannot be cultivated, others that it is a Protozoon, others again regard the supposed causative agent of certain authors

typhus may be conveyed through the atmosphere is of course an old belief, similar to that which prevailed formerly in respect to malaria and yellow fever, both of which are mosquito-borne. Of recent authors, Kraus (rr. 1915, p. 314) and Bujwid (v. 1915, p. 531) still cling to this old belief. Proof is lacking that the virus of typhus occurs in the sputum.

as merely representing degeneration products of the host's cells. Whereas it has been claimed by some that the virus is capable of traversing a bacterial filter others deny that this is the case. It appears inexpedient therefore to dwell further upon the matter in this paper. Those who may desire to study the literature on the subject are referred to the more recent publications of Ricketts and Wilder (1910), Prowazek (1915), Nicolle, Blanc and Conseil (1914). Bodies called *Rickettsia prowazeki* are regarded as the cause by Rocha-Lima (1916 and before), Töpfer (1916), Töpfer and Schissler (1916), Noeller (1916). The *Bacillus typhi-azanthematici* is regarded as the cause by Plotz (1914), Olitsky, Denzer and Husk (1916), and Paneth (1916). Supposed Protozoa have been described by Stempel (1916). The *Diplobacillus azanthematicus* is regarded as the cause by Rabinowitch (1914-16). Penfold (1916) describes a *Micrococcus*. Proescher (1915) describes minute *Diplococci* and *Diplobacilli* as present in the endothelial cells of the human subject.

Some of these supposed causative agents have also been found in lice, either in infected or non-infected insects. Rocha-Lima denies that *Rickettsia* is ever found in normal lice, and his followers agree with him; on the other hand Rocha-Lima states that minute bodies, morphologically similar to *Rickettsia*, occur in uninfected lice, but that they differ in not undergoing multiplication in the cells of the insect's midgut.

## II. RELAPSING FEVER AND ITS CONVEYANCE BY LICE.

### 1. GENERAL CONSIDERATIONS.

It has already been noted that epidemics of typhus and relapsing fever may occur side by side as was first clearly recorded in Ireland in 1739, and that the two diseases agree in respect to their epidemiology. Both diseases were much more prevalent in former times.

The geographical distribution of relapsing fever is similar to that of typhus, it is also a disease of cool and temperate climates, but it is not recorded from as many countries by Hirsch (1881, p. 417) and Clemow (1903, p. 364). In Europe, it occurs in Great Britain and Ireland, Belgium, Germany, Austria, Russia, Finland, Bulgaria and on islands in the Mediterranean. Like typhus, it is rare in Norway and Sweden. There are no records of it from Switzerland, France<sup>1</sup>, Italy and Spain

<sup>1</sup> It has occurred among soldiers in the present war as an army surgeon informs me.



that I can find. It occurs in *Northern Africa*, like typhus, in countries bordering the Mediterranean. In *Asia*, it is recorded from India, China (constantly associated with typhus), the Caucasus, Turkestan, Siberia and Russian Central Asia. In *America*, it occurs in the Northern Continent, but apparently not in Central and South America<sup>1</sup>.

Our knowledge of the cause of the disease dates from Obermeyer (1873), who discovered the parasite, *Spirochaeta recurrentis* Lebert 1874. This parasite is so well known that it needs no further consideration here. Moczutowski (1876) was the first to transmit relapsing fever from man to man by inoculation with blood taken from a patient, whilst Carter (1877-8) discovered that monkeys could be similarly infected. Rats and mice were subsequently found to be susceptible to infection, and since that time a very large amount of literature has been published in relation to the disease. As in the case of typhus the parasite occurs in the blood of the affected individual; it can be maintained in a state of undiminished virulence for an indefinite period by passage through animals in series.

## 2. THE EXPERIMENTAL DEMONSTRATION THAT LICE CONVEY RELAPSING FEVER.

Mackie (14. xii. 1907, pp. 1706-1709) was the first to investigate the subject of lice in relation to relapsing fever. He observed an outbreak of the disease in a school at Nasik Mission Station, India, where boys and girls occupied separate buildings. When the outbreak began, some of the inmates departed, leaving 145 boys and 114 girls, of whom respectively 137 and 35 developed relapsing fever. The first outbreak started. At this time many of the boys harboured body-lice, whilst the girls were free from these parasites; some head-lice were found on the girls, fewer occurring upon the boys. As the outbreak progressed, body-lice were also found upon the girls. Mackie reported that *Spirochaeta recurrentis* was found in 14% of the lice taken from the boys, and only in 2.7% of those collected from the girls. <sup>Head</sup> <sup>Body</sup>

Mackie failed to transmit relapsing fever to monkeys by means of infected lice. He states that the spirochaetes multiply in the insect's

<sup>1</sup> The relapsing fever of tropical Africa is distinct from that of temperate climates being caused by *Spirochaeta duttoni* which is transmitted by a tick, *Ornithodoros moubata*. Some isolated reports of relapsing fever from Central and South America indicate that in these regions a species of tick may perhaps serve as a carrier.

gut, attaining their maximum development in three days<sup>1</sup>. He also noted the presence of *Cyrtidia* in the intestines of lice. Spirochaetes were found in the insects' ovaries and Malpighian tubes, and they were expelled with fluid exuded from the oral aperture when the lice were compressed. Spirochaetes were not found in ova laid by infected insects.

Sergent and Foley (iii. 1908, pp. 174-176), impelled by the publication of Mackie, issued a preliminary note upon their researches. They reported upon an epidemic of relapsing fever occurring during the winter at Béni-Ounif de Figuig, Sud Oranais, Algeria. Body-lice were observed in large numbers on nearly all the patients who were examined, the persons affected being mostly poor, living promiscuously, sleeping on mats and using heavy coverings in common, hardly ever washing or changing their clothes. Many of these persons showed self-inflicted scratches upon their bodies due to the presence of vermin.

The authors were able to exclude mosquitoes, *Cimex*, and *Argas persicus* as carriers on epidemiological grounds. *S. recurrentis* was seen to disappear rapidly in *Cimex*, *Argas* and *Pediculus* that had fed upon infected blood. Some non-motile spirochaetes were discovered in the coelomic fluid of *Argas* up to the sixth day, but they did not reappear (as do *S. gallinarum*) when the ticks were subsequently placed at a temperature of 24-37° C. After biting relapsing fever patients in Algeria, the bugs, ticks, and lice were taken to Paris, where, after a period of six days from the time of feeding, the arthropods were crushed and their substance inoculated subcutaneously into monkeys. A positive result was only obtained with a monkey that had been inoculated with one of the crushed lice; following upon an incubation period of eight days, the monkey died of relapsing fever on the third day of illness.

Smith (1909) in Egypt, observed an outbreak in which lice were common on the bodies of the affected persons. Spirochaetes were found in stained films prepared from lice, examined within four hours of their feeding on infective blood. He failed to infect a monkey by means of lice taken from the patients. Smith (1910, pp. 374-376) subsequently reported that he had failed to transmit different strains of spirochaetes (from New York, Egypt, Morocco) by the bites of infected lice. He sought to transmit spirochaetes in this manner from rat to

<sup>1</sup> This is contrary to subsequent experience in Northern Africa. Involuntarily one asks oneself did Mackie perchance mistake the spermatozoa of the louse for spirochaetes as Klodnitzky (1908) did in the case of *Cimex* (vide Nuttall, *Parasitology*, i. p. 144). I have twice, since that date, saved others from making a similar mistake.



rat, monkey and man; from monkey to monkey; from man to man, monkey and rat. By inoculating a *Cercopithecus* with 50 lice crushed 18 hours after feeding on infective blood, he obtained, however, a positive result.

Sergent and Foley (v. 1910, pp. 337-373) in Algeria, noted the increase in the number of cases of relapsing fever in cold weather, and a marked reduction during the warm season<sup>1</sup>. The indigenous population wear the same clothes day and night for weeks, and this favours the propagation of body-lice, especially in winter, when vermin are found on nearly all natives. In summer, the children are almost free from vermin because they wear little clothing, frequently nothing more than a shirt. Body-lice were found on all affected persons.

