Further reports (no. 6) on flies as carriers of infection.

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REPORTS

TO THE

LOCAL GOVERNMENT BOARD

ON

PUBLIC HEALTH AND MEDICAL SUBJECTS.

(NEW SERIES No. 85.)

Further Reports (No. 6) on Flies as Carriers of Infection :—

1. *Empusa Muscæ* and the Extermination of the House-fly, by Dr. Güssow.
2. Hibernation of House-flies (Preliminary Note), by Dr. Copeman.
3. Further experiments on the Range of Flight of *Musca domestica*, by Prof. Nuttall, Mr. Merriman, and Dr. Hindle.
4. Note on the Colour-preference of Flies, by Dr. Hindle.
5. Further Observations on Non-lactose Fermenting Bacilli in Flies, and the Sources from which they are derived, with special reference to Morgan's bacillus, by Dr. Graham Smith.

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To the Right Honourable John Burns, M.P., President of the Local Government Board.

Sir,

In presenting the present continuation of investigations on Flies as Carriers of Infection, it is convenient to summarise the investigations previously carried out, as well as those described in the following pages.

In view of the importance of the subject, in 1908 you authorised an investigation into the possible carriage of infection by flies. This has been carried out under the general supervision of Dr. Monckton Copeman, in co-operation with Professor Nuttall, Quick Professor of Biology in the University of Cambridge. The investigation was expected to extend more or less intermittently over several years, and to comprise the following scheme of work:—

(1) The preparation of a digest of work done on this subject up to date.

(2) Detailed study of the natural history of the various house-flies, including the characteristics and duration of the various stages in their life-history; identification of the chief breeding and hibernating places; the systematic collection and identification of flies in different places and at different seasons; experimental determination of the possible extent of the flight of house-flies, vertically as well as horizontally; and the bacteriology of flies.

Up to the present time six reports have been issued. They are numbered respectively 5, 16, 40, 53, and 85 in the New Series of Reports to the Local Government Board on Public Health and Medical Subjects.

The following summary of investigations not contained in the present report is reproduced in the main from the Annual Reports of the Medical Officer to the Board for 1910-11, pp. lxiv. to lxix., and for 1911-12, pp. lxxv. to lxxvii.

I. The first report (No. 5) contains the following articles:—

(1) How to Distinguish the more Important Species of Flies found in Houses.

(2) Mr. E. E. Austen's Notes on Flies examined during 1908.

(3) Mr. Jepson's Report on the Breeding of the Common House-Fly during the Winter Months.

Of these papers the first gives a tabulated statement of the distinctive features in their various stages of the more important flies found in houses. It was compiled by Mr. E. E. Austen of the British Museum (Natural History), and his authoritative descriptions are illustrated by a series of plates, the figures in which were specially drawn from nature by Mr. Terzi.

In this paper also Mr. Austen emphasizes the fact that *growth* in these insects is confined to the *larval stage*: although flies feed, they do not grow, consequently individuals apparently below the normal size either belong to distinct species, or have

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originated from larvæ which were prevented from attaining their full dimensions owing to failure of their food-supply. These remarks bear on the fact that specimens of *Homalomyia canicularis* are sometimes supposed to be "young house-flies."

Mr. Austen's notes on flies sent to him for examination in 1908, showed that in every case *Musca domestica*, Linn., largely outnumbered the other species. After this the commonest species were *Homalomyia canicularis*, Linn., *Calliphora erythrocephala*, Mg. (the blue-bottle), and *Muscina stabulans*, Fln. He notes the occurrence of *Protocalliphora grœnlandica*, Ztt., in Bermondsey, as worthy of special mention. Larvæ of this fly, which feed as a rule on carrion, are evidently imported in sacks of old bones received at a local glue and size works, and it is possible that the species also breeds in these works. *P. grœnlandica* is not a species which is ordinarily found in dwellings, even in the country. Its occurrence in some numbers on August 10th, in the kitchen of a London County Council School about 150 yards from the glue and size works in question, is therefore, specially noteworthy.

Mr. Jepson's observations on the breeding of the common house-fly (*Musca domestica*) during the winter months show that flies do not disappear altogether during the winter, but may be found in places where the temperature conditions, &c., are favourable. Whether under such circumstances they ordinarily continue to breed as in the warmer months cannot be said, but under experimental conditions they *will* breed in winter. On the other hand, the fact that flies captured during the winter appear more hardy and long-lived than those taken and kept under the same conditions in the summer, seems to support the view that the former may persist throughout the winter as adults.

II. The contents of the second report (No. 16) are as follows:—

(1) Memorandum on Lines of Investigation: by Dr. Copeman.
(2) Notes on Colouring Flies for Purposes of Identification: by Mr. Jepson.
(3) Preliminary note on Examination of Flies for the Presence of *Bacillus coli*: by Dr. Graham-Smith.
(4) Abstracts of Literature and Bibliography: by Prof. Nuttall and Mr. Jepson.

In his preliminary memorandum Dr. Copeman set out certain conditions as necessary for securing comparable data.

Mr. Jepson, working at the colouring of flies for purposes of identification, showed that the employment of finely-powdered coloured chalks gave the most satisfactory results, and that of the colours employed *Yellow* and *Brick Red* were the best, lasting in the first case for nine days and in the second case 20 days. The dusting was accomplished by placing the balloon containing the flies in a paper bag, pouring in the ground-up chalk, and gently shaking it about. By this means the flies became completely covered with chalk, which persistently adhered to the upper portion of the thorax and the base of the wings.

Dr. Graham-Smith's preliminary note on the presence of the colon bacillus dealt with the examination of 148 flies, mainly

M. domestica. In 60 cases the surface organisms, and in 88 cases the intestinal contents, were examined. Dr. Graham-Smith states that, so far as can be inferred from the small numbers hitherto examined, the highest degree of infection is found amongst the flies obtained from the neighbourhood of decaying animal matter, and the next highest amongst those caught near manure.

House flies, small flies, and blue-bottles were found to be infected in approximately equal numbers. Surface infection was two-and-a-half times more common than intestinal infection.

Attention was first confined to those coli-like organisms capable of producing acid and gas in lactose, but, later, certain other organisms were examined. Amongst these an organism which corresponds in its cultural reactions with *B. dysenteriæ* (Flexner) was isolated on two occasions, once from the intestinal contents and once from the surface of a fly.

Professor Nuttall and Mr. Jepson contributed a summary of the literature dealing with the spread of infective diseases by *M. domestica* and allied (non-biting) flies. Taking the monograph by Nuttall (1899) as a basis, they brought the literature up to date.

The evidence collected by them appears conclusively to incriminate house-flies, of which *Musca domestica* may be regarded as the type, as carriers of cholera and typhoid fever, and the prevalence of flies, especially where privy-middens persist, becomes an important index of the possibilities of spread of infection.

Attention is also directed in their report to the fact that a fly may cause *relatively gross infection* of any food upon which it alights after having fed upon infective substances, whether typhoid, cholera, or diarrhœa stools. Not only is the exterior of the fly contaminated, but its intestine is charged with infected material which may be discharged undigested upon fresh food which the fly seeks. Consequently, the excrement voided by a single fly may contain a greater quantity of the infective agents than, for instance, a sample of infected water.

A bibliography of the literature on the subject was appended to the report by Professor Nuttall and Mr. Jepson.

III. The third report (No. 40) included the following papers:—

(1) Observations on the ways in which artificially infected flies (*Musca domestica*) carry and distribute pathogenic and other bacteria: by Dr. Graham-Smith.

(2) Summary of literature relating to the bionomics of the parasitic fungus of flies (*Empusa muscæ*): by Dr. Bernstein.

(3) Note as to work in hand but not yet published, and as to proposed further work in reference to Flies as Carriers of Infection: by Dr. Copeman.

The experiments recorded in Dr. Graham-Smith's paper, were undertaken to ascertain during what periods of time certain micro-organisms could be recovered in culture from the legs and wings, the crop and intestinal contents, and the fæces or other deposits of flies artificially infected by feeding on cultures. Some observations were also made on the infection of food materials by flies, and on the infection of previously uninfected flies, by means of the deposits of infected flies.

The general conclusions arrived at were as follows:—Flies feed readily on various fluids such as syrup, milk and sputum. The food first passes into the crop, and subsequently, if the meal is continued, directly into the intestine. If the meal is discontinued after the crop has been distended, its contents gradually pass, during the next few hours, into the intestine. After a meal, flies usually regurgitate some of the contents of their crops through the proboscis. When feeding on semi-fluid or solid soluble materials, flies frequently moisten or dissolve them by means of the regurgitated fluid or "vomit." On such substances as partially dried milk, imprints of proboscides are frequently seen. A fly which has access to abundant food produces between 15 and 30 deposits (vomits and fæces) in 24 hours.

Infection experiments show that non-spore-bearing pathogenic bacteria do not usually survive more than a few hours (5-18) on the legs and wings. Nevertheless flies allowed to walk over sterile agar plates may cause infection for several days. This seems to be due to the fact that they frequently attempt to suck the surface, and in so doing infect it with fluid regurgitated from the crop. Within the crop non-spore-bearing bacteria frequently survive for several days, and they usually survive even longer in the intestine. No evidence of multiplication in either of these situations has been obtained. The fæces deposited by such flies often contain the organisms in considerable numbers for at least two days, and are frequently infective for much longer periods. Anthrax spores survived for many days on the exterior and in the alimentary canal.

In the experiments described, gross infection was produced in most cases by emulsions of pure cultures. It is improbable, however, that under natural conditions flies would often have the opportunity of feeding on materials which contain pathogenic organisms practically in pure culture. Consequently it would be premature to conclude that the experiments and observations described in this paper do more than indicate that, under exceptionally favourable conditions, certain bacteria can be recovered from the contents of the alimentary canal and fæcal deposits of infected flies for several days after infection; and that these flies are capable of infecting certain materials on which they feed for several days. The experiments with tubercular sputum and anthracic blood, however, afford evidence as to the duration of life in the contents of the alimentary canal, of pathogenic bacteria taken up under natural conditions.

IV. The fourth report (No. 53) contained the following papers:—

(1) An Experimental Investigation on the Range of Flight of Flies: by Dr. Copeman, Prof. Howlett and Mr. Merriman.

(2) Memorandum on the Result of Examinations of Flies from Postwick Village and refuse deposit: with a

note on the occurrence of the Lesser House-fly at Leeds: by Mr. Austen.

(3) The part played by Flies in the dispersal of the eggs of Parasitic Worms: by Dr. Nicoll.

(4) Further observations on the ways in which artificially infected Flies carry and distribute pathogenic and other Bacteria: by Dr. Graham-Smith.

Determination of the possible range of flight of flies is obviously of considerable importance in relation to the question of the carriage of infection by these insects, and consequently advantage was taken of an exceptional opportunity afforded in the summer of 1910 for carrying out a series of experiments at the village of Postwick, near Norwich, in order to test this question of the range of flight. Postwick was selected on account of an excessive prevalence of flies there at that time. It was ascertained that the breeding centre of these flies was a refuse tip half a mile from the nearest point of the village and on the opposite bank of the River Yare. Numbers of flies caught at this refuse tip were liberated after having been marked for purposes of identification by dusting them with a small quantity of coloured chalk. On each occasion on which several hundred marked flies were liberated, a certain number were subsequently recovered from human habitations in Postwick, at points of the compass which were apparently dependent, to a considerable extent, on the direction of the prevailing wind, and at distances varying from 300 yards to 1,700 yards from the refuse deposit. On one occasion marked flies were caught, within 45 minutes of being liberated, 800 yards from the point at which they were set free.

Dr. Nicoll's paper on the dispersal by flies of the eggs of parasitic worms deals mainly with the results of experiments devised to ascertain to what extent, and for how long a period, flies can carry eggs by actually ingesting them and retaining them within their intestine.

Dr. Nicoll, while recognising that corroboration from observations under natural conditions is desirable, concludes, as the result of his experiments, that flies may convey the eggs of certain parasitic worms from excrement to food and that they may do so in two ways, namely, on the external surface of their body and in their intestine.

The latter mode is practicable only in certain cases, where the eggs are of small size (under ·05 mm. in diameter). On the external surface eggs of larger size (up to ·09 mm. in the experiments) may be conveyed.

Eggs adhering to the external surface are usually got rid of by the fly within a short time, but those which are taken into the intestine may remain there for two days or longer.

The eggs which are conveyed in either of these ways may remain alive and subsequently cause infection.

Dr. Graham-Smith's further observations on the ways in which artificially infected flies carry and distribute bacteria indicate that both house-flies (*M. domestica*) and blow-flies (*C. erythrocephala*) are able to infect fluids, such as milk and syrup, on which they feed and into which they fall. In the case of the house-fly infected with certain micro-organisms (*B. prodigiosus* and *B. anthracis*) gross infection may be produced in milk for at least three days, and a smaller degree of infection for ten days, or even longer. It is probable, at any rate in the later stages, that infection is mainly due either to direct infection with the crop contents vomited through the proboscis, or to indirect infection by means of the limbs which have been reinfected with vomited material during the process of cleaning them.

V. A fifth report (No. 66) contained the results of three investigations, as set out below: —

(1) Observations on the Range of Flight of Flies: by Dr. C. Gordon Hewitt.

(2) British Flies which cause Myiasis in Man: by Mr. Ernest E. Austen.

(3) An Account of the Bionomics and the Larvæ of the Flies *Fannia* (*Homalomyia*) *canicularis* L., and *F. scalaris* Fab., and their relation to Myiasis of the Intestinal and Urinary Tracts: by Dr. C. Gordon Hewitt.

Dr. Hewitt's paper on the range of flight of flies contains the results of experiments carried out in the city of Ottawa, Ontario.

Marked flies, bred in stable refuse, were liberated on a small island lying in the Rideau River, which runs through a part of Ottawa. An important reason for the choice of the locality for experimental purposes was that the results might be useful as indicating whether the presence of a small-pox hospital on the island constituted a menace to the public health of the neighbouring district.

Fly-papers were placed in as many as possible of the neighbouring houses on both sides of the river, and were collected after one or two days. It was found that the wind was the chief factor in determining the direction of the flight of flies.

Altogether 13,600 flies were liberated on various dates from 29th August to 7th September, 1911, and of this number 172 were recovered at distances varying from 180 yards to 700 yards from the point of liberation. The experiments are of value as indicating the possibilities of the range of flight of flies under normal city conditions.

The range of flight of flies has possible significance in reference to the administration of isolation hospitals. Strict precautions should be taken against the access of flies either to patients or to infective matter.

Mr. Austen contributes a paper on British Flies which cause Myiasis in Man. By myiasis is signified the presence of dipterous larvæ (*i.e.*, the maggots of flies) in the living body, whether of man or other animals, as well as the disorders, whether accompanied or not by destruction of tissue, caused thereby. Cases of myiasis are by no means rare in the British Islands, the form most commonly met with being that affecting the alimentary canal, as the result of which living larvæ or pupæ are discharged from the bowel. A classified list of the species known to have been concerned in the production of myiasis in the United Kingdom, arranged in order under the families to which they belong, is set out in the paper.

The author describes the appearance, characteristics and habits of these different species of flies, and gives details of cases of myiasis in the human subject. The presence in the alimentary canal of the larvæ and pupæ of these flies may be caused by drinking polluted water or by eating unsound food or uncooked vegetables. Many cases of intestinal myiasis have also occurred in country districts, where sanitary conveniences are often of an extremely primitive type. Human myiasis in this country must be regarded as being for the most part of accidental occurrence, being due to larvæ which are not habitual parasites, but wont to lead a free and independent existence, in many cases living in dead, decaying, or fermenting animal or vegetable matter, or in excrement.

