Las Vigas, 7,900 ft., July 30–31, 1942; 2 ♂, 1 ♀, Cofre de Perote, 10,500 ft., July 30–August 4, 1942 [males averaged 46.3 grams (40.0 to 53.7); two adult females, 38.3 and 39.8 grams]. This sparrow is characteristic of the coniferous belt of central México. It occurred on all the high mountains visited by us (Cofre de Perote, Orizaba, Popocatepetl, Iztaccihuatl, Tres Cumbres, etc.) at elevations ranging from 7,900 feet at Las Vigas to nearly 14,000 feet on Mount Popocatapetl. It preferred open meadows and was one of the common timberline sparrows. One of the females from Las Vigas is a nearly full-grown young of the year. The adult female had a well-developed brood patch and the testes of the two males were considerably enlarged.

**Aimophila rufescens rufescens* (Swainson), RUSTY SPARROW.—1 ♀, Jalapa, 4,500 ft., July 2, 1941. Widely distributed in central Veracruz, preferring thickets in the vicinity of water.

Junco phaeonotus phaeonotus Wagler, MEXICAN JUNCO.—1 ♂, Las Vigas, 8,000 ft., August 4, 1942; 1 ♂, Cofre de Perote, 10,500 ft., August 4, 1942 (testes small; weights 21.5 and 22.5 grams). A common breeding bird in the conifer-clad areas of the Mexican plateau, occupying an altitudinal range from near 7,000 feet to timberline (specimens were taken on Mt. Popocatepetl at 13,500 feet).

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THE HOMING ABILITY OF THE CARRIER PIGEON ITS VALUE IN WARFARE[1]

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THE homing ability of the carrier or homing pigeon[2] is, in a general way, well known—so much so that this, their chief characteristic, is frequently employed in metaphor and simile as an expression of precision and accuracy which would rebound much to the discomfiture of the writer were all in full possession of the relevant facts. In the light of recent occurrences, the subject is not without topical interest and the biologist, on examining the data and experiments described below, may be able to fill in some of the gaps which puzzle the pigeon enthusiast. For the latter invariably knows his birds well, develops his own method of selecting the wheat from the chaff, from personal experience constructs his own theories, but all too often fails to view his subject objectively and shrouds his conclusions with an anthropomorphic and teleological aurora that defies clear vision.

It is the intention of the writer to review in this paper the known achievements of the homing pigeon; the uses to which they have been

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[2] The terms "carrier" and "homing" pigeon are used interchangeably in this paper.

put in peace and war (described for the benefit of interested readers who may not have had access to the scattered literature on this subject); and to discuss the ways in which they have been used in the present war in so far as it may be told. Finally, an attempt will be made to correlate the problem of the homing ability of this domesticated species with the homing abilities of migratory birds in general in order to discover what light the former will shed on the subject as a whole.

Darwin (1) has shown that the homing pigeon has been evolved from the wild rock-dove which still breeds in western England and which, by continued artificial selection, has been developed into the bird employed today. Moreover, the modern homer is the result of the cross-breeding of several distinct varieties of domestic pigeon and, as such, originated in the nineteenth century although only within the past hundred years have its homing abilities been widely used. Pigeon racing in the past has been a very popular sport in western Europe and even more so in Great Britain. To a smaller extent pigeon races have been held in North America where some of the events have been characterized by abnormally long distances. Annually, the young and the old bird races have attracted many participants and as the result of the selection which these races have exercised, a bird strong in physique, which can be relied upon to return to a known loft after proper training, has been obtained. Certainly the homer is larger than its wild progenitor. Little is known of the homing ability of the rock-dove whose major flights seem to be from feeding grounds to social nesting sites. Consequently, the following is the maximum which can be predicated:—

1. Selection has favored homers with best physique and homing ability. It is impossible to distinguish the relative importance of these two factors in the case of any winning bird.
2. The modern homer possesses homing ability at least as nice as that of the natural species.