The authors next infected a monkey by inoculation with the substance of lice crushed 5-6 days after the insects had fed on a relapsing fever patient in the middle or during the course of the first attack. They infected two women by means of lice placed beneath their clothing and by means of blankets which harboured lice that had fed upon a man two days after he had suffered from his first attack of fever. They gave the name of *Spirochaeta berbera* to the strain of *S. recurrentis* they encountered in cases of relapsing fever in Africa. They repeat that bugs could be excluded as vectors of the disease<sup>2</sup>.

In the winter of 1910-11, Sergeant, Gillot and Foley (l. 2. vii. 1911, pp. 438-440) observed an epidemic of relapsing fever in Algiers. They examined 17 patients, all of whom were lousy and belonged to a class of men who huddled together at the midday siesta on the harbour quay. The authors succeeded in infecting five out of eighteen monkeys that were inoculated with crushed lice collected from the patients 1-9 days previously. In four of these monkeys the incubation period

<sup>1</sup> Casaux (rv. 1914, p. 142) reports that relapsing fever also prevails in winter in Tonkin when the natives are confined in their huts; he regards lice as probable carriers.

<sup>2</sup> For the earlier work on *Cimex* as possible carriers of relapsing fever, see Nuttall (vi. 1909). Note on the behaviour of *Spirochaetae* in *Acanthia lectularia*, *Parasitology*, i. 143-161, wherein, besides the author's experiments, are cited those of Ticlin, Karlinki, Schaudinn, Christy, Breinl, Kinghorn and Todd, and Klodnitzky. To these may be added the work of (1) Sergeant and Foley (v. 1910, p. 370) wherein it was found that the *spirochaetes* usually disappear within the bug within 24 hours after they have fed upon infective blood. (2) Stefanaky (1915), who appears to be ignorant of all previous work on this subject, judging from the review of his paper ("Do bugs play a part in the transmission of relapsing fever?" Русский Врач, No. 11, reviewed in Медицинское Обозрение, LXXXIII, 377), wherein it is stated that he fed bugs on relapsing fever cases and afterwards on monkeys with negative results; the *spirochaetes* in bugs vanished in two days, and the progeny of infected bugs were non-infective.

lasted eight days, in the fifth monkey it lasted six days. *Spirochaetes* were not discoverable microscopically in the infective lice. The period of incubation observed in the monkeys corresponds to that observed in men who became infected under natural conditions. This is in marked contrast to what obtains when monkeys are inoculated directly with blood taken from cases of human relapsing fever, in the latter case the incubation period is always less than 24 hours.

Nicolle, Blazot and Conseil (10. vii. 1912, pp. 1636-1638) noted the striking similarity in the epidemiology of typhus and relapsing fever as seen in North Africa. The two diseases spread in the same manner, occurred in the same localities, attacked the members of hospital staffs who were concerned with the admittance and handling of incoming patients with their effects, whereas the physicians and nurses who handled the patients after they were bathed and cleansed escaped the infection.

The authors' observations regarding the mode of infection in relapsing fever were most interesting. They found that when body-lice were fed upon infective blood, the *spirochaetes* disappeared rapidly from the insects' intestinal tract, but few could be detected microscopically after the lapse of 5-6 hours and all had disappeared after 24 hours. On the 8-12th day, typical, active *spirochaetes* reappeared in the lice. At first the *spirochaetes* were short, subsequently they attained the usual dimensions they possess in man's blood. They were seen to persist until the 19th day in the louse. A monkey was infected with the substance of a louse which had been crushed 15 days after it had fed on infective blood. Thousands of infected lice were allowed to bite monkeys and a man with negative results<sup>3</sup>. It is clear that in nature infection must occur through the infective lice being crushed upon the individual. All lousy persons scratch themselves, thereby crushing vermin upon their bodies, and infecting the excoriated skin with contaminated fingers and nails. That infection occurs in this way was demonstrated experimentally by one of the authors upon his own person; crushed lice, placed upon the excoriated skin, produced relapsing fever after an incubation period of five days. A drop of blood containing the

<sup>1</sup> About this time Balfour (1911, p. 70) working in the Sudan, examined a few body-lice that had been taken from relapsing fever patients; he failed to infect monkeys through their agency and failed to keep the insects alive under experimental conditions.

<sup>2</sup> In one experiment a man was subjected to 6515 (later increased to 16,000) bites of infected lice. Further details of these experiments will be found in a later paper by these authors (1913, pp. 17-19, 28) and the papers of Nicolle and Blazot (1914). The latter record a second experiment on man wherein 1000 bites did not produce infection.



substance of crushed lice, when dropped upon the excoriated skin or upon the intact conjunctiva, produced relapsing fever in man. These cases were promptly cured in a few hours with salvarsan (or ludy).

In a later paper (26. viii. 1912, pp. 481-484), the authors state that a man was bitten 336 times by certainly infected lice and remained well, and that two persons did not become infected after being bitten respectively 1186 and 2828 times by lice which were the progeny of infected parents. The authors reported three experiments to determine if the infectivity of lice is hereditarily transmitted; two experiments were negative and one positive. The latter experiment was reported upon in their earlier paper<sup>1</sup>. Some eggs, laid 12-20 days after the parent lice had fed on relapsing fever blood, were placed at 28° C. and began to hatch on the seventh day. The young larval lice and some unhatched eggs were now crushed and inoculated into a monkey which subsequently developed relapsing fever. Spirochaetes were not discoverable microscopically in the eggs.

Of 165 lice examined from the ninth day onwards, after they had fed on infective blood, 29 (ca. 18 %) subsequently showed spirochaetes in their coelomic cavity. Of 39 ♂♂ and 21 ♀♀ lice examined, respectively 10 % and 43 % subsequently showed coelomic infection, whilst spirochaetes were absent from the intestinal lumen and inoculations made with such lice gave negative results.

Nicolle, Blaizot and Conseil published three papers on their investigations in the following year. In the first paper (12. ii. 1913, pp. 106-107), they report that in seven lots of body-lice fed on men or monkeys suffering from relapsing fever, rapid degeneration and disappearance of the spirochaetes was observed in a few hours, followed by their reappearance after seven days. After about five days, the spirochaetes appeared in the coelomic cavity of the insects, and persisted there for 8-12 days. The spirochaetes contained in the lice at this period were virulent for man and monkeys. They subsequently disappeared<sup>2</sup>.

The authors' second and third papers (iii. 1913, pp. 204-205; and

<sup>1</sup> This experiment is also cited in their paper of iii. 1913, p. 222. They express the belief (p. 223) that the spirochaetes persist in nature through their being hereditarily transmitted in lice. This we know is what occurs with the *Spirochaete duttoni* in the tick, *Ornithodoros moubata*, in connection with the relapsing fever of tropical Africa.

<sup>2</sup> The authors failed to obtain similar results with *Spirochaeta duttoni*, which, as has already been stated, is transmitted by a tick occurring in tropical Africa. In lice fed upon a severely infected monkey, the spirochaetes disappeared within the insects after two hours and they failed to reappear in 69 lice examined. The authors therefore conclude that lice are not suitable hosts for *S. duttoni*.

1913) are practically identical, although the latter (pp. 17-19, 29) gives some details not contained in the former. They cite the work of previous authors, and dismiss it as inconclusive. They express doubts as to the accuracy of Mackie's statement that spirochaetes multiply in lice, this being contrary to what others have since observed. Sergeant and Foley excluded other carriers than lice in connection with the Algerian epidemic they studied. In two experiments, they succeeded in producing infection with lice crushed 5-8 days after an infective feed of blood. Smith also succeeded in one experiment made with crushed lice. The authors cite Lemaire (no reference given) as having tried to infect a monkey by inoculation with two crushed lice and by the bites of infected lice.