Intestinal myiasis in this country is usually due to the presence of the larvæ of *Fannia canicularis* (the Lesser House-fly), with which the larvæ of *Fannia scalaris* are sometimes found associated. Myiasis due to *Musca domestica* (the Common House-fly) would seem to be rare.

The larvæ of the flies known as *Thereva* are said to feed upon other insects or upon vegetable matter, so that their occasional transference to the human alimentary canal is not difficult to understand. The larvæ of *Eristalis tenax* have also been known to cause myiasis in cases where infection was probably due to the consumption of uncooked vegetable matter or to the drinking of polluted water. The presence of the larvæ of certain other species in the human body must be regarded as purely accidental. The author has met with one case of myiasis due to *Piophila casei* (the Cheese-Maggot Fly).

Dr. Hewitt's second paper gives an account of the bionomics and of the larvæ of the flies *Fannia* (*Homalomyia*) *canicularis*, L. and *Fannia scalaris*, Fab., and their relation to myiasis of the intestinal and urinary tracts. It thus forms a complement to Mr. Austen's paper.

Next to *M. domestica*, *F. canicularis* is the most important fly inhabiting houses, though from observations made by the author in many localities in different neighbourhoods, he does not think that, except in early summer, this latter species would often form more than 25 per cent. of the total fly population. It is noteworthy that males form by far the larger proportion of these flies found in houses, the females being more commonly found out of doors, especially in the neighbourhood of breeding places. The breeding habits of this species are somewhat similar to those of *M. domestica*. The eggs are laid in decaying and fermenting vegetable and animal matter and also in excrementitious matter. The larval period of this fly varies from one to four weeks, while the pupal period lasts from seven to twenty-one days, or longer, and it is possible that individuals, which have developed very late in the season, pass the winter in the pupal state.

F. scalaris, Fab., which, on account of its breeding habits, may be called the Latrine Fly, is very common in European countries and in North America. It is slightly larger than *F. canicularis*. For breeding purposes it prefers excrementitious matter, and is commonly found breeding in human excrement. The larvæ emerge as early as eighteen hours after the deposition of the eggs and become full-grown in six to twelve days. The shortest time recorded by the author for the pupal stage was nine days.

F. scalaris is not infrequently found as the cause of intestinal myiasis, and in its development it commonly affects human excrement. These facts make its economic relation to man one of not a little importance.

Many cases have been recorded of the presence of dipterous larvæ in the human intestine, frequently resulting in more or less serious intestinal troubles. The presence of these larvæ in the stomach or intestines is usually indicated by nausea, vertigo, and violent pains. The author cites several cases of intestinal myiasis caused by the larvæ of *F. canicularis* and *F. scalaris*. Although the manner in which the urinary tract can become invaded by dipterous larvæ is difficult to understand, yet a number of cases of myiasis of this nature have been recorded.

The probable methods of infection in the various forms of myiasis have been indicated in the review of Mr. Austen's paper.

VI. The present report contains papers on:—

Empusa muscæ: by Dr. Güssow, Dominion Botanist, Ottawa.

Hibernation of House-flies (Preliminary Note): by Dr. Copeman.

Experiments on the Flight of Flies in the Town of Cambridge: by Prof. Nuttall, Mr. Merriman and Dr. Hindle.

Colour-preference of Flies: by Dr. Hindle.

Further observations on Non-lactose Fermenting Bacilli in Flies, and the Sources from which they are derived; with special reference to Morgan's bacillus: by Dr. Graham-Smith.

Dr. Güssow, like other experimenters, has failed in attempts to cultivate *Empusa muscæ* in artificial media, and so to trace out the complete life-cycle of this fungus parasitic on flies. He records, however, and illustrates photographically an interesting observation bearing on the method of infection. It has been very generally held that infection of a fly was brought about by hyphæ, developed from a spore or spores which had come in contact with the body of the insect, finding their way through the inter-spaces between the segments of the abdomen, and so to the "fat-body" which afforded the nutriment necessary for their extension. Dr. Güssow, however, as the result of finding numerous proboscis-marks on collections of *Empusa* spores, comes to the conclusion that ingestion into the alimentary canal of the fly may afford an alternative path of infection. Mr. Hesse, who, with Dr. Bernstein, is carrying out experimental work for the Board on this fungus, had independently arrived at a similar conclusion.

The paper by Prof. Nuttall, Mr. Merriman and Dr. Hindle dealing with experiments on the flight of flies in the town of Cambridge is illustrated by a series of charts, the form of which was devised by Prof. Nuttall. These show at a glance the relative situations at which flies loosed from a central station were recaptured. The authors' results in regard to flight against or across the wind do not appear to coincide with those previously recorded by Dr. Copeman, Prof. Howlett and Mr. Merriman, and by Dr. Gordon Hewitt, in previous reports of this series.

One cause of this difference may be the attractive influence in a town of the odours from restaurants, butchers' shops, &c., in determining the course of the liberated flies. Such an influence would be unlikely to affect, to the same extent, experiments carried out in a rural district such as Postwick, in the neighbourhood of which previous experiments for the Board were made.

Dr. Graham-Smith records the results of further work carried out in 1912, in extension of observations (in 1911) on non-lactose fermenting bacilli in flies, and the sources from which they are derived. Contrary to his experience of the previous year, he was unable to isolate a special member of this group (Morgan's bacillus) from any flies caught either in houses infected or uninfected with diarrhœa. This fact he attributes mainly to the differing meteorological conditions having proved unfavourable to prevalence of diarrhœa, and so also to dissemination of infective material by flies.

The remaining papers, by Dr. Copeman, on Hibernation of House-flies; and by Dr. Hindle, on Colour Preference of Flies, which are brief and self-explanatory, hardly require special comment.

The investigations summarised above possess much general and scientific interest, and have important practical bearings. While these investigations have been proceeding other observers have been at work, and among these the work of Dr. Niven in Manchester and Dr. Hamer in London is especially important. The exact share borne by flies in conveying the infection of epidemic diarrhœa cannot yet be stated. It would be a mistake, with our present knowledge, to assume that the problem of the prevention of this disease is limited to the destruction of flies. It is concerned also with the personal cleanliness of the mother who has to prepare the infant's food, and with the cleanliness of the house, the backyard, the court, and the street, from which infective material may obtain access to the infant's food, with or without the intermediation of flies. For practical purposes, however, the number of flies in the summer months may be regarded in towns as a valuable index, under present conditions, of the possibilities of contamination of food by pathogenic microbes or by decomposing organic matter, especially in districts in which privies and pail closets persist, and in which accumulations of house refuse or stable refuse are permitted.

I am, Sir,

Your obedient Servant,

ARTHUR NEWSHOLME,

Medical Officer of the Board.

August, 1913.

Further Reports (No. 6) on Flies as Carriers of Infection:—

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1. *EMPUSA MUSCÆ* AND THE EXTERMINATION OF THE HOUSE-FLY.

By H. T. Güssow, Dominion Botanist, Department of Agriculture, Ottawa.

Since it has become generally recognised within recent years that the common house-fly (*Musca domestica*) is a potential source of danger to the public health as a carrier of pathogenic micro-organisms, the question of an effectual and practical method of exterminating, or at least reducing the prevalence of this insect during the summer and autumn months has naturally attracted considerable attention.

As a means towards the solution of this problem detailed study of the natural enemies of the fly, and more especially of the fly fungus *Empusa muscæ* appeared likely to prove serviceable. The parasitism of this fungus is well established, and for a considerable number of years this fungus, as one of the commonest entomogenous species, has formed the subject of careful investigation from the mycological point of view. Unfortunately, however, the complete biological development has not yet been observed, and the gaps in our knowledge became particularly prominent when it was sought to employ this fungus as the means of causing an epidemic among flies, and thus to achieve their extermination. The use of *Empusa muscæ* for this purpose seems reasonable, since it is well known that under normal conditions it destroys flies in large numbers, every autumn; and that it is an easy matter, experimentally, to spread the disease among flies in captivity. It is quite another question to determine whether there ensues a spreading of the disease among other flies of the same kind when *Empusa*-infected flies are afterwards liberated; partly for the reason that it is impossible to say that the experimental flies, while still active, are really infected, and partly because the experiments are necessarily confined to a brief period in autumn, when flies naturally infected are fairly abundant. As a matter of fact there does not appear to be any record of the fly fungus causing a virulent epidemic among flies at any time of the year. In comparison with the enormous masses of flies that may be noticed in a stable, for instance, even as late as October, all of which disappear when the cold weather sets in, comparatively few *Empusa*-infected flies are usually to be found in such places. It is possible that a large number may become infected and subsequently die out of doors, but though a considerable number of dead bodies of flies may be discovered lying on the ground, it is a recognised fact that the *Empusa*-infected fly is invariably firmly attached to various substrata in a life-like posture and surrounded by the white halo of spores. It is reasonable to suppose that, if the disease were of an epidemic nature, one should discover far more flies killed by it than is usually the case.

We must further bear in mind that the disease is most conspicuous about the time when the flies would naturally disappear. This is an important fact, because in our experiments we have observed that, in the case of artificially "contact" infected flies, but 8 to 10 days will have elapsed before the fungus has done its work. The disease, while occasionally observed as early as June on some syrphid flies occurring out doors—and which, by the way, though at present attributed to the same species of fungus, may be a distinct biological form—is hardly ever recorded, nor has it been observed by ourselves, before the latter part of the fly season. It is not unlikely that the fly becomes more susceptible to this disease as it grows older, while newly emerged broods are more or less resistant. Unfortunately, at the time when fresh spore-material of this fungus is available for experimental work, the flies are already considerably more sluggish than at any other time earlier in the season.

We have devoted considerable attention to the study of this interesting fungus and its life history, but, hitherto, as soon as the fly material has died out our cultures have met with the same fate. The artificial germination of the spores has been closely studied, but we have never succeeded in carrying cultures from the spore to the spore outside the body of the fly. In the following lines some of our recent experiments and other observations are summarised.

Auto-infection of Flies with Empusa *Spores.*

Experiments in infecting flies with spores contained in water painted on the abdomen and other parts of the body of flies, have proved invariably successful. Experiments were also carried out for the purpose of ascertaining whether dead flies covered with the fungus spores are capable of infecting living flies coming into contact with them. Thus eighty flies were caught of which half were used for a control. The other forty flies were confined to an Erlenmeyer flask the mouth of which was closed with a plug of cotton wool. The plug was subsequently replaced by a fairly long cork, through which a hole, big enough to allow for easy passage of the flies was bored; this cork was hollowed out on one side to form a cup. In this cup was placed a number of recently collected dead flies showing the whitish-grey rings of *Empusa* conidiophores; over the flask containing the flies another flask was then inverted and its neck pushed over the protruding portion of the cork until it rested upon the neck of the lower flask. The lower flask was then covered with black cloth, the upper remaining exposed to the sun. Soon a fly found out the passage through the cork and made its way into the upper flask. After some time all the flies, with the exception of two, had made the passage, and the rolling about of the infected dead flies placed in the cup-shaped hollow in the cork indicated that the living flies had had to work their way through them. After the flies had passed into the upper flask they were transferred to a large bell jar, provided with water and some cane-sugar crystals, and carefully watched. As a result of this experiment 84 per cent. of the flies died after 6-10 days from *Empusa*. Some died without showing development of the fungus, after a few days, for the death of which no cause was apparent. In the control flask a similar number had died, but no *Empusa*-infected fly was observed. Some of the flies had fed rather freely on the sugar, and their abdomens were distended to an enormous size owing to the abnormally filled crops—these flies were the first to die, as is usually the case with over-gorged individuals. The flies under both bell-jars were very lively at first, especially during sunny hours. But, after three days, a number of the infected flies became distinctly lazy, some indeed so indifferent that they would hardly move when touched with the point of a needle. Some of the sluggish individuals were removed and placed in Petri dishes, on microscopical slides, or on cover-glasses, and examined in order to observe spore development and discharge. The transfer at so early a stage, however, apparently arrested the development of the fungus, and although the mycelium was revealed on microscopical examination, no conidiophores appeared. We were successful, however, in obtaining excellent material by transferring the flies after the *Empusa* begun to show externally. While still fresh the spore-discharge was easily observed under the microscope, the spores, in a dry atmosphere, being discharged very rapidly and disappearing entirely from the field of vision. In a moist chamber (covered with moist blotting paper) the discharge of the spores continued for four days, as shown by microscope slides placed in various positions near the body of the infested fly. The spores were discharged in every direction, but particularly towards either side. This is natural as the conidiophores are specially abundant on the abdomen. We observed spores shot away some seven centimeters from the body.

Spore Cultures.

The fresh spore-material obtained almost entirely pure was now used in an effort to secure an artificial culture. For this purpose we used a small bell-jar with a mouth at the top into which a cork was placed. A fly freshly killed by the *Empusa* was then pinned inside to the cork, and sterile petri dishes were placed underneath containing the usual standard media; and after these gave negative results a large number of "special" media were substituted.

But even carefully prepared extracts from flies made by the cold method absolutely refused to induce germination. That this failure to induce germination of spores is largely due to the media employed, and not to a period of rest required by some fungus spores, was shown by the surprisingly rapid and energetic germination of the spores on microscopic slides kept in moist chambers. Although no nutrient material, not even water, was added to the spores, the " condensation " was sufficient to start the germination; and growth was observed till the store of food in the spore became exhausted. Apparently it should be possible to carry these cultures further, but notwithstanding repeated trials to do so, we can only record failure. The production of secondary and tertiary conidia by a process of sprouting from the previous one is well known, and can be observed in any spore deposit that has not dried out. These conidia do not appear to shoot off the next, but the contents of the parent conidium passes through a more or less long neck into the daughter-cell.

So far then our personal experience of attempts at artificial culture of this fungus has not been encouraging. But other investigators claim to have been more successful, at least mention is made by several of artificial cultures, though we cannot decide from the meagre reports whether they have actually obtained cultures from single *Empusa* spores, outside the body of the fly, on media of a suitable kind. I have been afforded an opportunity by my colleague, Dr. C. Gordon Hewitt, to examine the claims of Mr. Edgar Hesse, contained in an article re-printed from the " Shrewsbury Chronicle " of November 29th, 1912. He agrees with White that " confining living flies with the bodies of those who had died of the fungus proved unsuccessful," which, apparently, is incorrect in the light of our own experiments. He does not believe in external infection, yet claims that the " biting " stable fly has been successfully experimented with. We have never been so fortunate as to find *stomoxys* infected by this disease. We have subjected to experiment some pieces of Mr. Hesse's " prepared " fly-paper which he states " has been in daily use with great success and still contains 'fertile' spores (January 7th, 1913)." This paper he states " contains the spores of *Empusa* and is saturated with a syrup compound of sugar." " The flies ingest the spores during the process of sucking the paper, after moistening it with vomit." We have not been able to confirm his observations, from the material examined. Careful examination of the macerated paper, and centrifuged liquid, revealed no signs of spores, yet those who have examined dried *Empusa* spores know how conspicuous they appear when moistened again even after long periods of desiccation. All that we found was a dense growth of *Mucor racemosus*.

Nevertheless Mr. Hesse claims that he has " cultivated artificially the spores produced on the dead flies, thus completing the life cycle of the fungus."

Before it is likely that the fungus can be employed for economic purposes, it is necessary to become thoroughly acquainted with its complete life history. As regards the life history of *Empusa* some most important factors still require eluicidation as, for instance, how the fungus is carried over from year to year. Once this point is clearly ascertained, it might enable us to start new infections earlier in the year, when the flies are commencing to emerge; but, as yet, we doubt whether any investigator has really been successful in observing the germination of spores in hibernated flies early in spring. This is one of the most important points, for it matters little whether the spores are ingested or infection takes place from the exterior; we have indeed been able to observe that both processes occur in nature. The accompanying photograph shows a deposit of *Empusa* spores on a pane of glass on which there are numerous proboscis marks of flies which must have ingested large numbers of spores. We are not aware of this circumstance, indicating, as it does, one way in which the disease, when present, may spread, having been previously recorded.