Details of training programs used by pigeon racers are as varied as the number of participants and every gradation can be found from the case of the man who swears by the effects of night water or chimney sweepings to the person who calculates his procedure with graphic accuracy. The following, however, is a general and representative picture. Young birds are purchased or hatched in a loft and are settled in that site as their permanent home. They are weaned and gradually learn to fly short distances. By judicious attention and handling, the fancier accustoms the bird to his presence. They are

released daily for exercise and they fly about the immediate loft area, gradually becoming stronger on the wing and learning to maintain close flock formation ("kitting"). They are fed only on return to the loft and birds which fail to enter the trap readily may be penalized until their performance improves. Some particular call is utilized to call the birds back to the loft, usually the sound of dry corn rattling in the feed tin. After this preliminary training, birds are selected for the different events and are sent away varying distances on the flight route which will be followed during the actual race. They are released at these points and fly home. A program of tosses for a long-distance race might be somewhat as follows: ½ mile; ½; 1; 1; 2; 3; 5; 10; 16; 25; 40; 60; 90; 130; 175; and 250 miles. And in the final toss, at the time of the actual race, the bird may be jumped to 500 miles. Breeding is utilized as a stimulus to return by certain fanciers who try to arrange that the racing birds will have eggs or young at some particular stage of development at the time of the race, and breeding may be employed also to alter the time of the molt so that the bird will have the maximum number of pinions on race-day.

This homing ability of the pigeon, in common with the migratory habits of other species, early attracted notice. Most of the classical references to message carrying by pigeons can be discounted due to technical inaccuracies, and it is not until the nineteenth century that we find authentic instances. During the siege of Paris, homers were carried out of the city by balloon and were used to carry correspondence inscribed on collodion film into the beleaguered city. The proportion of returns was about 17 per cent. Despatches were also carried by pigeon during the siege of Ladysmith and to isolated garrisons in Nigeria shortly after the Boer War. These birds have also been employed by various prominent newspaper companies to obtain detailed news of sporting events in time for their several editions. But it was in the war of 1914 to 1918 that the homing pigeon was first extensively used as a means of communication. Here it played a remarkable rôle in many fields. Birds were sent out with trawlers and mine-sweepers which at first lacked wireless as a means of communication. They were dropped by plane over enemy-occupied territory to be used by agents and sympathizers. And, finally, thousands of birds were used by the services on the western front as an aid to communication.

The method employed by the army was briefly as follows. Lofts were settled somewhere behind the lines, frequently at divisional headquarters and preferably close to a signal office or message centre. Young birds were favored and thoroughly accustomed to their location

by long residence and exercise flights. They were then carried away increasing distances from the loft along the route which would be followed during actual operations and released to fly home. Finally, when trained, they were carried up to battalion and company headquarters in suitable panniers by despatch riders and orderlies before an attack and were released by commanders to send reports and requests for support to headquarters in rear. Osman (2) states that such birds homed faithfully in 99 per cent of the cases.

The advantages of using pigeons in this type of warfare were numerous. It was very economical of human lives since many runners would otherwise have been killed in crossing shell-torn country with messages, whereas the birds were hard to shoot on the wing and could pass over shelled areas with relative impunity, and even when wounded would press on as long as they could fly. They were not disturbed by shell fire as long as the loft itself was not hit nor badly shaken. They were much less susceptible to certain types of poison gas than men. Skilled operators were not required to release them in forward and exposed areas. Against this must be set the fact that they were unreliable in fog, smoke or darkness; that they would only carry messages in one direction, and that they lacked mobility in the sense that long residence was required before the bird could be relied upon as a messenger in any locality.

On the outbreak of hostilities in 1939, the use of pigeons in warfare required re-examination since it was soon apparent that many of the signals problems of the War of 1914 to 1918 were not applicable to this new warfare with its terrible alterations in tempo and method. Pigeons are again being carried by naval vessels and also by planes of the air forces. The latter have evolved special techniques for their release from aircraft but, interesting as such details are, they lie outside the scope of the present paper. Among the ground forces, with the advent of more mobile warfare in 1940, when rigid lines became replaced by defended localities and maneuver again became possible, the possibility of using pigeons as a means of communication became questionable. They are obviously of greatest value to forward elements whose means of communication are slight. In such areas, telephone lines at first are flimsy and exposed to frequent interruption, and wireless is of short range and often hampered by atmospherics at night. The use of visual signalling and messengers is subject to interruption and expensive in personnel. *Caeteris paribus*, pigeon service could parallel or supplant such means of communication and, in the case of isolated parties cut off from the rest of the force, the birds could be dropped by parachute. Much work and ingenuity have been expended on this

subject by pigeon fanciers in the armed forces and their results are discussed below.

We may consider the several problems which have been met as follows:

1. Training pigeons for maximal mobility.
2. Training birds to fly at night.
3. Training birds for two-way communications.