Nicolle, Blaizot and Conseil point out that previous investigators lacked two valuable methods in the study of the problem: (1) they did not use the ultra-microscope for the easy detection and observation of spirochaetes, and (2) they did not know the methods of raising lice under experimental conditions. With these aids, the authors determined that the spirochaetes become less motile already a few minutes after they enter the gut of the louse; in 1-2 hours their movement ceases; the spirochaetes then begin to degenerate, and all trace of them within the louse vanishes after 24 hours. They reappear, however, on the eighth, but more usually on the twelfth day, the number per louse being estimated at 10,000 to 20,000. The spirochaetes are now very active. At first they are thin and short, later they attain the normal size they possess when multiplying in human blood.

Sergeant, Foley and Vialatte (3. iii. 1914, pp. 964-965) note that typhus and relapsing fever epidemics may occur together. We have already referred to this as an old and oft repeated experience. The authors, however, record an interesting observation wherein they accidentally transmitted typhus fever to a man and a monkey with the offspring of lice which it had been assumed were only infected with relapsing fever.

Sergeant and Foley (21. iii. 1914, pp. 471-472) describe an experiment wherein lice were removed from a man on the fifth day of his first attack of relapsing fever; the lice, after starving for six days, were crushed in normal salt solution and the infective fluid was dropped into the nose of a monkey with positive result, the monkey suffering from a single attack.

Sergeant and Foley (6. vii. 1914, pp. 119-122) note an earlier observation of theirs which showed that the blood of convalescents is virulent during the first apyretic period although it contains no microscopically



discoverable spirochaetes. In their experiments, in which they infected men and monkeys with lice crushed 1-8 days after the insects had fed on spirochaetosis blood, it was noted that no spirochaetes were discoverable microscopically in the infective material.

The authors confirm the observations of Nicolle and his colleagues that spirochaetes reappear in lice after an interval of about eight days; they rightly lay stress upon the results of their experiments conducted in 1908-11 which demonstrated that lice harbouring no visible spirochaetes, are infective. It is therefore evident that spirochaetes must assume a minute form during the apyrexial period in man, and during a period lasting about eight days in the louse, after the latter has fed on spirochaete-containing blood. The authors conclude that spirochaetes undergo a cycle of development both in man and the louse, this being in accord with the view held by a number of authors, including the writer, that spirochaetes are Protozoa.

Bisset (19. i. 1914, pp. 114-119), who studied relapsing fever in the Meerut Division, India, examined 663 lice taken from patients, and found 26.3% thereof infected; 100 control lice gave a negative result. He only found spirochaetes in the insects' gut and coelomic cavity, and rarely found many after the lice had starved for 5-6 days. Lice infected all the families which suffered from relapsing fever, and the epidemiology of the disease pointed to lice being the only carriers. The author ignores the work already carried out by Sergeant, Nicolle, and their colleagues in Africa.

Toyoda (1914, pp. 313-320), likewise ignored the work of the French observers. He fed body-lice on mice whose blood harboured *S. recurrentis* (Russian strain); he afterwards maintained the insects at 20-25° C., and fed them once daily upon a monkey which did not become infected. The spirochaetes in the lice were active for 4-5 hours, but they disappeared from the gut after 24 hours. A few were present in the coelomic cavity up to the seventh day, as demonstrated in stained sections. Crushed lice were infective for mice up to three days after they had fed on infective blood. He believed that spirochaetes multiply in the coelomic cavity and he found them in the region of the head in lice. Toyoda's results, in the main, confirm those of the French observers, but his experiments were very much less detailed.

Nicolle and Blanc (15. vi. 1914, pp. 1815-1817, preliminary note, and 1. xii. 1914, pp. 69-83) next reported upon five series of experiments in each of which 20 lice were fed upon a monkey with relapsing fever, the lice being subsequently fed upon healthy animals or men

for variable periods of time before they were examined microscopically or used for inoculation purposes after being crushed.

In four experiments, the lice were killed 2-4 days after the infective meal; these lice showed no spirochaetes, and they were not infective. In three experiments, the lice were killed 5-6 days after the infective meal; these lice showed no spirochaetes, but they were infective. Five lots of lice, killed after 10-12 days, showed spirochaetes but none were infective. Exceptions occur, however, with regard to the time when the lice become infective and cease to be so. Thus, in two experiments by Nicolle, Blaizot and Conseil (previously referred to), some lice were found infective on the ninth day, but in this case the spirochaetes are stated not to have attained their full size, and Nicolle and Blanc have found lice to be infective for a man on the third day (one experiment) and for a monkey on the 15th day (one experiment).

If we combine these interesting results of Nicolle and his colleagues with those of Sergeant and Foley, previously cited, they may be tabulated as follows:

Lice on days	Spirochaetes	Infectivity
2-5 after an infective meal	absent	inconstant
day 6	absent	constant
days 8-9	"	"
"	inconstant	exceptional

Therefore the infectivity of the lice does not depend upon the presence in them of microscopically visible spirochaetes. Lice usually become most infective about the sixth day, just before the spirochaetes reappear in them. Their infectivity subsequently diminishes, and it vanishes when the spirochaetes are constantly present and have attained their full size. Lice may occasionally be infective as early as the third and as late as the 15th day after feeding on infective blood.

Nicolle and Blanc reach substantially the same conclusions as Sergeant and Foley. They believe that the spirochaetes in man and in the louse, after attaining their full dimensions, dwindle in size, and become no longer recognizable as spirochaetes. The minute forms are the only ones that are infective and capable of multiplication. It is doubtful if the fully grown spirochaetes undergo division either lengthwise or crosswise as has hitherto been believed.

Nicolle and Conseil (20. i. 1915, pp. 18-20) state that the intravenous administration of arseno-benzol, ludyf, or galyf, causes the spirochaetes to disappear in a few hours. We would add that Ehrlich was the first to discover that arsenic (salvarsan) exerts an immediate specific curative effect on relapsing fever.



### III. MISCELLANEOUS INFECTIVE DISEASES WHICH LICE MAY SERVE TO SPREAD.

Lice have been suspected as possible carriers of plague, typhoid fever, leprosy and beri-beri, the evidence adduced being as follows:

**Plague:** Bulloch and Douglas (1909, p. 374) state, without giving a reference, that Herzog in Manila found *Bacillus pestis* in three head-lice removed from a child dead of plague. Swellengrebel and Otten (vii. 1914, p. 601), in Dutch East India, experimented with clothes-lice taken from the garments of persons dead of plague. The clothes were chloroformed and the insects shaken out after 15 minutes; 24 hours later, the lice were crushed and inoculated cutaneously in lots of 11 to 254 into guinea-pigs. Of nine guinea-pigs that were thus inoculated, seven died of plague. The authors conclude that lice may convey plague under natural conditions by being crushed upon the skin. Raadt (1916, p. 39) took head-lice from a female plague patient, ground them up in salt solution and inoculated rodents therewith; all of the animals (five) thus inoculated died of plague.

There is no evidence that plague can be conveyed by the bites of infected lice, as occurs in the case of fleas.

**Typhoid Fever:** Abe (ix. 1907, p. 1929) believes that lice may play an important part in the spread of enteric fever. We know that *Bacillus typhosus* occurs in the blood, the organism having been found in about 93% of blood samples taken from the roseola spots. Abe, who examined head- and body-lice fed on typhoid patients, found that 75% of the insects harboured the bacilli. This requires confirmation.

**Leprosy:** Joly (1898, pp. 67-70) cites Sabrazès as suspecting lice of carrying this disease. It is well known that *Bacillus leprae* is present in enormous numbers in the skin in cases of cutaneous leprosy. Joly noted the prevalence of lice among the poorer classes in Algeria, these classes furnishing the greater number of lepers in that country. Lice which feed on such lepers cannot avoid imbibing the bacilli; and might well transfer the bacillus from affected to healthy individuals. Leprosy bacilli have since been found in two head-lice out of many examined by McCoy and Clegg (1912, p. 1464). It has still to be proved that lice can convey leprosy.

**Beri-beri:** Manson (1909, p. 627) has advanced the hypothesis that lice may possibly transmit beri-beri, a disease whose cause still remains undetermined.

**Impetigo contagiosa, Pityriasis, Favus and Progenae infections:** Aubert (1879) believed that lice spread impetigo, pityriasis, etc., by acting as predisposing factors and by generalizing the infection. Lice, according to this author, play a specially important part in the spread of favus, "dont les spores trouvent, dans le suintement ou les croûtes d'un impetigo, des conditions favorables de fixation et d'adhérence."