The technical difficulties met with in attempts at cultivating the fungus artificially will also have to be overcome; and it must further be demonstrated that the spores produced, under experimental conditions, have not lost their virulence *quâ* infection, since the danger of producing a possible immunizing effect by the use of an avirulent strain of the fungus has also to be borne in mind.

It is very doubtful whether any practical and economic use of this fungus can be made before the whole life cycle is known, and notwithstanding repeated researches, no investigator would seem, thus far, to have made any important addition to our knowledge since the publication of Brefeld's work on this subject.

H. T. GÜSSOW.

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2. HIBERNATION OF HOUSE-FLIES.

(Preliminary Note.)

By S. Monckton Copeman, M.D., F.R.S.

As indicated in my memorandum published in No. 3 of this series of "Reports on Flies as Carriers of Infection" (1910), considerable importance attaches to the subject of the hibernation of flies, concerning which, however, singularly little definite evidence is available at present.

It is, of course, matter of general knowledge that house-flies tend to disappear somewhat suddenly towards the end of October and during November, such disappearance often being coincident with the occurrence of the first sharp frosts of autumn. A lowered temperature is not, of course, the only factor in the disappearance of house-flies in late autumn; large numbers every year falling victims to attack by a specific fungus, *Empusa muscæ*, Cohn. Gordon Hewitt (The House-fly, 1910, p. 122) states that he found the majority of flies are killed by this fungus, while "of the remainder, some hibernate and some die naturally." But in the event of one or two comparatively warm and sunny days being experienced during the winter, a certain number of flies will be likely to appear, which presumably must have been hibernating during the colder weather. Such flies

Deposit of *Empusa* spores showing proboscis-marks of flies, probably *Musca domestica*. (Magn.)

usually are found to be more or less torpid, and even partially paralysed, seemingly having but little power of control over their legs and wings.

As to whether flies can persist through the winter in other than the adult form practically nothing is known; but as the egg and larval stages, at any rate, appear to be less resistant to the effects of a reduction of temperature than the fly itself, it is probable that the progeny of the later broods, for the most part, never arrive at maturity, both eggs and larvæ perishing in their breeding places. It might reasonably be thought that the pupæ would prove more resistant than the earlier stages, but, so far as I am aware, no observer has succeeded in breeding out flies from pupæ kept through an average winter in this country. Jepson (1909) in an earlier report of this series refers to an experiment bearing on this point carried out by him, in which an attempt to carry 200 pupæ through the winter met with entire want of success.

Newstead (1909) also records an interesting experiment, which seemed to afford proof that the house-fly does not pass the winter in either the larval or the pupal stage.

As regards persistence of the adult form during the period extending from late autumn until early summer, the researches of Jepson and others have shown that flies may be found in an active condition in warmed houses, and especially in such places as kitchens and bakehouses, where the temperature is kept relatively high; and further, that under these conditions and in presence of sufficient food material they may even continue to breed. These winter flies were also found by Jepson to be hardier and longer-lived than were individuals caught during the summer months. But Howard (1911) expresses a doubt as to whether a sufficient number of flies remain in active condition in such localities to perpetuate the species and to start the rapidly multiplying generations of the following summer.

Gordon Hewitt (1910) somewhat "begs the question," in giving expression to his belief that those flies which hibernate are the most recently emerged, and therefore the youngest and most vigorous. On dissection he found the abdomens of hibernating flies packed with fat cells, the "fat body" having developed enormously. On the other hand, the alimentary canal shrinks owing to absence of food. He makes the further statement that *M. domestica*, like most hibernating animals, becomes negatively heliotropic, and creeps away into some dark situation, a favourite place for hibernation being between wall-paper which is slightly loose, and the wall. He adds that, in houses, hibernating flies have been found in various kinds of crevices such as occur between the woodwork and the walls. But he does not record any definite observations of his own as to having found hibernating specimens of the house-fly in situations such as he describes in dwelling houses.

About a couple of years ago I received from Dr. Laver, of Colchester, interesting information to the effect that, as the result of his own observations on the bionomics of the house-fly, he had come to the conclusion that, in addition to the more or less active individuals which are usually to be found throughout the winter months in bakehouses and other warm situations, considerable numbers of flies in the adult stage hibernate *outside* dwellings, in various sheltered situations; the under-surface of the thatch of farmyard stacks having been found by him to constitute specially-favoured winter quarters.

More recently, I had opportunity of conferring with Dr. Laver on this subject, when he gave me further details as to his observations. He stated that he had found that not only house-flies, but many other insects, are wont to hibernate in stacks—more especially in hay-stacks—and that they may be found not only under the thatch but in the sides of the stack. He added that, in his experience, it was on the *north* side only of a stack that they were likely to be discovered, probably for the reason that this aspect is, for the most part, protected from rain and snow, which usually, in this country, are associated with prevalence of a south-west wind.

In view of the general interest and importance of the matter, and with the aid of a small grant from the Board, it was decided to carry out some preliminary investigations on the subject, including the hunt for hibernating flies in various likely situations, their collection and transmission to the Board, and the subsequent identification by an expert of the precise species, and also of the sex, of all the specimens received. Accurate determination of the species of flies captured in winter quarters is obviously most necessary, as indicated by Howard, who calls attention to the possible fallacy underlying observations uncontrolled by expert identification of all the flies collected. Referring to the fact that many insects have been found to remain dormant throughout the winter months in sheltered, but cold, situations, he adds that "observations have been made which indicate that this is the case with the house-fly, although, as a matter of fact, sufficient attention has not been paid, in the observations on record, to the exact specific identity of the flies in question. As has been pointed out before, there are so many species of flies which so exactly resemble the typhoid (house) fly to the macroscopic eye that anyone may be pardoned for stating that house-flies have been seen tucked away carefully in cracks, when a microscopic examination would have shown that some other species was concerned."

The results obtained in the investigation undertaken for the Board, so far as can be judged from the comparatively small amount of work that has been accomplished thus far, emphasizes in a remarkable degree the importance of the criticism contained in the quotation set out in the previous paragraph.

Through Dr. Laver, arrangements were made with a working naturalist, Mr. John Pettitt, living in the neighbourhood of Colchester, for the collection of any flies that could be found in various situations of character similar to those indicated to me by Dr. Laver as constituting the favourite winter-quarters of hibernating flies. Through the co-operation also of the Rev. A. Garry Copeman, Rector of Ingoldisthorpe, near King's Lynn, Norfolk, a large quantity of flies were received on two separate occasions, which had been collected, while still in a dormant condition, in a large attic in the rectory house. Incidentally it may be noted that, as will be seen from the records appended, a particular fly included in the first of the batches from Ingoldisthorpe Rectory proved to be of a hitherto undetermined species, of which, according to Mr. Austen, the British Museum (Natural History) had previously possessed a single specimen only.

Of the flies collected by Mr. Pettitt the first lot were taken early in March, 1913, in the thatch of an old disused hen-house standing in a field by itself, distant about 500 yards from any other building. In accordance with arrangements which had been made with Mr. Ernest E. Austen, F.L.S., these flies, as also all further batches received, were sent to him at the British Museum (Natural History) for identification.

As regards the species and sex of the flies in batch (A), Mr. Austen reported as follows:—

(A)

Name.	Number of Specimens.	
	Males.	Females.
Pollenia rudis, Fabr.	13	10
Pyrellia eriophthalma, Macq.	7	9

Mr. Austen's report on the second collection of flies (B), caught on March 27th, 1913, deals with a somewhat larger number of insects.

British Museum (Natural History),
Cromwell Road,
London, S.W.

(B)

14.4.1913.

The following are the particulars with regard to the flies caught in an attic at Ingoldisthorpe Rectory, Norfolk, on March 27th, 1913:—

Name.	Number of Specimens.		Remarks.
	Males.	Females.	
Pyrellia eriophthalma, Macq.	31	38	
Musca corvina, Fabr. ...	—	1	
Pollenia rudis, Fabr. ...	6	7	
Pollenia, sp. incert. ...	1	—	The Museum collection contains a single male of this species, taken at Walton-on-Thames on April 1, 1894: the specimen from Ingoldisthorpe is therefore only the second so far received. Attempts to determine the species more precisely have hitherto failed.

In addition to the above, about 20 females of a small Anthomyid, apparently *Fannia canicularis*, Linn., but indeterminable with certainty owing to condition.

Also odd fragments of one or other of the above.

Musca domestica is once more "conspicuous by its absence," and, so far as the very limited data go, the preponderance of females over males is so slight as to be practically negligible; it is certainly not what one would have expected in the case of hibernating flies.

The occurrence of a single specimen of the unknown *Pollenia* is very interesting.

E. E. AUSTEN.

On April 17th, 1913, a second lot of flies were received from Ingoldisthorpe Rectory, Norfolk, where they had been collected on the previous day, in the same situation as those caught nearly three weeks previously. In absence of Mr. Austen, the desired particulars as to species and sex were kindly provided by Mr. C. Hill, of the British Museum (Natural History), as follows:—

(C)

Name.	No. of Males.	No. of Females.
Musca corvina, Fabr.	19	31
Pollenia rudis, Fabr.	6	30
Pyrellia eriophthalma, Macq.	1	21

In the course of the first fortnight in April, 1913, Mr. Pettitt, with the assistance of a local thatcher, examined no less than 25 corn and hay-stacks, in addition to a number of buildings, but entirely without success as regards obtaining specimens of the house-fly; although flies of other species were found, in addition to a quantity of butterflies, moths, wasps and spiders. Not a single hibernating fly *of any sort* was found in a number of *corn*-stacks, although careful search was made when the thatch was removed before the operation of thrashing was commenced. The suggestion is made, however, that as the stacks were found to be infested with mice, it is possible that these animals may have devoured any flies originally present.

In view of the meagre results referred to, attention was next directed by Mr. Pettitt to search for hibernating flies in dwelling-houses, the most successful results in point of numbers being obtained in the attic of a farm-house near Colchester. The details of Mr. Austen's report on this batch (D), given below, may therefore be usefully compared with those relating to batches (B) and (C) caught in a somewhat similar situation, but in Norfolk, and in one instance about six weeks, and in the other about a month, previously.

(D)

26.5.1913.

Flies "caught on May 14th in a torpid condition in the attic of a farmhouse near Colchester."

The names and other details are as follows:—

Name.	Number of Specimens.	
	Males.	Females.
Hydrotæa dentipes, Fabr.	0	1
Fannia canicularis, *L.*	51	10

That in the case of *F. canicularis* the males should outnumber the females in the proportion of five to one would be remarkable, were it not for the fact that, in houses, males of this species always seem to be more numerous than females.

E. E. Austen.

The one specially interesting and unexpected point that emerges from this preliminary investigation is found in the fact that not a single specimen of the house-fly (*Musca domestica*) was met with among the considerable number of hibernating flies caught in situations which have hitherto been regarded as its special habitat.

This may possibly be accounted for, in part, by the comparatively slight prevalence of the common house-fly during the summer of last year (1912). But it is obvious that further detailed investigation is needed in order to elucidate the precise facts as to where, and under what circumstances, the winter months are passed by such individuals as survive from the previous season, and which serve, therefore, to perpetuate the species in the following year.

S. MONCKTON COPEMAN.

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3. THE RANGE OF FLIGHT OF *MUSCA DOMESTICA.*

Experiments conducted in the town of Cambridge.

INTRODUCTORY NOTE.

It having been considered desirable that further experiments upon the range of flight of flies should be carried out, the investigation of the subject was entrusted to Dr. E. Hindle and Mr. G. Merriman, who are engaged in research in my laboratory. Although the experiments here recorded were carried out under somewhat adverse climatic conditions, they appear of sufficient interest to warrant publication, since the results with regard to the influence of wind seem to run counter to those recorded by previous workers, and also, apart from Hewitt's work referred to on pp. 6 and 21,* data have hitherto been wanting in respect of the range of flight of flies (*Musca domestica* Linn.) in towns. The simple graphic method of recording the results of the flight experiments, which occurred to me during the course of the work, may commend itself to others who may carry out similar investigations in the future.

GEORGE H. F. NUTTALL,
Quick Professor of Biology, Cambridge.

REPORT UPON EXPERIMENTS.

By Edward Hindle, Ph.D., and Gordon Merriman,

(With 13 Charts.)

(*From the Quick Laboratory, Cambridge.*)

Previous Investigations.

The first attempt to investigate this subject experimentally was that made by Dr. Arnold, at Monsall Hospital, Manchester, in 1906 (recorded by Niven, 1906). Three hundred flies, each marked by a spot of enamel on the thorax, were liberated from the hospital of which five were recovered at distances varying from 30 to 190 yards.

In 1910, Copeman, Howlett and Merriman (1911) made a number of experiments for the Local Government Board on the range of flight in open country. The investigations were carried out at Postwick (a small village about five miles east of Norwich),

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* Previously published in Reports to the Local Government Board (New Series, No. 66).

where the inhabitants suffered from a plague of flies, resulting from the breeding facilities afforded by a large refuse tip about half-a-mile away. Several thousands of chalk-powdered flies were liberated from the tip, which was situated in open country, the nearest cottages being about half-a-mile distant, and under these conditions invariably a number of the flies travelled distances exceeding 300 yards. In one case a fly travelled 1,700 yards, this distance being covered within 48 hours from the time of liberation. This constitutes the longest flight that has yet been recorded, although many of the flies in this series of observations were found to travel between 800 and 1,000 yards.

In these experiments, owing to the nature of the country, long distances had to be travelled before the flies could enter any houses. Therefore, the results, although important as showing the powers of flight, are no indication of the behaviour of flies in a locality where houses are many, and in consequence, food plentiful.

The same year J. S. Hine (1910), in the United States, also made an effort to determine the distance travelled by flies in open country. Three hundred and fifty flies were captured, coloured by means of spots of gold enamel, and liberated from a barn. The greatest distance at which they were recovered was 240 yards from the point of liberation, but Hine remarks (cited by Howard, 1911, p. 55): " It appears most likely that the distance flies may travel to reach dwellings is controlled by circumstances. Almost any reasonable distance may be covered by a fly under compulsion to reach food or shelter. Where these are close at hand the insect is not compelled to go far, and consequently does not do so."

Howard (1911, p. 56) also mentions some experiments made under the direction of S. A. Forbes in Cook County, Illinois, U.S. America. Flies were trapped and, after being sprayed with a chemical solution, were then liberated from a hospital in that district. They were recovered at distances ranging up to a quarter of a mile from the point of liberation.

In the summer of 1911, Dr. C. G. Hewitt (1912) carried out for the Board some experiments on this subject in Ottawa, Canada. The flies were coloured by spraying them with a solution of rosolic acid in 10 per cent. alcohol. The presence of a marked fly on a sticky fly-paper was indicated by its producing a ruddy colouration when the paper was dipped into slightly alkaline water. The flies were liberated from an island in the middle of the town and individual examples were recovered at distances of 520, 600, and 700 yards respectively. They were usually recovered in those areas of the town towards which the wind had been blowing.

As far as we are aware no other experiments upon this subject have been recorded, and it seemed desirable to obtain further information regarding the range of flight of flies in towns. The present investigation, therefore, was undertaken for the Local Government Board, in continuance of the work arranged for in 1910 (*see* p. 46, 3rd report on Flies as Carriers of Infection).

Experiments conducted in Cambridge during 1912.

During the months of July, August, and the first week in September, 1912, we conducted a series of experiments on the range of flight of *Musca domestica* Linn. in Cambridge. In the course of these experiments upwards of 25,000 flies have been liberated under very variable meteorological conditions, and 191 were recovered at one or other of about 50 observation stations employed for their recovery.