Problem 1.—Training birds for maximal mobility.

Details of such training no doubt vary among the armies of different nations, but the following will serve as a representative example. Small lofts are used, either light enough to be manhandled or mounted on trailers. Young birds are chosen, usually about five weeks old, and are settled in these lofts. The initial part of their training consists of making the birds strong on the wing, "kitting" (*i. e.* flock formation) and teaching the birds to trap readily. Fundamentally the last mentioned is based on a simple conditioned reflex established through calling the birds into the loft by rattling feed in a can or blowing a whistle. Then, as soon as the birds pass through the trap, they are given their allowance of corn. Thus the birds come to associate certain sounds and the act of trapping with food. Immediate and automatic trapping is obviously of great importance when the recovery and delivery of a message in the shortest possible time are set at a premium. At this stage the lofts are moved short distances daily in order that the birds will not become irrevocably accustomed to any one spot. When strong on the wing they are packed in panniers and carried away short distances for release. Following this preliminary training, lofts are moved greater distances, up to 20 miles or more every three to seven days, and at each location the birds are given tosses in a direction set as the axis of advance. A limit of these tosses is tentatively placed at 50 miles. In cases where time of return is very long or some birds are lost altogether, earlier stages in the training must be retraced and repeated. Finally, the birds are released in pairs at suitable intervals so that they cannot kit together and message carriers are affixed to their legs so that they can become accustomed to wearing them.

The objects sought in such a training program are patent. Owing to the facility with which a bird localizes itself to any one place, the lofts are moved frequently to prevent the crystallization of such a fixation of association. There is no good reason for assuming that, as a result of such training, the bird's basic tendency to become absolutely attached to a given spot is weakened since a kit of such mobile-

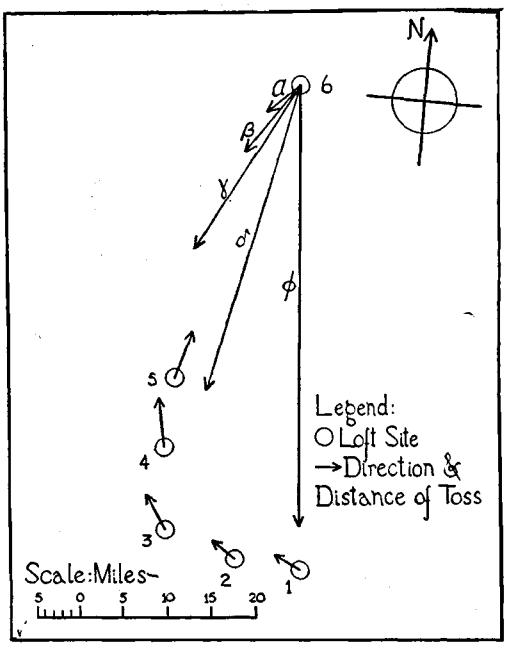
trained birds, when established in any particular location for several weeks or months, are just as difficult to settle in a new locality as birds which have never been moved any time from a fixed loft. What it does accomplish is to prevent the development of a close association of loft with a particular locality. During the first day, preferably in late afternoon or evening, the birds are released for exercise. They fly about the loft area for ten or fifteen minutes and are then called in for food. On subsequent days they are given tosses at selected and increasing distances, *e. g.*, 1, 2, 5, 10, 15, 25 and 45 miles, respectively. These stages are always on some predetermined axis of advance. Tosses are given only in clear weather and during daylight. Visual training is obviously the only factor considered. In the initial flight the bird sees the topography of its immediate surroundings and establishes an association of home and food with those details of objects and spatial relationship which differentiate one spot from another. On subsequent tosses it gradually learns the surface features of the ground it will traverse, with each step in its training based on that which preceded it, and the greater the number of such flights, the faster does it home. Thus far the tale is simple, but it is necessary to analyze all those cases in which the bird fails to return or in which the time of return is abnormally long.