Dewèvre (1892, pp. 232-234) showed by experiment that head-lice may convey impetigo. He removed lice from impetigo cases and placed them on the heads of healthy children, who, some days later, developed impetigo. Lice from healthy children's heads were placed upon the head of an affected child for twenty minutes, and were then transferred for half-an-hour to clean children's heads with the result that 50% of these children became infected. Dewèvre regards lice in the light of mechanical carriers of the infective agents.

Correspondent (1901, p. 918) describes the case of a girl of three years at Toulouse, who died from acute skin infection (nature not stated) brought about by general infestation with lice.

An Editorial (1905, p. 234), referring to a paper by Benenati (*Gaz. d. Ospedali e d. Cliniche*, 26. iii. 1905), gives reasons for doubting that deaths attributed to lice by classical authors were really due to these insects. One of the more recent historical instances of death attributed to pediculosis concerns the case of Ferdinand II., King of Sicily, who died in 1859. The Editorial expresses the view that the King's death was due to pyaemia; the lice upon his person probably caused eczema, followed by secondary infection through the skin.

Brumpt (1910, p. 550) refers to the scratching caused by head-lice as favouring skin-infection and the production of impetigo. The lice gather beneath the scabs in impetigo, the skin secretion becomes viscid, then dries, a characteristic nauseous odour being given off. The scratching that ensues may spread the infection to the face and body, whilst the cervical glands often become involved.

Malcolm Morris (1911, pp. 158-159) advises the physician to look for nits in cases of impetigo contagiosa associated with itching of the scalp.

Salomon (1912, p. 201) writes that head-lice produce characteristic effects, these being (1) impetiginous eczema of the back of the neck, and (2) a condition he has observed in 35 cases and regards as a specific affection: the last phalanges of the fingers, rarely the other phalanges and palm of the hand, show superficial, painless blisters containing either serum, which may be blood-tinged, or else thin pus. The blisters

head lice

head lice

head lice



may attain the size of a two-shilling piece, and are accompanied by multiple phlegmons. He denies that the condition is merely due to *Staphylococcus* infection, and is inclined to attribute it to the effects of the contents of the lice that are crushed upon the fingers.

Sobel (1913, pp. 656-664) who has had a very large experience of pediculosis in school children during 11 years in New York, states that head-lice are the indirect cause of pyogenic infection, frequently leading to involvement of the lymphatic glands followed by suppuration; lice also indirectly cause impetigo contagiosa, dermatitis, furunculosis, eczema, and folliculitis.

Pinkus (1915, pp. 239-241) describes similar sequelae to those mentioned by Sobel, adding that some children suffer from head eczema throughout the winter, getting well in the summer, this being due to the lice that accumulate upon their heads in winter owing to their not being washed because of the cold. In summer the hair of the head is clipped short. The inflammation of the scalp may lead to falling out of the hair.

Eye disease: de Font Réaulx (1912, pp. 385-387) regards head-lice as the cause of phlyctenular conjunctivitis, and cites numerous authors in support of his contention. Hudson (1914, p. 966) states that a common form of eye-disease, phlyctenular keratitis, prevails among Board School children, causing much suffering and corneal scars with resultant disabilities. He refers severer cases primarily to head-lice, infective material being conveyed from the scalp to the eyes by the hands. Improvement, he states, frequently follows the treatment of the head for lice, and anti-lice measures, clipping boys' hair short, etc., are obviously indicated.

Some experiments with pyogenic bacteria, carried out by Widmann (28, ix, 1915, pp. 1336-8), may be mentioned here. This author succeeded in making lice bite mice in which he had produced *Pneumococcus* septicaemia. He failed to infect a clean mouse by allowing 18 lice to bite it 10 hours after they had fed upon infected mouse blood. The louse dejecta were infective during the first 24 hours. The cocci were confined to the intestinal tract of the louse and they did not multiply therein but decreased after 48 hours, and after 60 hours microscopic and cultural examinations gave negative results. He also failed to transmit *Staphylococcus* septicaemia by repeated louse bites during 24 hours after the insects had sucked infected blood; a few living cocci were recovered from the louse excreta after 60 hours but not later.

#### IV. SOME OTHER PATHOLOGICAL EFFECTS ATTRIBUTED TO LICE.

The penetration of lice beneath the skin. That lice may occur beneath the skin is contested by Hebra, but Rust, Forestus, Schenck, Wilnot, Cloquet and others state that lice do occur in this situation. Landois (1865, pp. 501-502) supposed that the lice bored themselves into the skin by their "suckers," and mentions how the jigger, mites, etc., are occasionally found in a similar situation. The supposition of Landois is erroneous, for lice possess no suckers and cannot be compared to jiggers and mites. He quotes Kurz (1832, p. 99) verbatim; this author describes the case of a poor anaemic woman in Vienna, who suffered from rapidly forming swellings, which, on bursting, freed innumerable lice. Landois cites a similar case of a Pole, described by Faulke. In this instance the lice occurred in large numbers and had "bored themselves into the skin," giving rise to "covered louse-ulcers," which, on opening, liberated the contained lice. Kurz also described the case of a Corsican woman who suffered from a cutaneous disease accompanied by serous discharge which formed scabs under which lice were present in large numbers. A number of similar cases are described in the older literature under the name of "Phthiriasis" or "Läuse-sucht," the condition being regarded as a specific disease due to lice. Alt attributed the affection to a distinct species of louse (*P. tabescens* Alt 1824), but he was mistaken, for the insect he described was merely the body-louse occurring in excessive numbers. Murray (1861) described a somewhat similar case.

That the irritation produced by lice may lead to various cutaneous lesions, has already been mentioned, violent scratching can accomplish a good deal and doubtless the effects here described may be attributed in part to the lice alone and partly to secondary invasion of the tissues with various microorganisms. As stated, Hebra denied that lice could occur beneath the skin, but it may be a rare occurrence which that distinguished dermatologist had no occasion to observe. Railliet (1895, p. 828) has seen *Haematopinus* form real subepidermal nests in an old horse.

*Prurigo senilis*, *Urticaria*, *Eczema* and *Porrigo*. Nettleship (1869, p. 435), Squire (1869, p. 549) and Hebra whom he cites, as well as an Editorial (1869, p. 612), referred prurigo senilis to the presence of lice. Nettleship found body- or head-lice present in 52 out of 55 cases. No relation existed between the number of lice upon the person and the



cases, may extend to the mucous membranes, being visible in the mouth. This pigmentation has at times led to a false diagnosis, the condition having been mistaken for Addison's disease. As pointed out in an Editorial (1905, p. 234), there should be no difficulty in distinguishing the two conditions. In grave pediculosis there may be extensive skin maculae, but in Addison's disease the pigmentation occurs in skin regions that are rich in natural pigment; there are no pedicular macules on the mucous membrane; there are no pediculi present. Malcolm Morris (1911, p. 158) also notes the different distribution of the pigmentation in Addison's disease and the absence of the itching which characterizes pediculosis. Pediculosis can, moreover, be distinguished from scabies by the absence of lesions upon the hands and wrists. Pediculosis and scabies have frequently occurred together, especially in the course of the present war. In pediculosis the hands, forearms (and feet) are unaffected. The melanodermia is most marked between the scapulae.

Body-lice attack infested persons chiefly at night or while at rest. They cause a great deal of discomfort and sleeplessness. Apart from the itching due to the effects of the bites and their contact with the clothing, especially when the body is warm, much of the discomfort is attributable to the insects crawling about upon the person. The continued restlessness and lack of sleep may induce considerable irritability, and children, as noted by Sobel (1913), may become anaemic and so run down that their school attendance is much curtailed. Pediculosis is a sore trial to soldiers, as all who have had personal experience will testify.

The immediate effect of the bite varies in different persons, as is well known to those who have investigated the subject. This corresponds with what has been observed with regard to the bites of fleas, bedbugs, mosquitoes and other insects. Some persons state they have a "sensitive skin" and others that they are indifferent to the presence of lice.