In all cases the flies for liberation were either caught in balloon traps or directly netted. The method of obtaining flies by breeding was abandoned, as it was almost impossible to obtain them without numerous other species of insects, and also on account of the possible objections to such artificially-bred flies.

Prior to being liberated, the flies were kept for about 24 hours in cages made of mosquito netting and were fed on brown sugar, the moisture being supplied by a layer of damp sand. By this method it was assured that the insects had emerged sufficiently long to allow the full development of their chitinous exoskeleton, presumably necessary to obtain the full power of flight.

Preparatory to colouration, the flies were transferred from the mosquito cages into wire balloon traps. This transference was effected as follows:—The mosquito-netting cage was tied round the bottom of the balloon trap. The latter was then held towards the light and the whole of the cage surrounded with a black cloth. Owing to the strong attraction of the light, the insects all made their way towards the brightly-illuminated trap, and in passing through the small hole in the bottom of the latter, it was possible to make accurate counts of them, as not more than two or three were able to pass through at the same time. When about 1,500 flies had entered the balloon trap it was closed, then removed, and another trap fixed in its place.

The most satisfactory mode of marking the flies was found to be that devised by Nuttall (*vide* Jepson, 1909), and this was employed in all our experiments. The balloon trap containing the flies was placed in a large brown-paper bag, in which was a handful of powdered blackboard chalk, coloured either red, orange, or yellow. The mouth of the bag was then closed, and the whole gently shaken for one or two minutes so that the flies were thoroughly dusted with the chalk. The balloon was then removed and after being taken to the point selected for the liberation, the trap was opened and the flies allowed to escape in any direction they chose. The flies were recovered either by means of fly-papers or balloon traps, several of which were exposed at the various observation stations. The traps and papers were examined for several successive days after the liberation of a number of coloured flies, and as the observation stations extended as far as 900 yards from the point of liberation, comprising both thickly and sparsely populated localities, an accurate idea of their distribution was thus obtained. Full meteorological data were kindly supplied by Messrs. W. E. Paine, chemists, Sidney Street, Cambridge. Their observations were made in the centre of the town and in consequence indicated the exact meteorological conditions under which the flies travelled. In all, thirteen experiments were completed, after which the investigations had to be concluded as a result of the bad weather.

When the flies were liberated in the morning, the traps and fly-papers were examined on the afternoon of the same day. Subsequently, however, the observation stations were visited every morning and therefore, any flies then recovered would have been exposed mostly to the winds of the preceding days. This point should be remembered in examining the following results, for in some cases the flies seem to have travelled with the wind owing to its change of direction on the day of recovery.

Owing to the variable meteorological conditions, we consider it advisable to describe each of these experiments separately.

Experiment 1.—16th–21st July, 1912.

About 1,000 orange-coloured flies were liberated from the roof of the Medical Schools* at 11 a.m. on July 16th. The weather was warm and a light wind was blowing from the east, the conditions thus being favourable for the distribution of the flies. In spite of this, as will be seen from the following chart, only six examples were recovered, and these at comparatively short distances. However, since all the fly-papers and traps were set in buildings, the fine and warm weather prevailing at the time of the experiment would explain the few recoveries of marked flies, as cold and damp appear to be the main factors which cause these insects to seek shelter in houses.

[*See* Chart 1.†]

It will be noticed that of the five flies caught, all took a direction either across the wind, or somewhat against it. For For example, on July 17th flies were recovered from three stations situated respectively E.N.E., N.W. by N., and W.S.W. These were recovered subsequent to the first day, none of them at a greater distance than 160 yards.

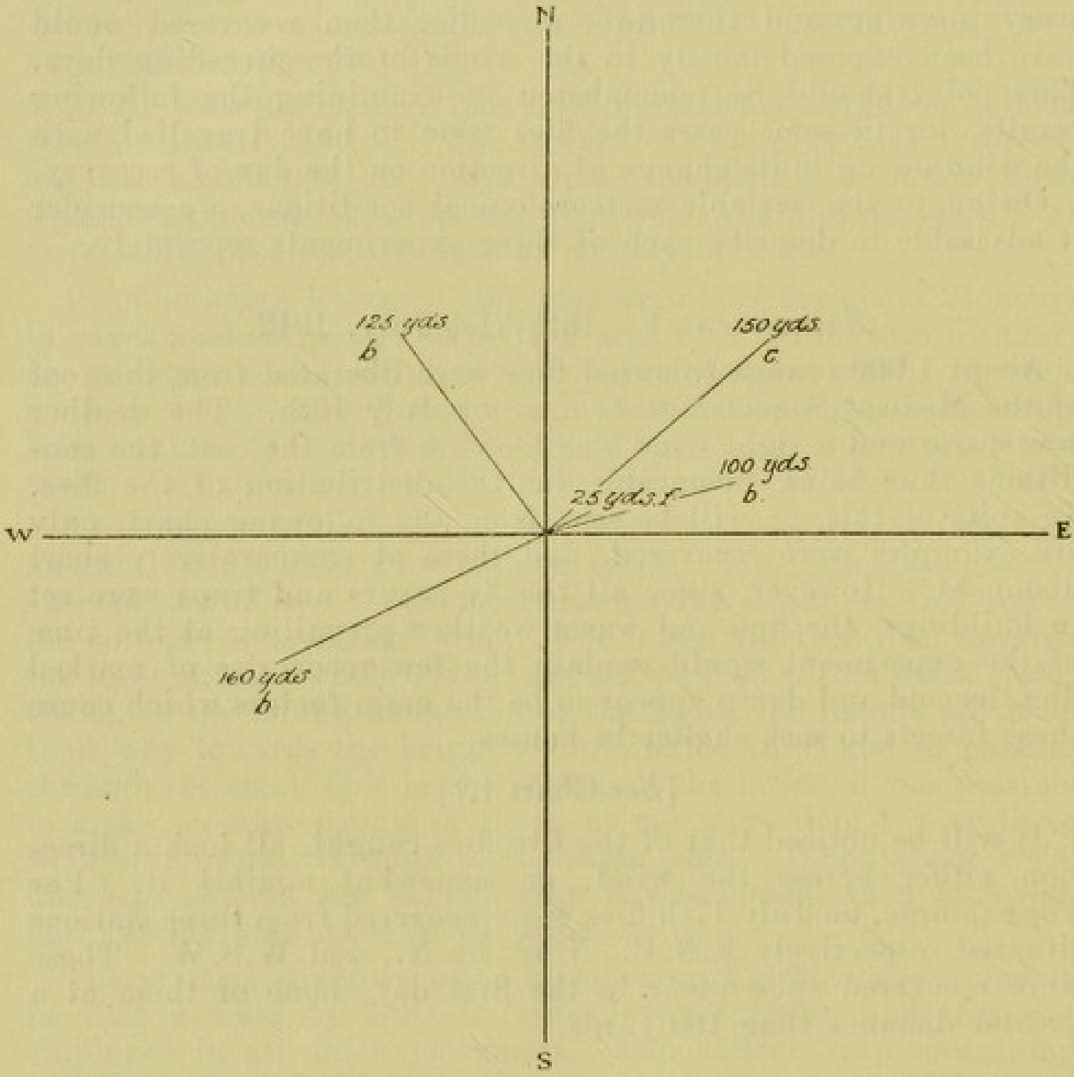
Experiment 2.—20th–23rd July, 1912.

1,650 red-coloured flies were liberated from the roof of the Medical Schools on July 20th. 1,050 were set loose at 10.30 a.m., and the remaining 600 at 1.15 p.m. The weather was warm, but later in the day was inclined to be showery, and probably owing to the latter fact a large number of flies were recovered at distances ranging up to as much as 650 yards. As will be seen from the accompanying chart (2), the conditions prevailing throughout this experiment seem to be very favourable for the distribution of the flies, as 21 were re-caught. Here again, in all the longer flights the flies tended either to fly across or *against* the wind. For example, the individual that flew 440 yards was recovered from a station W.S.W. from the point of liberation, and that at 650 yards from a point S.E. by S., whilst in

* A height of 45 feet.
† *See* p. 24.

both cases the wind on the day of recovery and preceding day was S.W. and S.E. respectively. It should, however, be mentioned that three flies recovered at a distance of 275 yards had apparently flown directly down the wind, which was from the S.E. on the previous day.

CHART 1.*

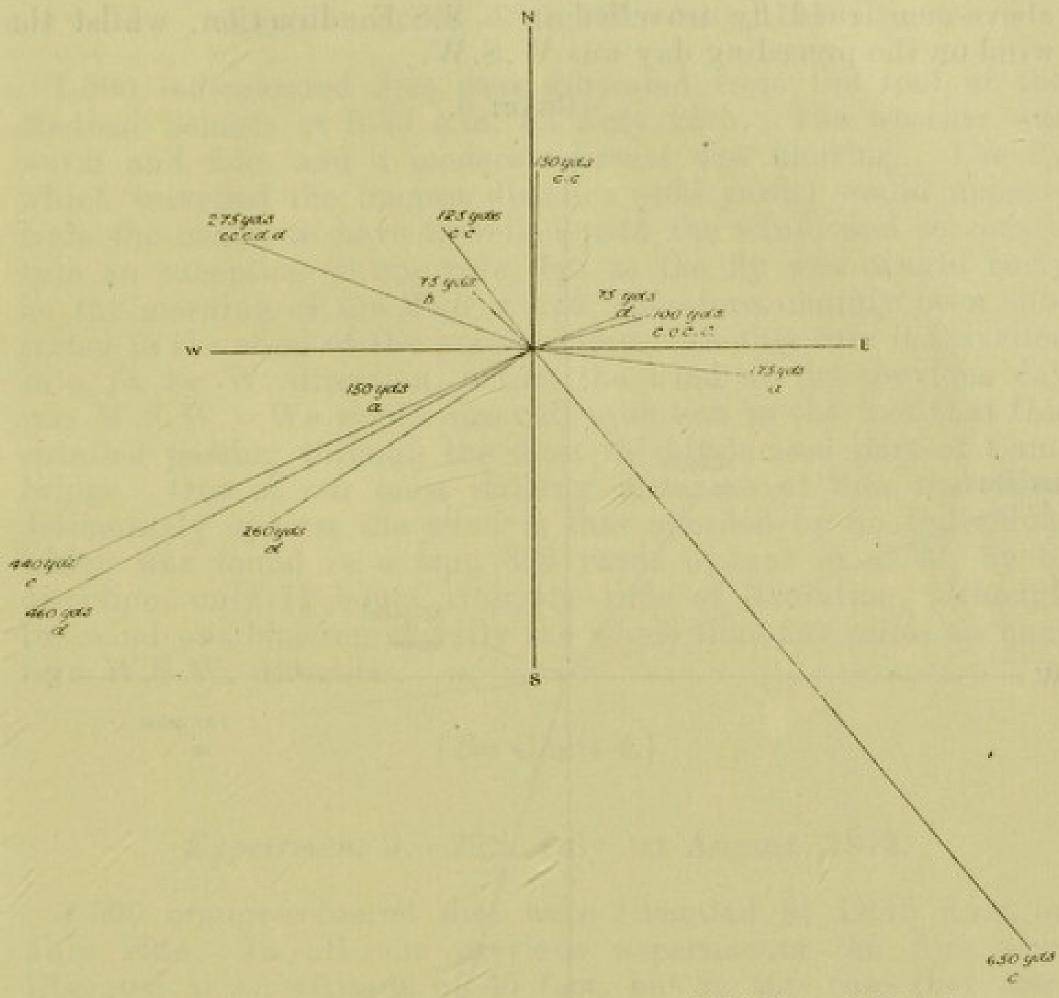


100 yds. = 0·75 inches.

—	Date.	Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
				Maximum.	Minimum.	
a	July 16	E.	6	89	59	0·0
b	" 17	N.	8	89	58	0·0
c	" 18	NNW.	7	78	57	0·0
d	" 19	NW.	8	68	48	0·0
e	" 20	N.	6	59	50	0·26
f	" 21	SE.	3	68	56	0·02

* The letters at the points at which the marked flies were captured represent the day on which they were caught, *e.g.*, a. = 1st day ; b. = 2nd day, and so on ; a.a. would thus signify that two marked flies were caught on that day. The figures represent the distance from the point of liberation.

CHART 2.



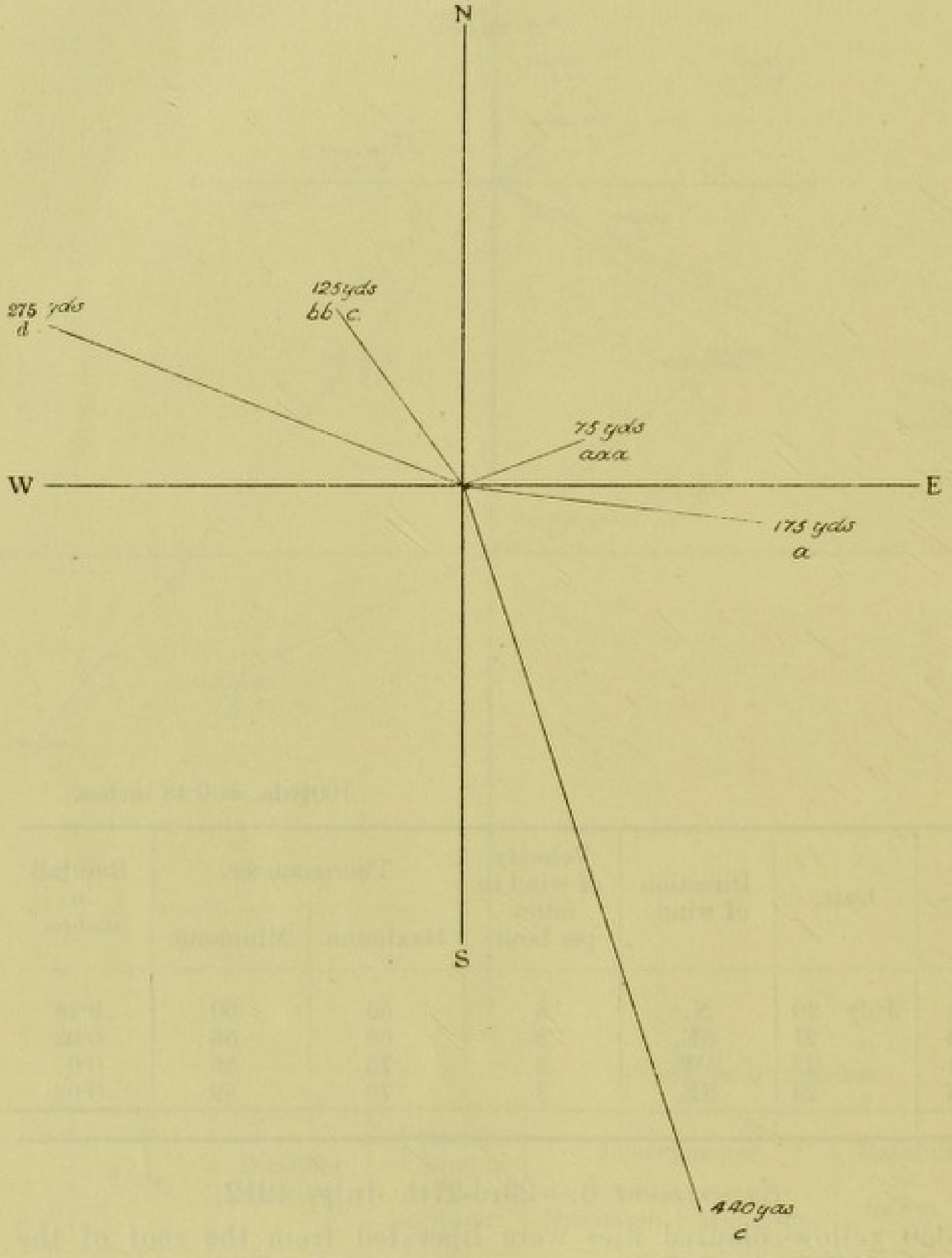
100 yds. = 0·48 inches.