The first instance is that which is known among fanciers as a "fly-away." They say the birds are "flighty" and, casting a measured glance at the sky, note that the air is misty. Whatever terminology is employed, it remains a fact that birds, on occasion, when first released in a new locality, will fly about the loft for a short time and then gradually veer off and fail to return even though the loft is in full view, the birds are hungry, and the loftsman to whose voice they are accustomed is calling them incessantly and rattling the feed can. Subsequently the birds may be found at the previous location of the loft, quietly feeding on the ground at the exact spot where the loft had been placed. They may visit several such old loft sites in turn and, if the loft has been moved many miles from the last position and the birds are in completely new country which they have never traversed before, they may disappear 'into the blue.' The factors operating here are complex but, in so far as they may be analyzed, the following seems to be the explanation. The loft represents to the bird food, water, a place to bathe, salt and grit of which it is inordinately fond, a place to roost (and each bird in the loft chooses its own particular perch) and finally protection. The potency of this last factor is seen in the reluctance with which the birds will enter the loft after it has been invaded by some predator, such as a cat or stoat. But the sight of the loft itself

is not enough for the bird which, as the result of all its training, is accustomed to direct itself to the locality of the loft by the aid of certain visual landmarks and, when in the immediate vicinity of the loft, to its exact location by the peculiar topographical relationship of that spot to its surroundings. Therefore, no matter how strongly the conditioned reflex that signifies food may be established in its neural system, it may obey impulses correlating flight to visually known localities with food and fly off to some previously significant locality. The bird has seen little or nothing of its new location, only part of the panorama is true—the loft—and that is situated in false surroundings. To overcome this difficulty the following procedure has usually been found successful. The birds are kept enclosed for some time at the new location before they are released and they are permitted to view their surroundings either by turning the loft about regularly or by the use of an aviary; they are given a few grains of corn before release to correlate feeding with their new surroundings; and they are released late in the day when fading light discourages extensive flight, since the pigeon is essentially a diurnal bird.

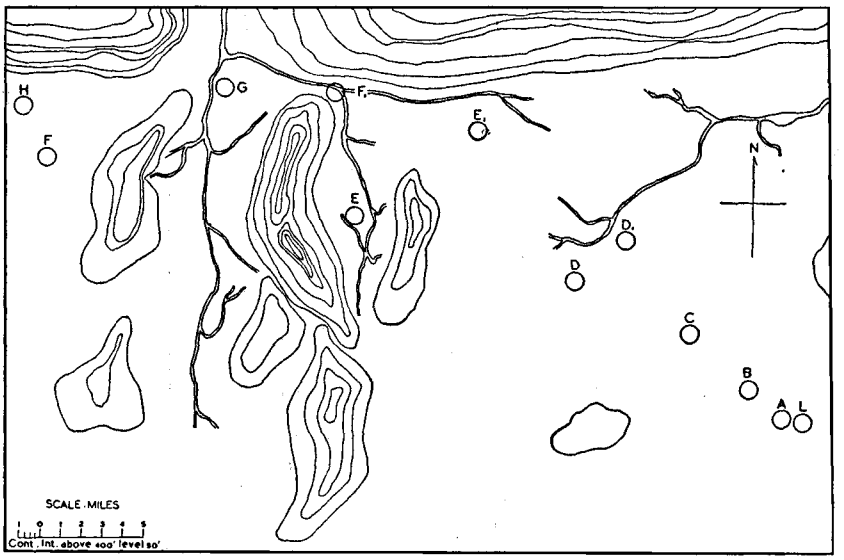
Falling within a similar category are those cases in which the bird is required to fly over old flight routes. Although the bird may have been thoroughly trained over part of the new route and may have successfully homed on frequent occasions to its loft, yet, when tossed over areas which it has traversed on earlier occasions when its loft was differently situated than at present, it may descend and fail to return. Here again, latent memory predominates, reinforced by the presentation of visually known landmarks and divorced from the pull which would be exerted by the features of its true loft site, and the bird obeys the more immediate call. Figure 1 represents one of the several such cases which have come within the writer's ken. Movements of lofts are depicted numerically in the order in which they occurred; position 6 was reached approximately six weeks after position 1 was occupied. Tosses are shown by the length and direction of arrows. These were, in general, north until position 6 was reached. Here it became necessary to train birds south of the station to fly over route ϕ. Tosses α, β and γ were successful but only 40 per cent of the birds returned from toss δ and only two birds out of 30 from toss ϕ, although the loft had been in position for three weeks before the last two tosses were essayed. Consequently, south of position 6 the result was a failure. It is apparent from this example that the use of pigeons in a withdrawal where they may be required to fly over old and disused flight routes may present insurmountable obstacles.