Different effects are attributed to louse-bite by various authors; Castellani and Chalmers (1913, p. 1578) state that after the bite has been inflicted, blood flows into the puncture and coagulates, a minute papule forms and is accompanied by much pruritus, leading to scratching. Sikora (viii. 1915, p. 531) denies that the bite causes itching, the author having been bitten about 4,000 times during three months in the course of experimental work. She reports that only about one out of ten lice produces a sensation like the prick of a fine needle when biting; itching only supervened when about 34 young larvae were

## Lice and Disease

amount of irritation produced. In 43 cases the lice were found upon the clothing, in 16 cases upon the head and clothing. The Editorial also refers some cases of urticaria and most cases of porrigio of young persons' heads to the presence of lice and suggests the name "Pedicularia" for diseases caused by lice.

It is difficult to know how much to attribute to the primary effects of lice and how much to secondary effects due to a number of different causes. Head-lice may produce urticaria, eczema and pustular dermatitis, the first two of these being probably primary effects due to the lice themselves and their secretions. In the previous section, reference was made to a condition which Salomon (1912) was inclined to attribute to the primary effects of lice that have been crushed upon the skin of the fingers and head.

Peacock (1916, p. 44) refers to "louse rash" as being distressingly common among the British troops.

Plica polonica. As a result of the eczema or pustular dermatitis accompanying the presence of lice upon the scalp, the exudation from the skin leads to the formation of scabs and crusts, especially about the nape of the neck. In bad cases that are neglected the condition known as plica polonica may supervene; wherein the hair, scabs and crusts become matted together in a solid mass at the back of the head. The name plica polonica had its origin from the condition having been frequently observed among the poor Jewish population of Poland.

## V. PRIMARY EFFECTS OF LOUSE-INFESTATION.

In persons who are infested by lice, the presence of the insects is at once indicated by the reaction which usually takes place about the seat of the bite. The bites produce minute haemorrhagic spots that are chiefly disseminated over the neck, back and abdomen. These spots are accompanied by more or less urticaria, the itching leading to scratching so that the skin appears scored in a linear manner by the fingers. In tramps, chronic drunkards and vagabonds who may harbour lice for years, the skin over the most frequently bitten areas becomes rough, thickened and deeply pigmented, the condition being known as morbus errorum or vagabonds' disease. Pediculosis alone may at times produce fever, which has been attributed to the cutaneous irritation and possibly to the toxic action of numerous louse-bites.

The melanodermia or skin pigmentation above mentioned, in marked

Good  
Seymour

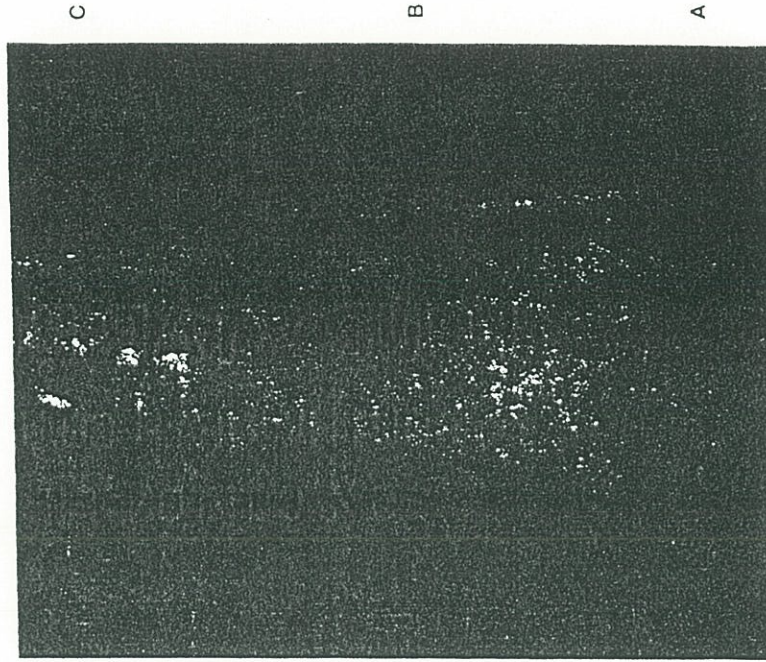


fed upon an area measuring 1.5 cm. across on the back of my hand, no itching followed when they bit above the ankle. The small red areas about the puncture had mostly disappeared within half an hour. Swellengrebel (1916), who allowed lice to bite his arm, observed a slight hyperaemia lasting an hour at the seat of the bite, there being no itching. If, however, he crushed the louse whilst it was feeding, the spot became reddened, oedematous, itchy, and slight necrosis of tissue took place, the spot being visible for 14 days. He ascribed the bad effects attributed to louse bite to the crushing of the insects and the scratching of the part. Bacot (in 1917, p. 235) reported that louse-bites produced more irritation on his person than did the bites of fleas and bedbugs; he attributed the effect of the bite to the insect's saliva.

In this connection I may cite my own experience when raising *capitis* by the wristlet method. I had previously, on repeated occasions, allowed a few *corporis* to bite me and had observed only transitory effects on my arm, the small congested areas about the seat of the bite usually disappearing within half an hour or an hour.

My Laboratory Assistant's arm having become so irritated from feeding many lice that the itching disturbed his sleep, I took over a wristlet (10. VI. 17) in which larvae had begun to emerge a day or two previously and undertook to raise 100 of the insects to maturity, this being duly accomplished. Only transitory effects were observed whilst the larvae were small, but shortly after the first adults emerged the bites began to produce more lasting effects. I nevertheless continued to feed the insects on my wrist, the position of the box being shifted about every 12 hours. As, however, the irritation continued and increased, and the tendency to scratch the bitten arm became difficult to control, I finally shifted the wristlet to the knee on 26. VI. 17. Here the bites produced similar effects to those on the arm.

The accompanying illustration (Plate I) depicts the inner surface of the forearm as it appeared six days after the last use of the arm as a feeding ground. The irritation had already begun to subside. The arm shows three patches (A, B, C) where bites had been inflicted. At (A) the bites form a circular pattern due to the lice having fed but once through the floor of the box, the latter not having shifted during the feeding period, at (B) at least two feedings occurred, the feeding areas overlapping, whilst at (C) a succession of about six feedings took place. At (A) the louse rash appears as a number of discrete conical elevations on papules, a few being confluent; these elevations were best seen by oblique light and could be felt by running the hand over the arm; the



Illustrating the after effects of the bite of head lice upon the author's arm.  
(For description refer to p. 72.)



centre of each papule was congested and it was surrounded by a small pink halo; each papule arose from a separate bite<sup>1</sup>. At (C) the whole area appeared fairly sharply defined, reddened, and dotted over with slightly darker nodular elevations, the skin feeling roughened and markedly thickened; it itched a good deal for several days. On stretching the skin a yellowish-brown discoloration was observable at the seat of each bite and over the whole area at (C). By 16. VII. 17, all traces of the bites at (A) had disappeared, at (B) there was still some discoloration and roughness. At (C) the incipient melanoderma gradually faded away but faint traces persisted until 28. VII. 17, it had lasted a month; slight thickening of the skin was still observable on 16. VIII. 17.

My Laboratory Assistant's arm, which has been used as feeding ground for months, shows well-marked diffuse bronzing over the whole surface on which the lice have fed. It will doubtless take longer for the bronzing to disappear than in my case.

Hase (XI. 1915, pp. 153-163), who studied the effects of lice on behalf of the War Office in Germany, reports upon some suggestive observations he made. He states that he questioned 1,000 persons on the subject, and that he was able to place them under four groups: (1) persons who are not attacked by lice, (2) who are attacked continuously and are sensitive to bites, (3) who, after suffering much from bites become immune to their effects, and (4) those who have been bitten continuously but do not suffer from the effects. Groups (3) and (4) he regards as dangerous "carriers," since they do not complain. The prevalence of lice among Russian civilians, and the marked tolerance shown by them to louse-infestation, is regarded by Hase as doubtless due to a process of immunization commencing in childhood. The author gives no figures as to the relative numbers of persons in each of the groups he distinguished. He mentions the cases of (1) a man who remained untouched by lice but who suffered from fleas, (2) a man who suffered from the effects of lice and fleas, and (3) a man who was bitten by lice but avoided by fleas.