—	Date.	Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
				Maximum.	Minimum.	
a	July 20	N.	6	59	50	0·26
b	„ 21	SE.	3	68	56	0·02
c	„ 22	SW.	2	75	56	0·0
d	„ 23	SE.	3	70	59	0·02

Experiment 3.—23rd-27th July, 1912.

1,350 yellow-coloured flies were liberated from the roof of the Medical Schools at 9.30 a.m. on July 23rd. The weather was warm and showery, with a slight S.E. wind blowing. Although the sun was shining at the time of liberation, a slight shower coming shortly afterwards drove a number of the flies (20–30) into the Quick Laboratory, which is situated on the ground floor of the Medical Schools. Possibly on account of this shower, a comparatively small number of flies were recovered at any of the stations, as they were mostly driven into buildings close at hand, for large numbers of the flies were observed to take shelter in the sheds below the point of liberation. One fly was recovered at a distance of 440 yards, to reach which, if it flew in a straight line, it had to pass over three high buildings. Yet again, the tendency of flies to travel *across* the wind was noticeable, as in this case the above-mentioned fly travelled in a S.S.E. direction, whilst the wind on the preceding day was W.S.W.

CHART 3.



100 yds. = 0·75 inches.

—	Date.		Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
					Maximum.	Minimum.	
a	July	23	SE.	3	70	59	0·02
b	"	24	SSE.	5	75	60	0·01
c	"	25	S.	3	79	63	0·07
d	"	26	WSW.	5	79	55	0·0
e	"	27	SE.	4	76	62	0·13

Experiment 4.—26th–29th July, 1912.

1,500 red-coloured flies were liberated from the roof of the Medical Schools at 9.30 a.m. on July 26th. The weather was warm and fine, and a moderate breeze was blowing. The fly which travelled the longest distance (400 yards) would appear, from the chart, to have travelled *with* the wind, and so constitute an exception to our rule, but as the fly was caught early on the morning of the 27th it had, therefore, mainly been subjected to the wind of the previous day. In this case it travelled in a N. by W. direction, whilst the wind of the previous day was W.S.W. We would also call attention to the fact that this entailed passing through the most thickly-housed part of Cambridge. One of our most striking instances of flies travelling deliberately *against* the wind is that afforded by an individual which was found in a trap 325 yards distant in a W. by S. direction, only 1½ hours after the time of liberation, although the wind was blowing steadily the whole time five miles an hour in a W.S.W. direction.

[*See* Chart 4.]

Experiment 5.—29th July–1st August, 1912.

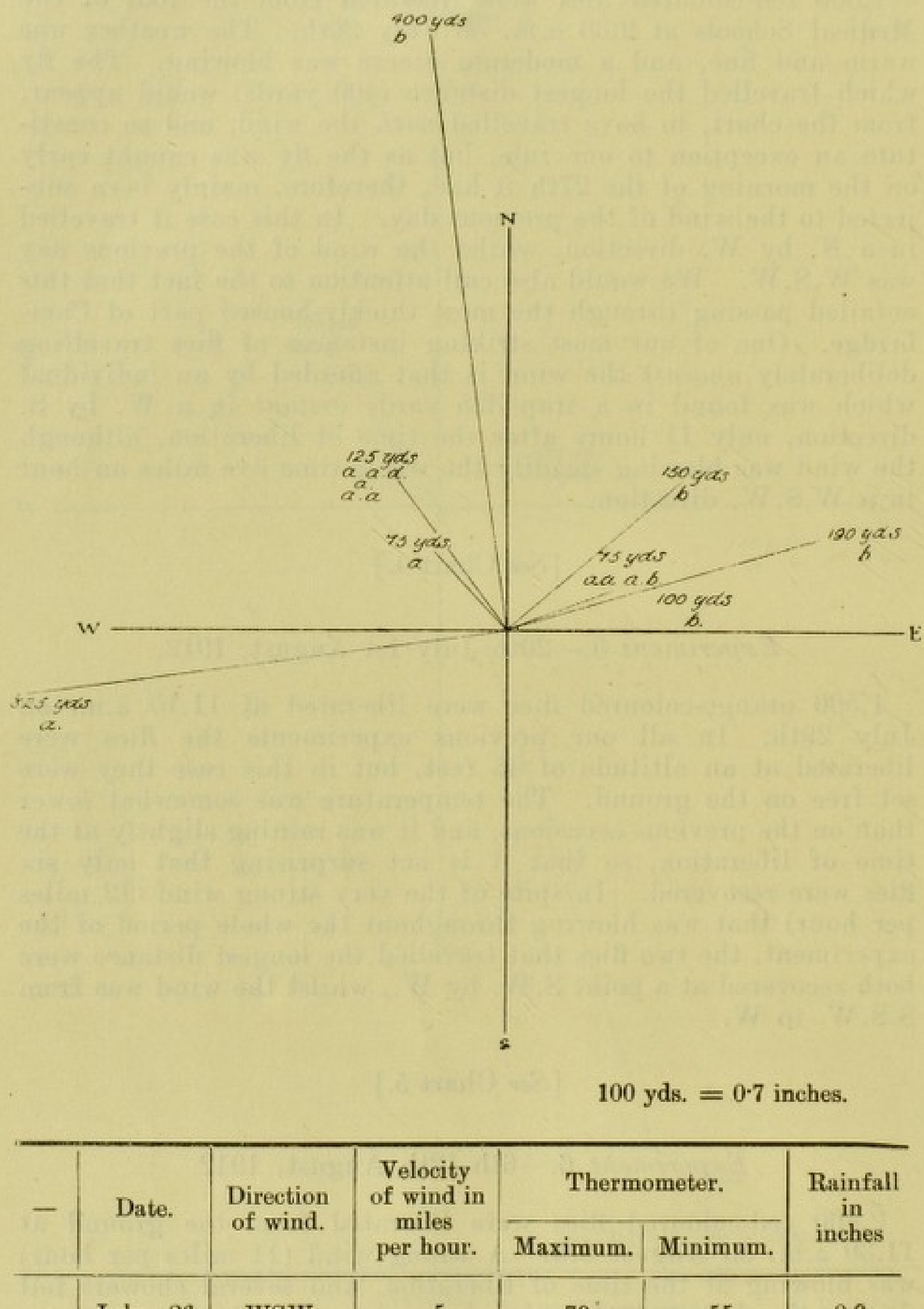
1,500 orange-coloured flies were liberated at 11.15 a.m. on July 29th. In all our previous experiments the flies were liberated at an altitude of 45 feet, but in this case they were set free on the ground. The temperature was somewhat lower than on the previous occasions, and it was raining slightly at the time of liberation, so that it is not surprising that only six flies were recovered. In spite of the very strong wind (12 miles per hour) that was blowing throughout the whole period of the experiment, the two flies that travelled the longest distance were both recovered at a point S.W. by W., whilst the wind was from S.S.W. to W.

[*See* Chart 5.]

Experiment 6.—6th–12th August, 1912.

2,400 red-coloured flies were liberated from the ground at 11.30 a.m. on August 6th. A strong wind (11 miles per hour) was blowing at the time of liberation, and several showers fell during the day, but nevertheless, no less than 34 flies were recovered at distances ranging up to 325 yards from the point of liberation. It will be noticed that most of the 15 flies which travelled a distance of more than 150 yards, had flown either across, or in the teeth of, the wind prevailing on the day previous to their recovery. In this case, a number of flies were recovered from rooms at an altitude of 30 feet, and in many cases the insects must have flown over buildings at least 50 feet high.

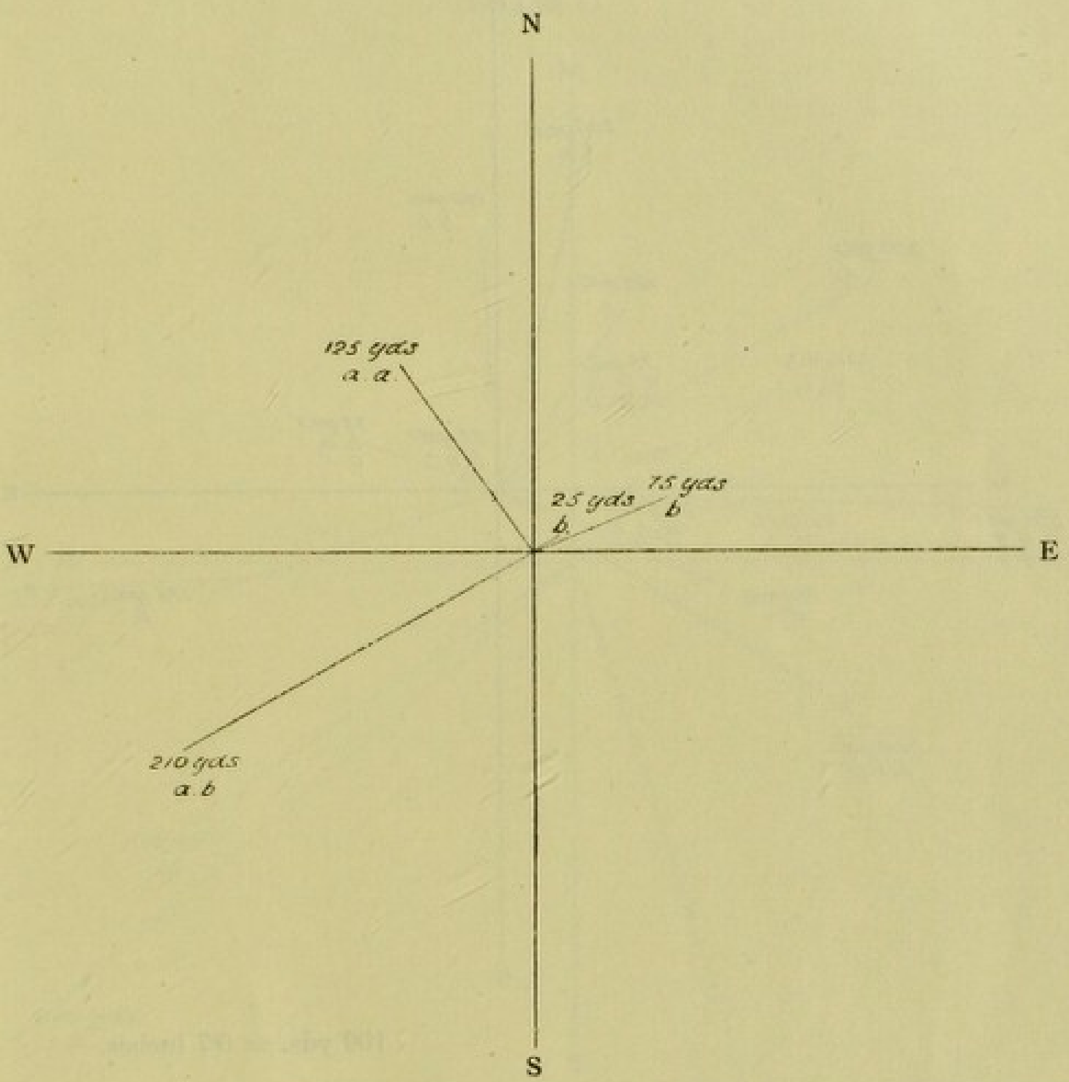
CHART 4.



100 yds. = 0·7 inches.

—	Date.	Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches
				Maximum.	Minimum.	
a	July 26	WSW.	5	79	55	0·0
b	„ 27	SE.	4	76	62	0·13
c	„ 28	SW.	8	77	61	0·01
d	„ 29	SSW.	12	71	56	0·06

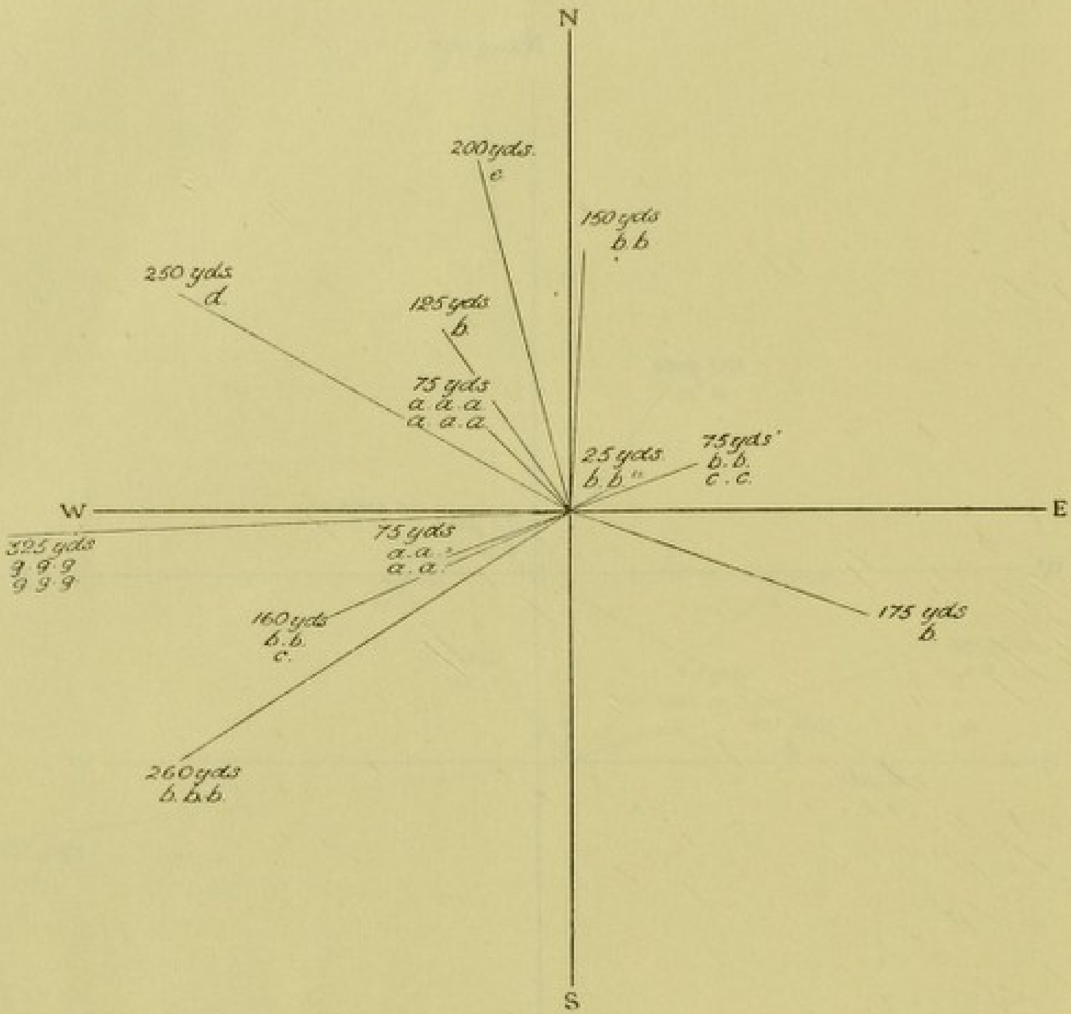
CHART 5.



100 yds. = 0·75 inches.

—	Date.		Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
					Maximum.	Minimum.	
a	July	29	SSW.	12	71	56	0·06
b	„	30	W.	12	65	53	0·08
c	„	31	S.	8	69	52	0·0

Chart 6.