Of the additional factors, with the exception of natural and artificial



TEXT-FIGURE 1.—Training of birds over disused flight routes.

death-dealing agencies, which may hamper or prevent the bird's return, one other will be described which falls within the writer's experience—namely, character of the terrain. Civilian fliers are agreed that pigeons are reluctant to cross large bodies of water and hilly country and, in the latter case, tend rather to follow valleys and gaps in the hills. Therefore, when training birds to fly over rough terrain, the practice has been to toss birds at consecutive points which link up a flight route following valleys and gaps and which outflank hilly obstacles. Figure 2 gives an example of difficulties encountered in such training and a solution that was found. Contours above 400 feet are shown at 50-foot vertical intervals. L represents the position of the loft; points A, B, C, D, E and F, in that order, are points at which the birds were tossed. One hundred per cent return of birds tossed in good time was experienced from points A to D. Birds were very slow in returning and 10 to 15 per cent losses were encountered when they were released at points E and F. For the last two points successive tosses at D_1, E_1, F_1, G and H were substituted. In these cases the birds homed in good time and losses were negligible, one to two per cent. All experience in training the carrier pigeon emphasizes the important part which vision plays in its homing ability. In



TEXT-FIGURE 2.—Training of birds in hilly country.

the immediate case under discussion, irregular terrain delimited the vision of the bird. Tosses at E and F were relatively unsuccessful, and this may be ascribed to the hills and cliffs which lay across the birds' path. Yet on subsequent tosses, when points were followed along low ground linking water courses between hills and open country, much greater success was attained. The bird is balked by steep rises where surface features present sharp transitions and its flight consequently tends to become canalized along routes where the panorama displays inconsequential alteration.

Problem 2.—Training birds to fly at night.

Since the homing pigeon is essentially a diurnal bird it is very difficult to train as a night flier. Much evidence from competitive races shows that in long flights the pigeon will alight at dusk and continue its flight at dawn the next day. Such birds in cross-channel races have remained overnight on ships at sea; and times of return substantiate this hypothesis. However, certain British fanciers have recorded success in training their birds to fly in twilight in cases where their lofts were situated at distances greater than average from the point of release, and the time of flight might be expected to exceed the hours of daylight. Priestley (3) records that in the war of 1914 to 1918 successful experiments were carried out in the British Army on night flying. The birds were given tosses at increasingly greater distances

from the loft and the trap was illuminated with a lamp of low candle-power shielded from aërial observation. Similar work has been done in the present war. The loft is static; that is to say difficulties are so great in this form of training that it is not possible to move the birds at frequent intervals. The birds are given tosses from twilight on into dark at distances which increase up to a maximum of 20 miles. The birds take longer to return than by day. Of the several methods of training the following seem to have attained equal success:

1. Birds are kept by day in a darkened loft which is illuminated within after dark.
2. The loft is not darkened during the day nor illuminated at night and the birds are released during daylight for normal exercise flights.
3. The trap of the loft is illuminated with a weak light or the roof or side covered with a white marker. The writer's experience is that birds will trap more readily when the trap is illuminated at night.

Problem 3.—Training pigeons for two-way service.

Normally the pigeon will fly only over one direction of its route and must be carried to the point of release. Its homing propensity depends on the attraction of the loft and all that this structure represents. Within this loadstone the following factors may be differentiated: breeding, food, salt, grit, shelter, roosting, protection. The process of training pigeons to perform a two-way service consists of dividing these factors between two points. Breeding can be discounted since it is discouraged in army lofts. The birds are settled in a static loft, placed in baskets, carried away a short distance to a point within sight of the loft and fed in the basket. They are then released to fly home. This process is repeated and the birds learn to correlate the position of the basket with food. Gradually the basket is removed farther away until the desired delivery point is reached. At each stage the pigeons must be shown the position of the basket and be fed there. Then, on being released from the loft, they take a direct course to the basket to be fed. Their messages may then be removed and new ones placed in the container and on release they fly back to the loft. So stereotyped and unvarying is the pigeon's behavior that, in the early stages of this training, before they have learned to correlate the basket with food, they will not fly to it, although it is in full view of the loft and bears evidence of food, unless they are first carried to that position and fed there. This system of message carrying has given very good results; the birds behave faithfully and do excellent service, slightly slower on the homeward journey when they are

carrying one-sixteenth of their weight in corn. The chief disadvantage from the army point of view is that one point, the loft, must be static although the second point can be altered at will.