That a tolerance to the presence of lice upon the person can be acquired in a relatively short time by some individuals, is evident from what a number of soldiers have told me. They have stated that after having been tormented for about a couple of months they no longer experienced any particular discomfort from the insects they harboured.

<sup>1</sup> The adults were removed as they emerged, therefore there were fewer bites inflicted toward the end of the experiment.



#### VI. NOTE ON THE PRESENCE OF ANTICOAGULINS IN THE SALIVARY GLANDS OF *P. HUMANUS*.

That anticoagulins are present in the salivary glands of lice was demonstrated by the following experiments conducted with clothes-lice received in May, 1916, from Dr Hamer in London. The method pursued was that described by Nuttall and Strickland in connection with similar experiments made on *Argas persicus* (see *Parasitology*, I. 305). The salivary glands of the lice were dissected out and rubbed up in a minimum quantity of salt solution to which was added an equal volume of blood drawn up into a capillary tube from the pricked finger-tip. The blood and gland extract were mixed and placed in capillary tubes at 14°C.

Expt. I. - Blood + glands of 4 lice  
(2 tubes) coagulated after 40 minutes.

Control showed coagulation in 12 minutes.

Expt. II. - Blood + glands of 4 lice  
(2 tubes) coagulated in 60 minutes.

Control showed coagulation in 15 minutes.

#### SUMMARY AND CONCLUSIONS.

The term Pediculosis denotes the pathological condition brought about by infestation with *Pediculus humanus*, either the head or the body or both of these being affected. Pediculosis may lead directly or indirectly to secondary infections of various kinds. *P. humanus* (*corporis* and *capitis*) has been shown to be the carrier of two important diseases affecting man, namely typhus and relapsing fever.

#### Typhus fever.

The earlier evidence which is cited regarding the epidemiology of typhus, is all in accord with the discoveries proving that *P. humanus* conveys the disease and is the sole agent in its spread<sup>1</sup>.

The geographical distribution of typhus is more restricted than that

<sup>1</sup> Zlatogoroff (in F. Kraus and T. Brugoch's *Spez. Pathol. u. Therap. inner. Krankh.* II. 682; cited by Eysell, IV. 1915, p. 238) is reported as stating that naked negroes on slave ships escaped typhus although they suffered much from other diseases. I have been unable to verify the reference, but as a piece of epidemiological evidence it is worth mentioning.

Body lice transmit clothing lice even but unlikely.

of *P. humanus*, the disease being confined essentially to cool and temperate climates<sup>1</sup>.

The virus of typhus occurs in the blood of affected individuals. Blood collected on the 3-10th day of the attack has been found to be virulent. The evidence as to the nature of the virus is still contradictory. The virus can be maintained in undiminished virulence by passage through animals (chimpanzee, monkey, guinea-pig).

Infection occurs through the bite of infective lice or through such lice being crushed upon the skin when the latter is scratched. Lice which have sucked blood containing the virus are capable of producing infection during 7-11 days after they have infected themselves. If such lice are flushed 9-14 days after an infective feed, or if their faeces are collected 3-6 days after they have fed on infective blood, their contents and faeces respectively are capable of producing infection if placed upon the excoriated skin. It has not been determined how long lice remain infective when once contaminated. The evidence regarding the hereditary transmission of the virus in the louse is contradictory.

Lice are invariably present in connection with typhus outbreaks. The destruction of lice upon a typhus patient renders him innocuous. The prophylaxis of typhus consists in louse destruction. Bedbugs and fleas do not convey the disease.

Recent experience is in agreement with observations, dating from 1739, in respect to the occurrence of typhus and relapsing fever side by side in epidemic form.

#### Relapsing fever.

Epidemiological evidence, as in the case of typhus, points to relapsing fever being louse-transmitted. The two diseases occur under like conditions: personal filth and squalor, the close contact of persons through overcrowding, facilities being offered for the propagation of lice by the continuous wearing of clothing day and night for weeks or months on end. All recently collected evidence (from India, North Africa,

<sup>1</sup> This appears to me to be due to the relatively restricted number of lice present on the populations of warm countries owing to the insects being largely confined to the head, the light garments or slight clothing worn affording unsuitable conditions for a considerable propagation of lice upon the body, and the high temperature to which they are exposed in proximity to the body in warm countries affecting the body-lice adversely. The louse population per man is usually much greater when the body is infested than when the head is affected, and the chances of lice finding a fresh host are greater among heavily clothed populations. The factor of temperature and its possible influence on the virus in the louse must likewise be taken into account. (See under *Biology of Pediculus humanus* pp. 80 et seq.)

A  
On the  
Noble  
Carpenter  
London.



Germany, Russia and Serbia) proves that lice are constantly present on infected persons. These remarks apply equally to typhus, which, as already stated, may coexist with relapsing fever in epidemic form. Judging from the accessible records, relapsing fever appears to be somewhat more restricted than typhus in its geographical distribution. It has been conclusively demonstrated by carefully conducted experiments that *Pediculus humanus* serves as a carrier of *Spirochaeta recurrentis* the causative agent, from man to man.<sup>1</sup>

When lice imbibe infected blood, the spirochaetes disappear rapidly from their alimentary canal and are not discoverable even by the ultra-microscope for a period of about 2-6 days after the insects have fed. The spirochaetes reappear in the coelomic fluid of the lice usually on the 8-9th day. They at first appear small, but, as time proceeds, they attain the dimensions and appearance they possess in human blood during the attack. When lice feed on infective blood, the number of insects that become infected with spirochaetes ranges from 10 to 42 %.

The spirochaetes are hereditarily transmitted in the louse, for the offspring of an infected female has been shown to be infective. This persistence of the spirochaetes in the louse no doubt serves to maintain them in nature. It has only been through the successful raising of lice under laboratory conditions, coupled with the use of monkeys and occasionally man for infection experiments, that it has been possible to demonstrate the phenomena herein described.

Although lice may be infective for a few hours after they feed on relapsing fever blood, it is probable that infection will rarely occur by their transference from man to man soon after feeding. When a louse has fed, it usually remains quiet, whilst digesting its meal. When lice have hungered for any length of time, as we have frequently observed, they feed to excess and take a longer time to digest the large amount of blood imbibed. If such lice are kept cold the process of digestion is impeded, and I have no doubt that any spirochaetes which they may harbour will remain virulent for longer periods, as I found was the case in bugs (see footnote 2, p. 60). How long gorged lice may remain infective at a low temperature remains to be determined. The experiments herein recorded point, however, to a rapid loss of infectivity in

<sup>1</sup> Töpfer (31. x. 1916, p. 1671) has the temerity to state that the work of Sargent, Nicolle, and their colleagues, is not "einwandfrei." He then proceeds to repeat their work. A few comparatively trivial experiments are described which are merely confirmatory, but in his opinion (!) afford the first demonstration that lice convey relapsing fever. Töpfer's behaviour in this matter, flimsy speaking, is thoroughly disbonest.

lice under ordinary conditions prevailing after an infective meal. The spirochaetes vanish in lice in which they subsequently reappear. Just before their reappearance, usually on the sixth day, but at times on the third to the fifteenth day, the lice have been found to be most infective. The infectivity of the louse does not depend upon the presence in its body of visible spirochaetes, in fact when spirochaetes reappear and attain their full size the lice are non-infective (Nicolle). This, coupled with the observation that human blood is infective during the apyrexial stage when spirochaetes cannot be found in the blood (Sergent and Foley), certainly bears out the view which I have upheld with others, that spirochaetes are Protozoa, for they obviously undergo a cyclical development in both the vertebrate and arthropod hosts. Nicolle advances the view that the typical spirochaete is incapable of multiplication or that it rarely divides, and that multiplication and consequent infectivity are entirely or largely confined to the minute forms which may coincide with the "coccoïd bodies" of some authors, assuming that they are not ultramicroscopic.