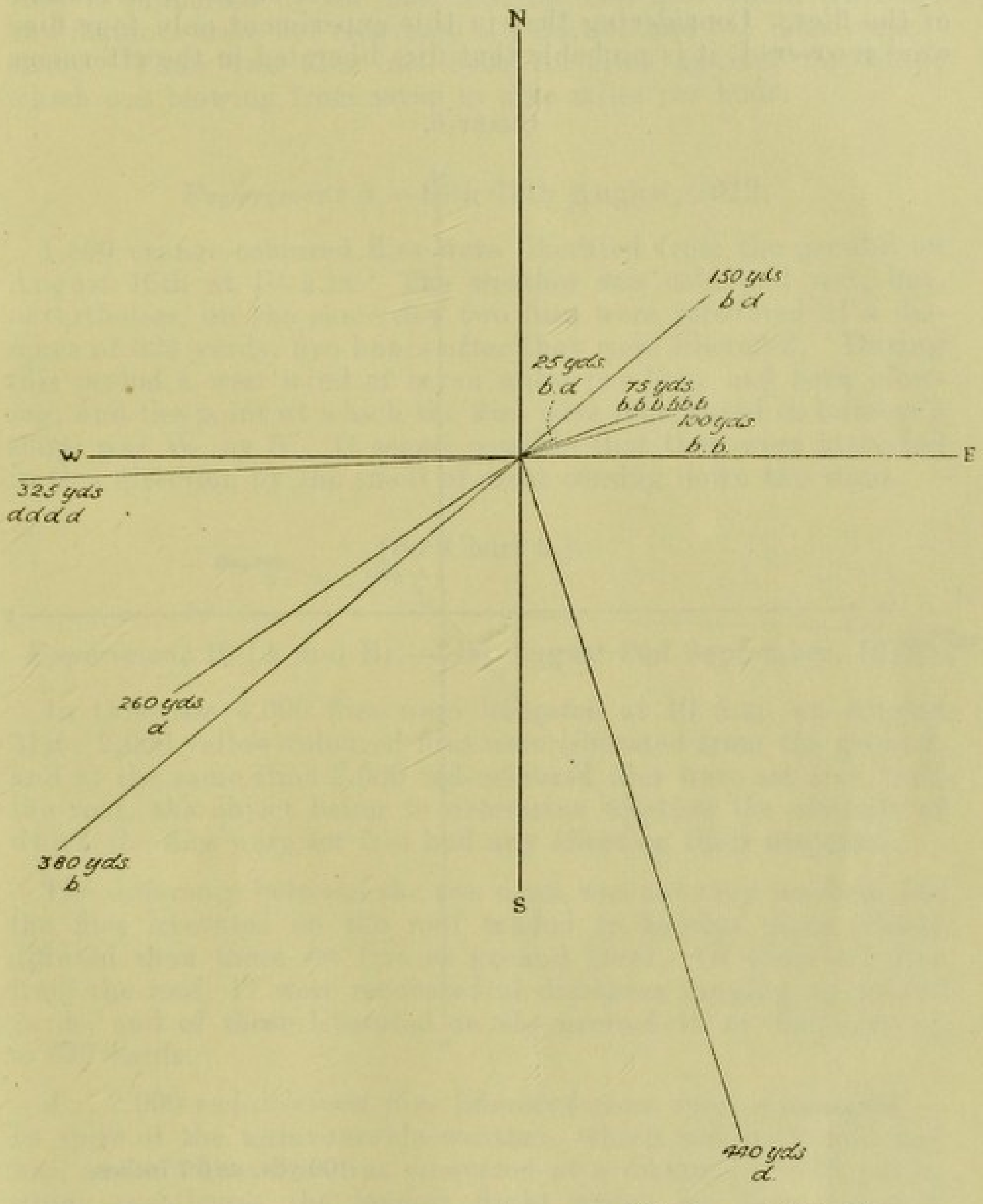
100 yds. = 0·7 inches.

—	Date.	Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
				Maximum.	Minimum.	
a	Aug. 6	SE.	11	68	56	0·1
b	" 7	WSW.	10	65	53	0·2
c	" 8	W.	8	66	52	0·16
d	" 9	W.	6	67	54	0·04
e	" 10	S.	5	67	52	0·0
f	" 11	W.	6	66	49	0·08
g	" 12	E.	4	64	49	0·03

Experiment 7.—9th–12th August, 1912.

3,000 yellow-coloured flies were liberated from the ground on the 9th of August at 11 a.m. The weather from now onwards was cold and rainy, so that the conditions were somewhat unfavourable for the distribution of the flies. In this experiment, however, 19 flies were recovered at stations up to a quarter of a mile distant in directions either across or against the wind.

CHART 7.



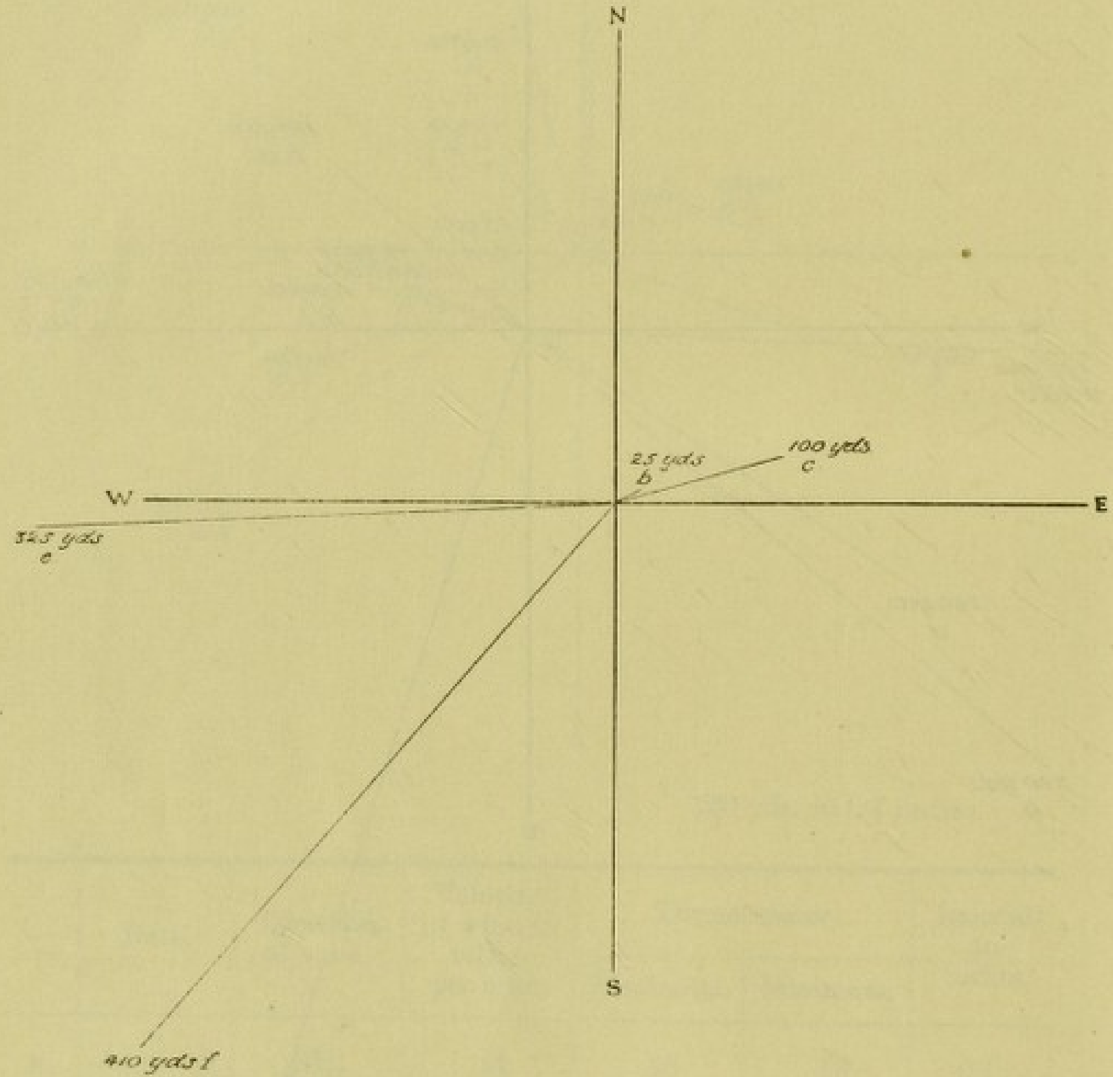
100 yds. = 0·73 inches.

—	Date.	Direction of wind.	Velocity of wind in miles per hour.	Thermometer. Maximum.	Thermometer. Minimum.	Rainfall in inches.
a	Aug. 9	W.	6	67	54	0·04
b	„ 10	S.	5	67	52	0·0
c	„ 11	W.	6	66	49	0·08
d	„ 12	E.	4	64	49	0·03

Experiment 8.—12th–17th August, 1912.

1,500 red-coloured flies were liberated from the ground on August 12th at 4 p.m., since we were desirous of finding out whether the hour of liberation had any effect on the distribution of the flies. Considering that in this experiment only four flies were recovered, it is probable that flies liberated in the afternoon

CHART 8.



100 yds. = 0·7 inches.

—	Date.		Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
					Maximum.	Minimum.	
a	Aug.	12	E.	4	64	49	0·03
b	„	13	N.	7	67	45	0·05
c	„	14	W.	7	61	46	0·0
d	„	15	W.	8	61	51	0·03
e	„	16	W.	7	61	51	0·05
f	„	17	WSW.	9	67	56	0·05

do not disperse so readily as those set free during the morning. During the night following the day of liberation the thermometer fell to 45° F., and the succeeding days being cold, the flies having taken shelter probably remained under cover. This view is supported by the fact that the two flies which travelled any distance were not recovered till the 4th and 5th days respectively. These two flies had both travelled against the wind, which was blowing from seven to nine miles per hour.

Experiment 9.—16th–19th August, 1912.

1,500 orange-coloured flies were liberated from the ground on August 16th at 10 a.m. The weather was cold and wet, but, nevertheless, on the same day two flies were recovered at a distance of 325 yards, five hours after they were liberated. During this period a west wind of seven miles per hour had been blowing, and the point at which the flies were recaptured (a butcher's shop) was W. by S. It seems possible that they were attracted in this direction by the smell of meat coming down the wind.

[*See* Chart 9.]

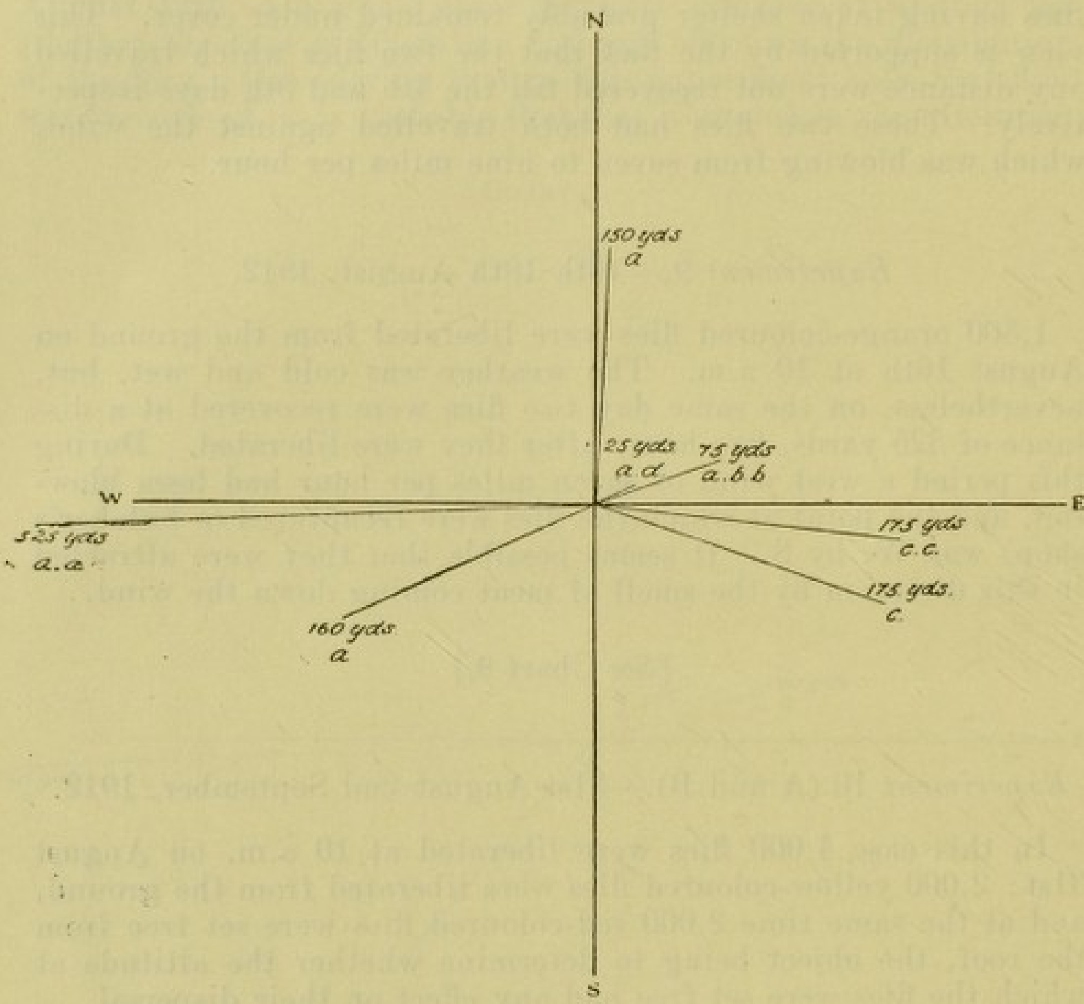
Experiment 10 (A and B).—31st August–2nd September, 1912.

In this case 4,000 flies were liberated at 10 a.m. on August 31st: 2,000 yellow-coloured flies were liberated from the ground, and at the same time 2,000 red-coloured flies were set free from the roof, the object being to determine whether the altitude at which the flies were set free had any effect on their dispersal.

The difference between the two cases was not very marked, but the flies liberated on the roof tended to become more widely diffused than those set free at ground level. Of those set free from the roof, 17 were recovered at distances ranging up to 770 yards, and of those liberated on the ground 11 at distances up to 320 yards.

A. 2,000 *red-coloured flies liberated from roof, August* 31.—In spite of the unfavourable weather, which was both cold and wet, one of these flies was recovered at a distance of 770 yards, which constitutes the longest flight which we have observed throughout this investigation. It should be noted, however, that of this 770 yards, 250 were across open fen-land. This was the first occasion on which we had a predominating north-westerly wind during an experiment, and also the first time flies were recovered from any considerable distance at stations N.W. of the point of liberation. Three flies were recovered at a restaurant situated N.W. by W. and 320 yards distant, and as the wind had been blowing from this direction, it is possible that they were attracted by smell. To reach this point it would be necessary for the flies to traverse a very thickly-housed locality comprising many high buildings.