DISCUSSION

The descent of the modern homing pigeon from the wild rock-dove has already been mentioned and the arbitrary statement made that its homing ability is at least equal to that of the wild stock; it may even be conjectured that it has been augmented by selection, but of this there is no real proof. It is furthermore reasonable to postulate that the homing ability of the rock-dove and, *pari passu*, the homing pigeon, is, at least in part, of the same nature as that possessed by all migratory birds. For purposes of discussion the migratory achievements of birds may be distinguished as follows:

1. The initial flights of birds of the year to winter quarters which they have never seen before and over routes which they are traversing for the first time.
2. Second and successive flights of older birds to winter quarters and the return of all members of the species to summer breeding grounds.

It is obvious from the nature of its training and the character of its achievements that the homing pigeon will not assist in throwing light on the first problem. It is only within the limits of the second that a suitable comparison may be made. In both cases the birds are flying to localities which have been seen at least once before; in both cases flight is possible over routes which have been traversed at least once. The whole training of the pigeon is visual. The position of its loft becomes thoroughly known. In its exercise flights it traverses many miles of the surrounding terrain. Its tosses are gradually stepped up, mile upon mile, with each toss dovetailing that which preceded it, and with repetition the route becomes better known and the time of return is shortened. The birds become lost or will not fly at all under adverse visual conditions. When special training is undertaken to train birds to fly at night, such training must be done again in easy stages so that the birds are afforded the opportunity of learning such visual guides as may be apparent in dim light. And, in the latter case, the loft is treated so that it may more readily be seen in the darkness. The pigeon tends to follow low ground and valleys where vision is less restricted. Finally, when the bird is required to fly over both directions of the route, both termini must be known to the bird by detailed training.

Nothing in such training programs as the army employs or in the character of the flights required of the pigeon leads us to believe that any sense other than vision is employed by the bird in proceeding from point A to point B. Even negative evidence afforded by cases of no, or late, return emphasizes this conclusion as in the case of mobile-trained birds when the presentation of a choice between old and new flight routes and loft sites may lead the bird astray. This visual component of homing or migratory instinct—the memory of perceived localities—is the only component which need be evoked to explain the phenomena so far discussed and by the rule of economy of hypothesis it is reasonable to apply it to the second of these migratory flights of wild birds described in this section. In brief, migratory birds are guided by landmarks which they have previously seen when pursuing a course traversed on one or more earlier occasions. Suitable comparison may also be made with those numerous cases in which wild birds have been removed varying distances from their nesting sites and have successfully returned home. The destination of its flight, as in the case of the homing pigeon, can be recognized by the bird and in its previous wanderings it may have seen part of the route.

Recognition must now be given to cases of long-distance flights. In training for such races, tosses may be given up to 250 miles, but in the race itself, the bird may be taken many hundreds of miles and thus be released over territory which it has never encountered in its experience. Part of the route may even lie over featureless water. Losses are considerably greater in such long races and birds may be greatly delayed. Comparison may be made with the analagous case afforded by the experiments of Watson and Lashley (4) in which Noddy and Sooty Terns were removed from nesting sites on the Tortugas Islands in the Gulf of Mexico and carried for distances of more than 850 miles northward into areas in which these species are not normally found. These birds homed successfully over water and memory of landmarks could have played no part in accomplishing that flight.

In conclusion, it may be stated that the homing pigeon normally utilizes landmarks which it has seen before to guide it on its course. But it can also successfully home for long distances over routes which are strange to the bird. And in such cases so-called "inherited memory" can play no part since the route followed is selected arbitrarily by man.

SUMMARY

1. Carrier pigeons can be trained to fly to loft sites which are frequently changed at intervals of three to seven days.

2. They can be trained to fly short distances at night.

3. By placing the loft at one point and feeding the birds at another, carrier pigeons can be made to fly over both directions of a route.

4. The pigeon utilizes visual aids in its flight and all training emphasizes this factor.

5. Homing flights of pigeons may be compared to those migratory flights of wild birds which are proceeding to destinations previously visited over routes traversed on one or more earlier occasions.

6. In long-distance races, pigeons are released at considerable distances beyond the point of their last training toss and are consequently compelled to home over territory new to their experience. "Inherited memory" can play no part in such flights since the route, selected arbitrarily, bears no relation to the flight habits of its wild ancestry.

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In the preparation of this paper the writer has drawn upon six-months' experience with the pigeon service in the Canadian Army, has watched the experiments carried out by British Army personnel, and has consulted the official instructions of the Canadian and British armies and the Royal Canadian Air Force. In addition, reference has been made to the following publications.

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