It has been proved that lice do not convey relapsing fever by their bites. As Nicolle and his colleagues have shown, persons may be bitten many thousands of times by infective lice with impunity. Infection takes place through the lice being crushed upon the skin which is commonly exoriated by the self-inflicted scratches of the individual harbouring the lice. Infective material may, moreover, be carried on the fingers to the nose or eye, and it has been demonstrated experimentally that the spirochaete is capable of invading the system through intact mucous membranes.

The period of incubation, under experimental conditions, as observed in man and monkeys following infection through the exoriated skin or intact mucous membrane, is 6-8 days, when crushed lice in the infective stage are used. This corresponds with clinical experience. A single infective louse, crushed upon the exoriated skin, has produced relapsing fever. Persons have been experimentally infected by placing infected lice upon their persons without their knowledge. Happily for these subjects and for the experimenters who intentionally infected themselves, the course of the disease can be cut short by the arsenical treatment discovered by Ehrlich.



Miscellaneous infective diseases which lice may spread.

It is reasonable to suppose that plague may occasionally be conveyed through the agency of infected lice that are crushed upon the person, the bacilli, recently ingested by the insects, entering through the excoriated skin.

Mycotic or pyogenic infections like favus, pityriasis, impetigo contagiosa, furunculosis and more generalized suppurative processes, may be spread by lice acting as mechanical carriers, the microorganisms perhaps merely clinging with the aid of pathological exudations to the outer surface of the insects. The irritation and consequent scratching induced by lice lead to the dissemination of the disease agents upon the person, the latter spreading the infection by auto-inoculation of the excoriated skin.

Various pathological conditions, other than those above mentioned, are cited as being attributed to the presence of lice; a number of these are referable to secondary infective agents, coupled with the general lowering of the infested individual's vitality induced by pediculosis.

#### Primary effects of infestation with lice.

In biting, as I have found by tests upon my arm, the louse produces a slight transitory pricking sensation or no sensation whatever; it is only after an appreciable interval that the seat of the bite begins to itch, this being after the louse has left. The reaction at the seat of the bite varies considerably in degree, it may be so slight as to be negligible or it may cause much itching. In the first case a minute congested spot is visible at the point bitten; the redness about the puncture may vanish in about half-an-hour or it may persist longer. In the second case a variable degree of oedematous swelling surrounds the puncture and forms a papule accompanied by pruritus. When bites are repeatedly inflicted on the same spot the papules coalesce, the skin becomes roughened, reddened, thickened, and more or less pigmented. The effect of the bites of individual lice varies even when they are allowed to feed without interruption. The amount of reaction following louse-bite varies in different persons. As the result of being frequently bitten, some persons acquire immunity to the effects of the salivary secretion of the louse, the secretion having, as evidenced by the reaction, some degree of toxicity. I have found that the secretions of the two sets of salivary glands of the louse (the reniform and con-

voluted glands) contain a substance which retards the coagulation of the blood.

The urticaria, eczema, and cutaneous pigmentation extending at times to the mucous membrane, are primary effects due to pediculosis alone.

#### REFERENCES.

The reader is referred to the Bibliography on pp. 1 et seq.



THE NUMBER OF *PEDICULI* THAT MAY INFEST A PERSON.  
CORPORIS.

No enumerations have hitherto been made on highly infested persons. A medical friend, who attended confinement cases among the poorest classes in Edinburgh, once gave me a graphic description of the thousands of lice he beheld upon the body of a patient whose skin had a greyish colour owing to the huge numbers upon it.

Haas (1915, p. 13), who enumerated the lice on a very verminous Russian, was disappointed to find but 3800 in all stages of development, having expected a larger total. Peacock (1916, pp. 45-52) gives some interesting figures relating to British troops in the present war: of the infantrymen examined, 274 (95%) were infested with an average of 20 lice per man after 6 months' active service; about 5% harboured 100-300 lice apiece. The number in some cases ranged from 168 to 895 per man, and Peacock estimated that one shirt held 1355 lice and 4260 nits, whilst another shirt contained no less than 10,428 lice and 10,253 nits. To these cases I may add that in a shirt worn by an old woman on admittance to Lambeth Workhouse in June, 1915, we found ca. 600 lice in all stages coupled with innumerable nits (Lot 204).

CAPITIS.

The number of head-lice that may occur upon a person is enormous; no enumerations have hitherto been made in heavily infested persons.

In the case of a paralytic woman, aged 45, who was admitted to a Poor House Infirmary in May, 1917, and whose hair and vermin were removed in my presence, I enumerated the lice and found 1004 present of all stages (208 adults and 796 larvae), coupled with innumerable nits; in the opinion of the sister in attendance, the case represented a very mild degree of infestation compared to others that have been admitted to the same institution. The woman's clothes harboured a few *corporis* (8 adults and some larvae) in addition.

In June, 1917, Captain Orr of the Canadian Sanitary Corps, stationed in Surrey, sent me the pubic hair shaved from a soldier. The hair harboured 82 lice (76 adults and 6 larvae), 2544 unhatched and 2636 hatched nits. The number of nits was estimated from a count made of one-quarter of the hair mass. The soldier was not infested with lice other than *capitis*.

SEASONAL VARIATION IN THE NUMBER OF LICE ON MAN.

On the ground that typhus is chiefly a disease which prevails in camps in winter, Kiskalt (13. v. 1915, p. 379) concludes that its increase at this season cannot depend merely upon the numerical increase of lice, for no seasonal variation in the number of lice was observable in Berlin. Several authors have sought to attribute the increase of typhus to a corresponding augmentation in the numbers of lice in winter.

Beginning with the year 1909, Dr W. H. Hamer, of the London County Council, conducted observations upon the prevalence of fleas, bugs and lice in the beds and bedding of common lodging-houses. The population of such houses is not stationary. Hamer's report for 1910 (p. 7, Diagram IV) illustrates the prevalence of the insects during the preceding year (1909). Inspectors examined the beds in 11 districts,

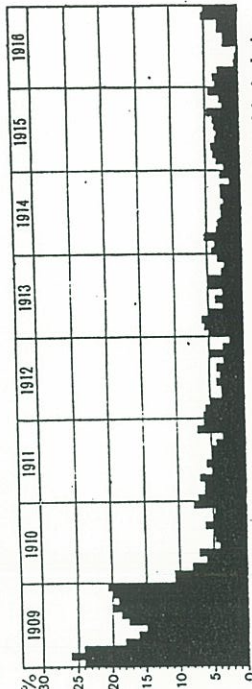


Fig. 1. Chart illustrating the variation in the percentage of louse-infested beds during the years 1909-1916, in London; the black columns represent the monthly records. The seasonal incidence is most clearly shown in 1909 and 1916. Curve constructed from data kindly supplied by Dr W. H. Hamer, of the London County Council.

"ten beds being examined daily on five days out of seven making a total of 550 beds weekly." The sheets of each bed were carefully scrutinized for lice. The louse-infested beds ranged from a maximum of 31% to a minimum of 12% in the first weeks of February and June respectively. The beds were found most frequently verminous in January-February; few were found infested in April-June, after which the curve gradually rose, attaining a fairly high point in August-October. The autumn rise appears partly attributable to the return to London, on the approach of winter (Sept.-Oct.), of hop-pickers who are frequently verminous, tramps and others coming later.

Dr Hamer has most kindly supplied me with data relating to the prevalence of lice in common lodging-house beds during the years

(with Hamer's report)



1909-1916, and the accompanying chart, which I have drawn, comprises the records for the whole period 1909-1916, the percentage of infested beds being shown in monthly columns. Dr Hamer informs me that he attributes the remarkable fall in the curve since 1909 to the undoubted improvement in the condition of the beds consequent upon the increased attention directed to them as the result of his investigation.