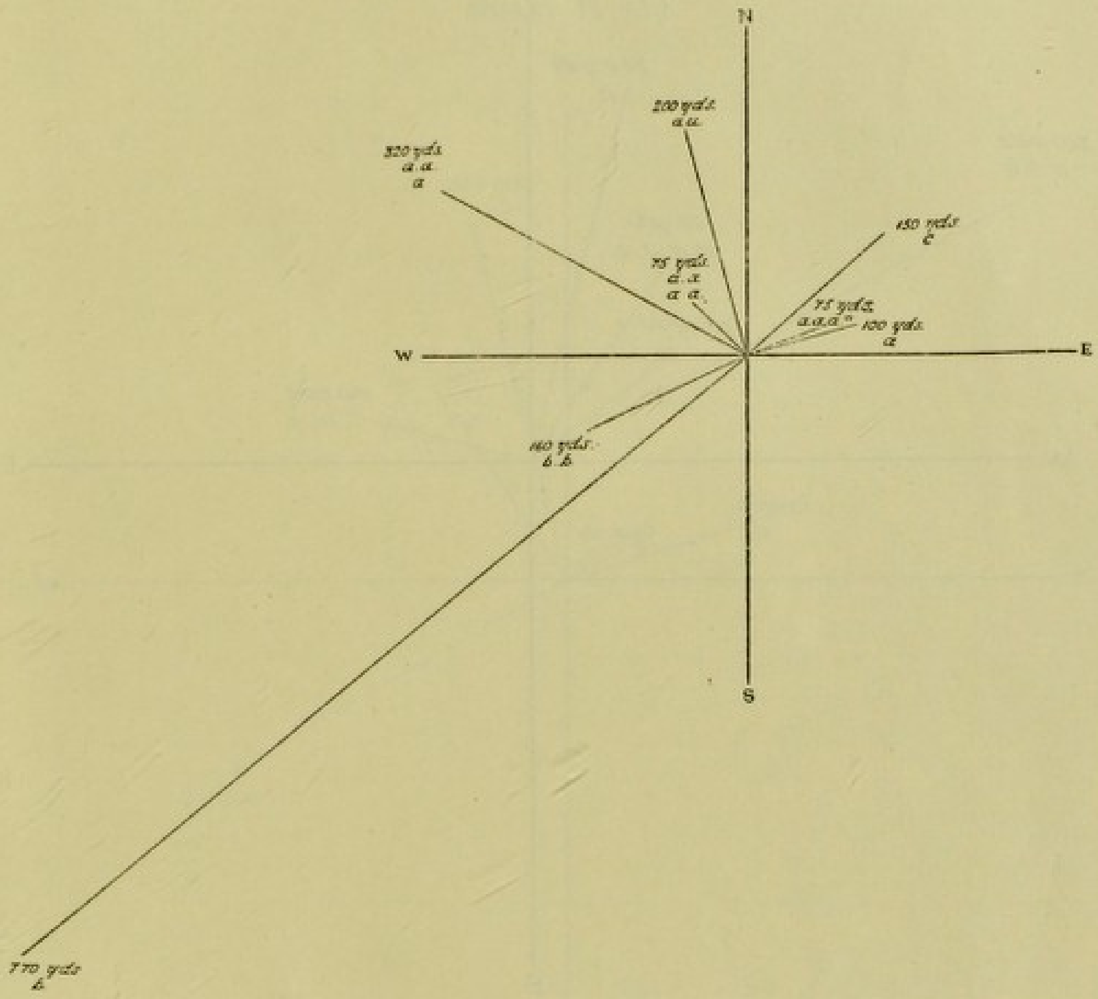
CHART 9



100 yds. = 0·7 inches.

—	Date.	Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
				Maximum.	Minimum.	
a	Aug. 16	W.	7	61	51	0·05
b	„ 17	WSW.	9	67	56	0·05
c	„ 18	W.	8	68	57	0·06
d	„ 19	S.	7	68	53	0·35

CHART 10 (A).

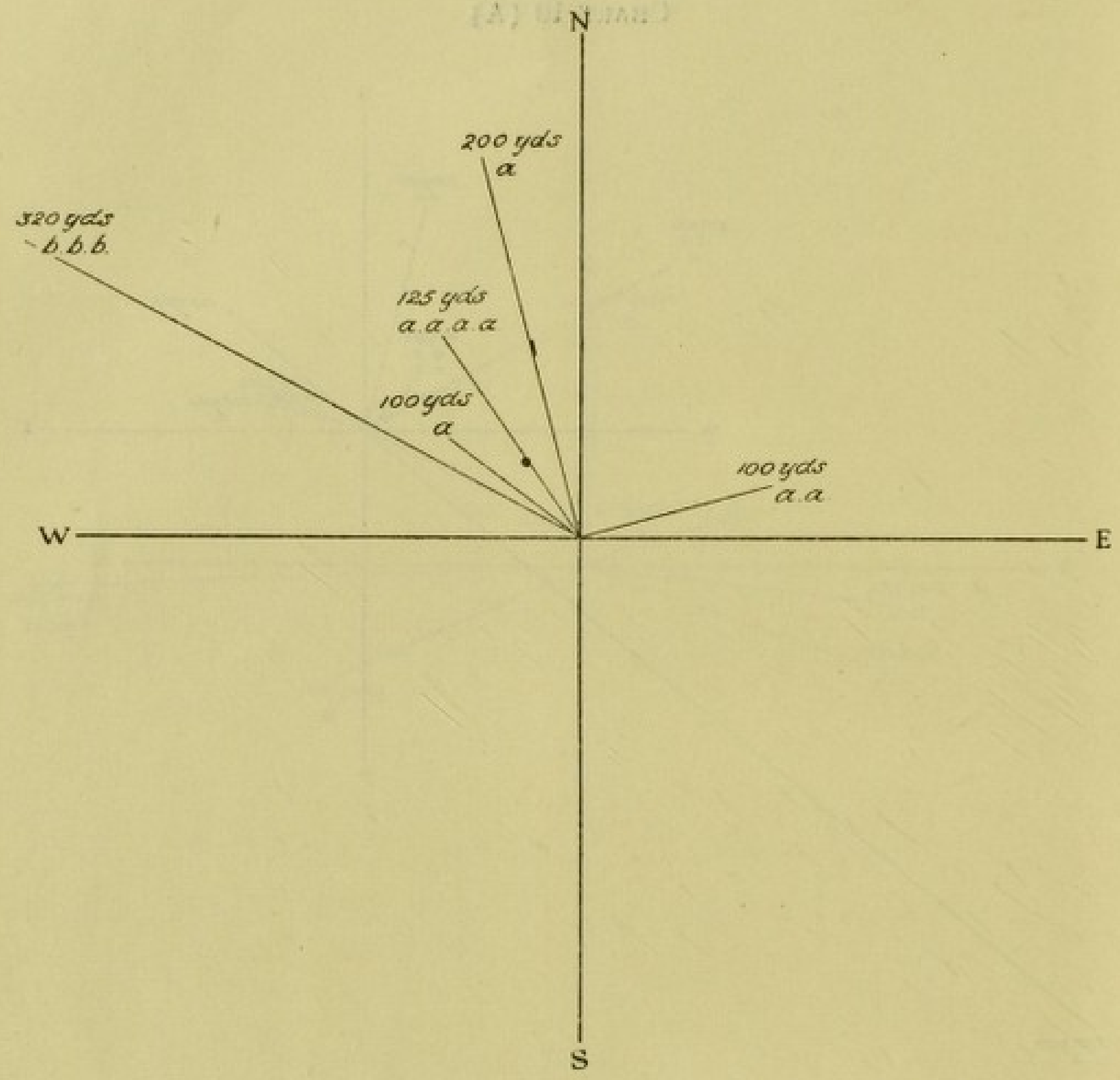


100 yds. = 0·5 inches.

—	Date.	Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
				Maximum.	Minimum.	
a	Aug. 31	NW.	8	68	49	0·01
b	Sept. 1	W.	6	65	52	0·22
c	„ 2	NW.	6	66	53	0·15

B. 2,000 *yellow-coloured flies liberated from ground, August* 31.—As mentioned above, these flies did not travel quite as far as those liberated from the roof, but three were recovered from the same restaurant—a distance of 320 yards. In every case, the flies recovered took a northerly or north-westerly direction, the prevailing wind being N.W.

CHART 10 (B).



100 yds. = 0·8 inches

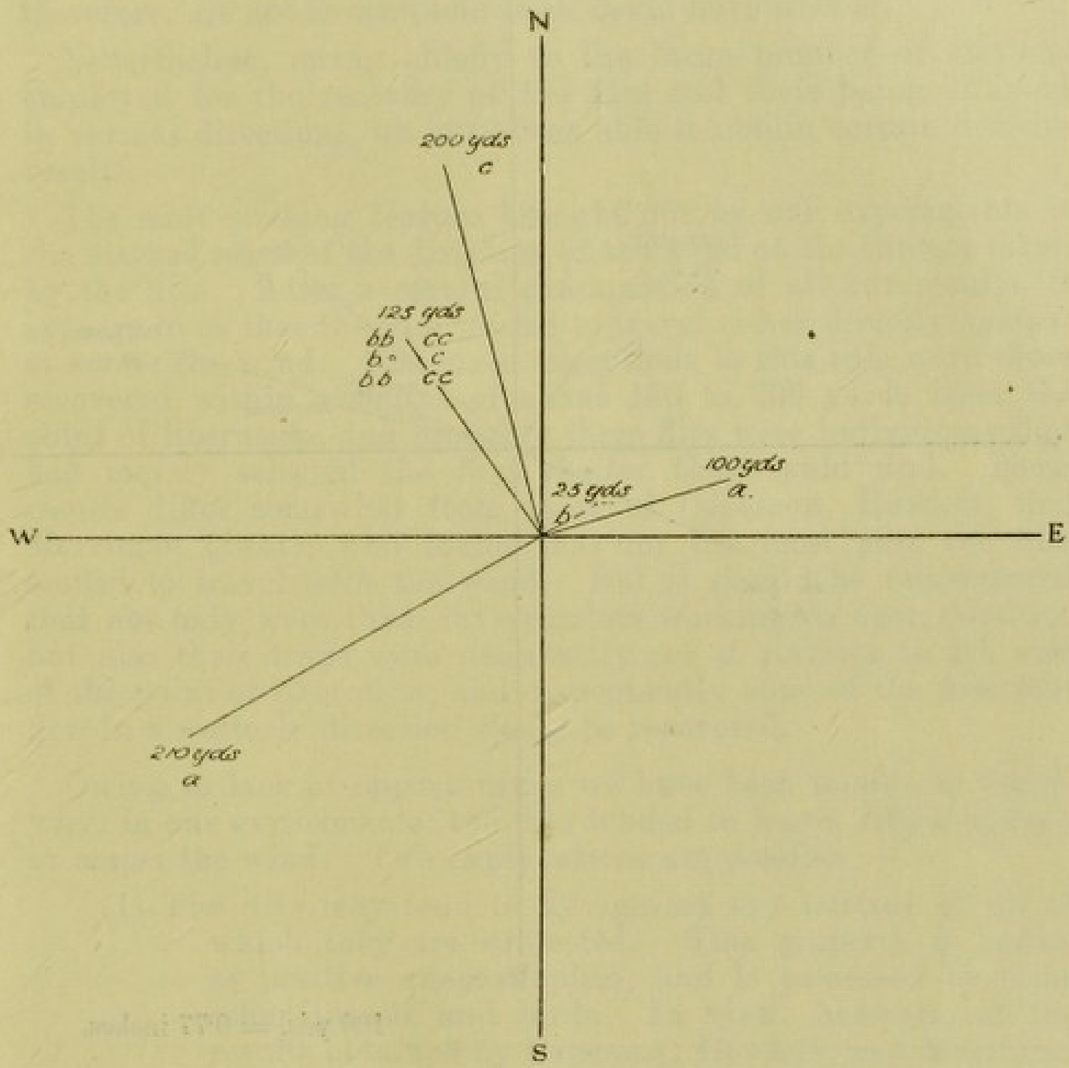
—	Date.	Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
				Maximum.	Minimum.	
a	Aug. 31	NW.	8	68	49	0·01
b	Sept. 1	W.	6	65	52	0·22
c	„ 2	NW.	6	66	53	0·15

Experiment 11 (A and B).—5th–7th September, 1912.

6,000 flies were liberated at 11 a.m. on September 5th. A strong wind (11 to 12 miles per hour) was blowing, and the weather was very cold. As in the previous experiment (10), half the flies were liberated from the ground and half from the roof. This experiment was very unsatisfactory, as the cold wind rendered the flies very torpid; but, as before, a larger number of those liberated from the roof were recovered.

A. 3,000 *orange-coloured flies liberated from roof, September* 15.—In this case, 23 flies were recovered at distances up to 190 yards, and no less than 17 from one station 125 yards distant. The short distances traversed clearly demonstrate the effect of cold in rendering these insects torpid.

CHART 11 (A).

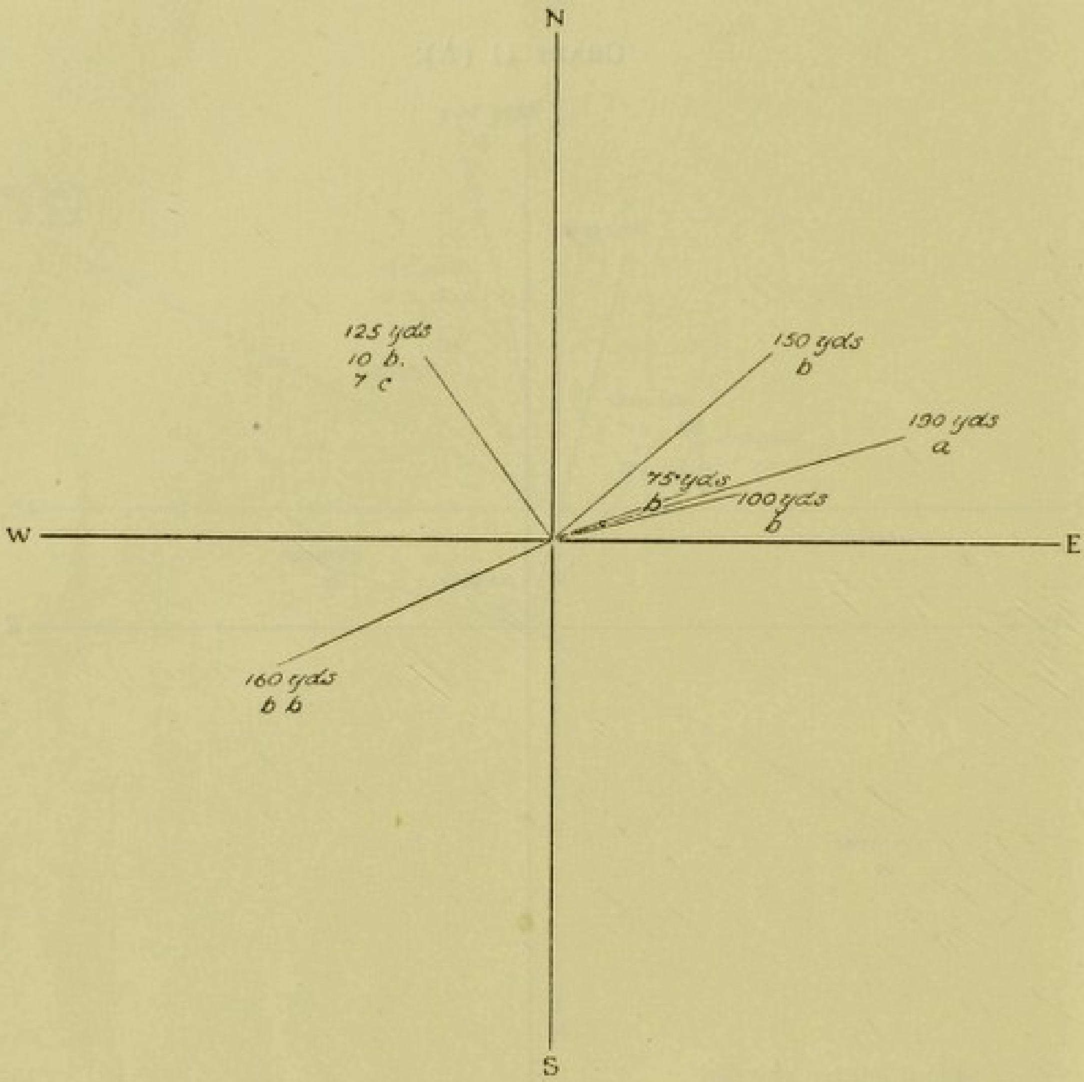


100 yds. = 0·75 inches.