Hamer (1910, p. 7) refers the greater prevalence of body-lice in winter in London to the clothes being less frequently changed and washed at this season. Sergeant and Foley (vi. 1910, pp. 337-373) observed a similar increase of lice during winter in Algeria, when the indigenous population wear their clothes continuously for weeks, few lice being found on their persons in summer when light clothes are worn, the children wearing hardly more than a shirt. Müller (1915, p. 53), in Austria, refers the increase of lice in winter to woollen clothes being more suited to lice than lighter fabrics. Klemperer and Zimm (ii. 1915, p. 324), in Germany, attribute the subsidence of typhus in summer to the effect of heat in killing off the lice, probably basing their statement upon the observations of Anderson and Goldberger in Mexico (see p. 90). Hase (xi. 1915, pp. 160-163) attributes the much lessened prevalence of lice in the German army, during the preceding summer, to three causes having been in operation: (a) the heat, (b) increased personal cleanliness, and (c) greater experience in dealing with lice; he states (p. 158) that lice are more frequently encountered on the outer garments in warm weather. An increase of pediculosis capitis in winter has been observed in children by Pinkus (1915, pp. 239-241) owing to the hair being allowed to grow and its not being washed because of the cold (see the section on lice and disease, p. 68).

From the foregoing evidence, we may regard it as established that there is an increase in the louse population in the winter months and a decrease in summer. Kisskalt's figures (p. 87), showing that there is no special difference in the number of verminous persons admitted to Berlin refuges in winter and summer, do not disprove this general conclusion, since they fail to take into account the probably increased louse population per man and relate but to a very limited class of persons.

Leeuwenhoek (ed. 1807, p. 163) already noted that lice particularly trouble those who cannot change their apparel frequently; such persons are necessarily unclean. It is a matter of common knowledge that the poorer classes are more prone to wear their clothing continuously and that they are more unclean in winter than in summer. During

the present war, the incidence of lice on troops who could not perforce change their clothing except at long intervals, and who could not keep themselves clean, proves how important these factors are in relation to the incidence of pediculosis. Moreover, in winter, in normal times, people congregate more in houses, and the chances of infestation spreading are greater because of increased personal contact and the increased shedding of lice by the more heavily infested individuals. In summer the clothing is lighter, either fewer garments are worn or they are of lighter material, people huddle together less, clothing is more often changed, and there is more personal cleanliness.

Apart from the factors above mentioned, which may influence the seasonal prevalence of lice on man, the climatic conditions prevailing in clothing deserve mention. Rubner<sup>1</sup>, who uses the word "Kleidungsklima," writes of it only in relation to man, but it is of equal importance to the louse. The temperature of the skin, when comfortably clothed, usually ranges, according to Rubner, between 30° and 32° C., the air temperature between succeeding layers of clothing falling toward the exterior, being lowest in the outside layer. The nearer the skin, the higher the temperature and the drier the air; *the air is very dry near the body*, and it is more charged with water in the outer layers of clothing in proportion as the air grows cooler.

In the heat of summer, there is an increased amount of moisture given off from the skin, and with or without physical labour, there may be so much watery vapour given off as to render the innermost atmospheric layer almost or completely saturated, condensation taking place upon the clothing so that it becomes wet, with the consequence that the temperature of the skin rises. It has been observed in febrile conditions, that lice wander away from the host, and moreover, lice have been observed more frequently upon the outer garments in summer. Evidently the overheated body-surface and the excessive moisture are uncongenial to lice. Needless to say, active perspiration would lead to their being flooded out or driven away, especially from their usual haunts where the clothing lies most closely applied to the body-surface. It is these parts of the clothing that become wettest when active perspiration sets in. It appears to me a fair hypothesis, therefore, that the climatic conditions prevailing in clothing in summer are on the whole less suited to the body-lice than in winter. This hypothesis is, moreover, borne out by the following evidence.

That a few degrees higher temperature than that normally found

<sup>1</sup> Rubner, M. (1911), "Die Kleidung" in *Handbuch der Hygiene*, i. 600-606.



### Biology of Pediculus humanus

94

#### THE DISTRIBUTION OF CAPITIS ON MAN'S BODY.

As a rule *capitis* occurs on the head, mostly about the occiput and about the ears (see Plate III, and its legend). A number of authors state that it only occurs upon the head, but this is incorrect. Pinkus (1915, p. 239) writes that it is "strictly limited" to the head, but contradicts himself in the same paper by mentioning that it occasionally occurs on the body hair, extending to that of the pubis; he adds, however, that it does not proliferate there and that it has no significance in this situation. Several authors record the presence of *capitis* on the body. Denny (1842, pp. 14, 17) states that it doubtless prefers the head, yet it will stray over every part of the body, and he cites an observation of his own made at Leeds (see mention thereof on p. 96). Piaget (1880, p. 622) writes that it occasionally occurs on any part of the body and has consequently been at times confused with *corporis*. Brauer (1915, p. 561) finds that *capitis* not rarely occurs on the body. Heymann (18. viii. 1915, p. 304) states that in heavy infestations it spreads all over the body and clothing; according to an observation communicated to him by Wodermann. Lydston (cited by Brumpt, 1910, p. 550, no reference) records its occurrence on the pubis. I describe a case of pure pubic infestation (see p. 86) wherein *capitis* proliferated actively in this situation.

We may conclude that *capitis* usually occurs upon the head, that it may spread over the body, establishing itself on other hairy parts, and that it may be confined to the pubic hair and proliferate there as my case demonstrates.

#### MODES OF INFESTATION AND DISSEMINATION OF PEDICULUS.

In considering the modes of infestation, it is well to bear in mind the power possessed by lice of clinging to hair and cloth. This clinging power constitutes an essential factor in their dissemination. If pediculi, especially when hungry and agile, are placed in a glass dish, they promptly cling to a piece of cloth or camels' hair brush, or to a single human hair that is brought in their vicinity; in fact this is the quickest way of collecting them out of the dish. Numberless *capitis*, under these circumstances, will cling in line upon a single hair, and they are not readily removed by forceps, for, if the grip of a leg upon the hair is loosened, another leg or two at once grasps the hair. If head-lice, thus attached to a hair, are dropped into 70% alcohol, the insects will all die *in situ*; they appear to excel *corporis* in point of tenacity.

In the case of *corporis*, the nature of the external clothing must play an important part in respect to its liability to pick up lice that are brought in contact with it. The rougher the surface the better it is for lice to cling to. A somewhat similar instance is afforded by certain ticks which infest long-haired dogs much more readily than those that are smooth-haired. The slightest effort only is required of the louse to cling to rough cloth, one might almost say that no effort is needed for dead lice can be readily picked up with a piece of rough cloth, because the six long and sharp claws on the feet penetrate among the fibres like so many fine curved needles. On the other hand, owing to the structure of the louse's feet, it is incapable of clinging to smooth surfaces, and a knowledge of this has led to the very general use of smooth overalls (oilskin, rubber) and foot wear for those who are exposed to louse infestation. In the laboratory, we often keep the lice we are raising in wide-mouthed unstoppered bottles, knowing that they cannot escape because they are unable to creep upward on clean glass, and, even when it is horizontal they tumble about on it and make no headway.

When *corporis* are once established in clothing they are but moderately influenced by its character. Clothing composed of rough woolly fabrics, especially where there are numerous folds and seams, affords the best protection to them. The use of silk underwear has been much advocated as being a protection against lice, on the assumption that it affords them a poor foothold and that they are less prone to oviposit upon it. There is no doubt, relatively speaking, that silk is not as suited to the louse as woollen materials, but it affords no safeguard against continued infestation. Lice oviposit upon silk without difficulty (see p. 132) and they cling well to silk fabrics, especially tricote. Pinkus (1915, p. 24) states that he once saw a lousy rabbi in Warsaw who was clothed in silk.

The main influence in permitting infestation to attain a severe character consists in the continuous wearing of clothing. This has been brought home to everybody in the present war. In former times, when lousiness pervaded all sections of society from king to beggar, it was observed that lice "especially trouble persons who cannot change their linen or other apparel frequently"; thus wrote Leeuwenhoek in the seventeenth century, at a time when most people ordinarily harboured a few lice. The frequent change of apparel was the agency which kept the numbers of the vermin down to a normal standard, for the louse population, clinging chiefly to the clothing, was removed periodically, thereby reducing the number upon the person sufficiently for practical purposes.

When examined in different parts of the body, the lice are found to be more numerous on the head than on the body.