—	Date.	Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
				Maximum.	Minimum.	
a	Sept. 5	W.	11	66	49	0·0
b	„ 6	W.	12	61	45	0·02
c	„ 7	NNW.	11	59	45	0·0

B. 3,000 *red-coloured flies liberated from the ground, September 5.*—In this experiment only 14 flies were recovered, as against 23 in (A); but it is rather curious that two of these flies covered greater distances than any of those liberated from the roof. This, however, is insignificant, as the maximum distance travelled was only 210 yards.

CHART 11 (B.)



100 yds. = 0·77 inches.

—	Date.		Direction of wind.	Velocity of wind in miles per hour.	Thermometer.		Rainfall in inches.
					Maximum.	Minimum.	
a	Sept.	5	W.	11	66	49	0·0
b	"	6	W.	12	61	45	0·02
c	"	7	NNW.	11	59	45	0·0

DISCUSSION OF THE ABOVE-DESCRIBED EXPERIMENTS.

Unfortunately, nearly all our experiments in Cambridge were seriously handicapped by the great difficulty of obtaining flies in sufficient numbers and also by the adverse meteorological conditions. Throughout August the weather was so bad that from the 19th to the 31st of this month not a single fly could be liberated. During the early part of September nearly all the flies became infected with *Empusa muscae*, and this, in conjunction with the cold weather, brought the investigation to a sudden end. In the earlier experiments we should have preferred to have liberated at least double the number of flies, but owing to the difficulty of procuring them this was impossible. Our results, therefore, are not as complete as we could have wished.

Nevertheless, owing chiefly to the large number of stations employed for the recovery of the flies and their being situated in various directions, we have been able to obtain certain definite results.

The most striking feature brought out by our experiments is the marked effect of the direction of the wind on the courses taken by the flies. After a careful examination of all our results, it appears to us that the flies tended to travel either directly *against* or *across* the wind. The main exceptions to this rule were those recovered within a radius of about 150 to 200 yards from the point of liberation, and probably these flies were individuals that had merely selected the first shelter they could find. These results differ somewhat from those of Copeman, Howlett, and Merriman (1911), who found that for the most part the flies tended to travel *with* the wind. But it should be remembered that not only were these investigators working in open country, but also their traps were necessarily set at stations to the east of the point of liberation, and consequently none of the flies that flew in a westerly direction would be recovered.

Owing to lack of opportunities we have been unable to decide why, in our experiments, the flies tended to travel either against or across the wind. Two explanations are possible:—

(1) The flies may tend to fly against any current of air to which they are subjected. This property is known as positive anemotropism, and is possessed by some other insects and birds. In view, however, of the results obtained by Copeman, Howlett, and Merriman (1911), we cannot come to definite conclusions on this point, and further experiments are required to determine if other factors than wind-direction influence the direction of flight.

(2) The flies may travel against the wind, being attracted by any odours it may convey from a source of food. A point in favour of this supposition is the nature of the stations at which flies were recovered after they had travelled any distance. These comprised a butcher's shop, public houses, and a restaurant, all of which gave off odours that are notoriously attractive to flies.

The maximum distance travelled by any of the flies we liberated in Cambridge was 770 yards, which is considerably less than that covered by those liberated in the open country at Postwick—in one case as much as 1,700 yards. This difference may be attributed to the absence of shelter in the case of the Postwick flies, whereas in Cambridge food and shelter were always plentiful. On the whole, we do not think it likely that, as a rule, flies travel more than a quarter of a mile in thickly-housed areas. Throughout our experiments the only fly that exceeded this distance had travelled 770 yards, of which a large part was across open fen-land.

The chief factors influencing the dispersal of the flies are probably the temperature, weather, and the time of day when the insects are liberated. The effect of temperature is very marked, as when it is low the flies become torpid and seek the first available shelter. This is shown in Experiments 11 (A) and 11 (B), respectively. Fine weather is also a necessary condition for long flights, as rain at once drives the flies into shelter. The ideal experimental conditions for a flight experiment are two or three days of fine warm weather, during which the flies can make their flight, succeeded by a wet or showery day, when they are driven indoors, and thus can be recorded at the various stations.

With regard to the altitude of the point of liberation, flies set free from the roof tended to disperse slightly better than those liberated from the ground, but the differences are not very considerable.

With regard to the vertical flight of the house-fly, although we have found no means of estimating the maximum, nevertheless, during our experiments, when liberating them from the ground, we have frequently observed the flies at once mount almost vertically upwards to a known height of 45 feet.

Summary.

Under the conditions of our experiments, indication was afforded that—

(1) House-flies tend to travel either *against* or *across* the wind. The actual direction followed may be determined either directly by the action of the wind, or indirectly owing to the flies being attracted by any odours it may convey from a source of food.

(2) It is likely that the chief conditions favouring the dispersal of flies are fine weather and a warm temperature. The nature of the locality is another considerable factor, as in towns flies do not travel as far as in open country, this being probably due to the food and shelter afforded by the houses.

(3) Under experimental conditions, the height at which the flies are liberated, and also the time of day, appears to influence the dispersal of the insects. As judged by one experiment, when flies are set free in the afternoon they do not scatter so well as when liberated in the morning.

(4) The maximum flight in thickly-housed localities in our experiments was about a quarter of a mile; but in one case a single fly was recovered at a distance of 770 yards. It should be noted, however, that part of this distance was across open fen-land.

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4. NOTE ON THE COLOUR-PREFERENCE OF FLIES.

By EDWARD HINDLE, B.A., Ph.D., F.L.S., Magdalene College, Cambridge. Assistant to the Quick Professor of Biology, Cambridge.

In the course of our investigations on the biology of flies, during the year 1912, a certain number of experiments were performed in order to ascertain whether house-flies possess any colour preference. In the case of mosquitoes, Nuttall (1901) has shown that these insects have a very well-defined preference for certain colours. When a number of boxes, lined with different coloured materials, were placed in a tent containing mosquitoes, the latter occurred most frequently on navy-blue, and, in descending order, on dark red, brown, scarlet, black, slate-grey, dark green, violet, leaf-green, blue, pearl-grey, pale green, light blue, ochre, white, orange, and yellow. Very few insects indeed were found to rest on the last seven colours.

A French observer, Fé, published the statement that, having noticed that flies did not rest upon walls covered with blue paper, he blue-washed the walls of his milk houses and found that insects did not visit them. Galli-Valerio (1910), who refers to Fé's statement, conducted a few experiments on this subject.

Different coloured pieces of paper of equal size were pasted over the walls of a large glass box, and afterwards a number of house-flies were introduced. The position of the cage was changed several times, and in each position the number of flies resting on the respective colours was carefully counted. As a result the flies were found to rest on each colour in the following numbers:—Clear green, 18; rose, 17; clear yellow, 14; azure, 13; clear red, 10; dark grey, 9; white, 9; dark red, 8; black, 7; pale grey, 5; dark yellow, 5; dark green, 5; red, 4; orange, 3; clear brown, 3; pale rose, 3; very clear green, 2; blue, 1; pale violet, 1; dark brown, 1; lemon yellow, 1.

Galli-Valerio notes that 87 flies rested on clear colours and 52 on the dark ones. From these results it seems that, although very few flies settled on the blue, the closely-related colour, azure, was one of those the most visited.

These results seemed so uncertain that it was decided to perform some experiments on the subject.

A strip of cardboard, 24 inches long and 7 inches wide, was painted with bands of colours 4 inches wide. The whole was then covered with a sticky substance so that any flies which settled on the card were caught. Later, it was found more convenient to cover the front of the coloured strip with transparent sticky paper, through which the colours were quite visible. The relative positions of the bands of colour were changed from day to day, and the flies that had accumulated on them removed and counted.

The results were as follows; the figures indicating the number of flies caught on each colour.

Date.	Blue.	Yellow.	Black.	Red.	White.	Green.
20. VII. 12... ...	24	47	21	37	41	55
22. VII. 12... ...	8	8	5	9	29	30
23. VII. 12... ...	33	34	16	23	28	27
24. VII. 12... ...	16	20	12	17	9	10
25. VII. 12... ...	22	19	20	20	22	24
26. VII. 12... ...	17	23	10	15	23	25
27. VII. 12... ...	17	16	21	17	13	14
29. VII. 12... ...	25	25	22	26	10	12
30. VII. 12... ...	8	14	18	16	9	10
31. VII. 12... ...	13	13	14	8	5	7
1. VIII. 12... ...	11	17	15	15	25	36
2. VIII. 12... ...	12	22	22	18	16	19
3. VIII. 12... ...	18	13	19	21	10	4
Total	224	271	215	242	240	273

A comparison of the total number of flies collected on each colour clearly shows that, under the conditions of the experiment, flies do not display any marked colour preference. Therefore, it seems unlikely that the adoption of any particular colour for the walls of houses and stables will have any effect on the numbers of flies entering them.

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5. FURTHER OBSERVATIONS ON NON-LACTOSE FERMENTING BACILLI IN FLIES, AND THE SOURCES FROM WHICH THEY ARE DERIVED, WITH SPECIAL REFERENCE TO MORGAN'S BACILLUS.

By G. S. GRAHAM-SMITH, M.D.

During the summer of 1911 the writer (1912, A) made a large number of observations on the presence in house-flies from various sources of bacilli which do not ferment lactose nor liquefy gelatin. It was shown that Morgan's No. 1 bacillus (G a 8*) was frequently present in the intestines of flies obtained from houses, both in Birmingham and in Cambridge, in which cases of summer diarrhœa had occurred, but that it was very seldom found in flies from other sources. During the summer of 1912 the observations recorded in this paper were made in order (A) to extend the previous observations and (B) to ascertain, if possible, the sources from which flies contaminate themselves with Morgan's bacillus.

A. *Observations on the presence of Morgan's bacillus in flies.*

In these experiments the same technique was employed as in 1911-12 (p. 305†), except that MacConkey's medium containing ·5 per cent. of mannite as well as ·5 per cent. of lactose was employed in order to avoid the necessity in the search for Morgan's bacillus of isolating those non-lactose fermenting bacilli which ferment mannite.

The weather conditions during 1912, especially during the epidemic diarrhœa season, were quite different to those prevailing in 1911. In the latter year the mean temperature was high and little rain fell in July, August and September, whereas during

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* For the method adopted in classifying non-lactose fermenting bacilli see Graham-Smith (1912, A, p. 305).

† This and subsequent page-references in brackets are, unless otherwise stated, to the Annual Reports of the Medical Officer of the Local Government Board.

1912 the mean temperature was low and the rainfall excessive; in fact, while the summer of 1911 was one of the warmest recorded, that of 1912 was one of the wettest and coldest. Both in Birmingham and in Cambridge diarrhœa cases were numerous in 1911 and few in 1912. In the former year flies were very common in both places, whereas in the latter they could only be obtained in scanty numbers.

During 1912 291 flies from 10 houses in Birmingham, in which cases of diarrhœa had occurred, and from 5 houses, mostly situated in congested districts, in which it had not occurred, were examined. From none of these flies was Morgan's No. 1 bacillus (G a 8) isolated. 397 Cambridge flies from houses in which no cases of diarrhœa had occurred were examined, and from none of them was Morgan's bacillus isolated.

Morgan's bacillus was found in flies from diarrhœa infected houses both in Birmingham and in Cambridge in 1911, when diarrhœa was very prevalent; but was seldom isolated from flies caught in non-infected houses, and in 1912, when the disease was very uncommon, it was never isolated from flies caught in diarrhœa-infected houses.

As no attempt was made to work out all the varieties of non-lactose fermenting bacilli, which occurred in these flies the findings cannot be compared with those of last year. It may be mentioned, however, that the following types were frequently present—A a 6, B a 6, C a 8 (very common), C g 5, C g 6—all of them commonly found in flies in last year's investigation. No bacilli belonging to group G were isolated, and the other groups were not investigated.

B. *Experiments made with the view of ascertaining whether Morgan's bacillus is present in animal excreta.*

It is evident from the observations of those workers who have recently studied the bacteriology of infantile diarrhoea that although Morgan's No. 1 bacillus is occasionally found in the fæces of healthy infants, it is found more frequently in those of infants suffering from this disease. Lewis (1911-12, p. 287) concludes that "the evidence adduced brings under such strong suspicion the causal relationship of one variety of non-lactose fermenting bacilli, viz., variety 8 of sub-group a of Group G (*i.e.*, Morgan's No. 1 Bacillus) that further concentration of research upon this variety is desirable."

Flies doubtless frequently infect themselves from the excreta of diarrhœa cases, or from milk, or other articles which have been contaminated. Flies thus infected may carry and distribute Morgan's bacillus. They cannot, however, originate an infection with this organism amongst human beings unless they can convey it from animal or other sources in which it may be present.

Very few observations seem to have been made regarding the presence of Morgan's bacillus in animal excreta. Morgan and Ledingham (1909, p. 142*) isolated it once from fresh cow's fæces (18 animals examined), but not from the fæces of the horse

* *Proc. Roy. Soc. Med.* II. Epidem. Section.

(13 animals examined). Lewis 1911-12, p. 285) found it in the fæces of five out of twenty mice in Birmingham. In regard to this observation he makes the following remarks: "If this variety should hereafter be shown to cause the disease (infantile diarrhœa) its presence in the fæces of mice provides one source from which food might be contaminated either by the mice themselves, or by flies or by other modes of conveyance. Among other non-lactose fermenting bacilli found in mice, three varieties of group B correspond to varieties found in the fæces of infants. Sub-group g of group H is common to the fæces of both mice and children. . . . It must be admitted that these non-lactose fermenting bacilli in these mice may be as abnormal, or as normal as they are in the fæces of healthy infants, since the food of the mice consisted mainly of bread and milk, which enter into the diet of children."

In the summer of 1912 the writer carried out a large number of experiments with the fresh excreta of various animals, and with material derived from manure heaps. The material was in each instance collected on sterile cotton-wool swabs, and emulsified in salt solution. From the emulsion plate cultures on solidified MacConkey's medium containing ·5 per cent. of mannite and ·5 per cent. of lactose were made. Specimens of many of the non-lactose fermenting colonies were investigated in pure culture. Of horse fæces 32 samples, of cow 34, of sheep 15, of goat 4, of dog 16, of cat 8, of ferret 3, of rat 8, of mouse 8, of rabbit 5, of guinea-pig 5, and of fowl 7, were examined, but Morgan's bacillus was not isolated from any of them.

Organisms belonging to group A were common in horse, cow, and sheep fæces and were occasionally found in rabbit, mouse, and ferret fæces. No bacilli belonging to groups B or G were met with. The C g type, which is very common in flies, was found occasionally in rat and mouse fæces. The other groups were not investigated.

Samples from eleven manure heaps also gave negative results. A few examples of damaged fruits were also examined with negative results as regards the presence of Morgan's bacillus.

From the observations of previous workers already quoted there can be little doubt that Morgan's bacillus is occasionally present in the excreta of certain animals, and no doubt flies visiting such excreta may become infected. Moreover, as the writer (1912, B) has shown, flies which develop from larvæ bred in contaminated excreta, may sometimes be infected with this organism. Possibly the weather conditions of 1912, which apparently influenced the occurrence of summer diarrhœa and the presence of Morgan's bacillus in flies, may also have influenced its presence in animal excreta and other situations in which it may occur. Further observations are required in order to elucidate this point.

Conclusions.

During the hot summer of 1911 flies were very numerous and epidemic diarrhœa common. Taking the results of all the examinations made, bacilli of the Morgan type were found in 5·3 per cent. of flies caught in diarrhœa infected houses in Cambridge and Birmingham as contrasted with a percentage of 0·6 in flies caught in non-infected localities.

In 1912, when the summer was cold and wet, flies scarce, and epidemic diarrhœa uncommon, Morgan's bacillus was not isolated from flies obtained from *either* infected or non-infected houses.

Attempts (in 1912) to isolate this bacillus from samples of excreta from apparently normal animals have likewise been unattended with success.

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