CONTRIBUTIONS TO THE EXPERIMENTAL STUDY OF EPIDEMIOLOGY.

THE EFFECT OF VACCINATION ON HERD MORTALITY.

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In several previous reports we have described the behaviour of communities of mice, submitted over long periods of time to the risks attendant on the epidemic prevalence of a bacterial infection. These communities have been recruited in ways varying both as regards the rate of immigration and the nature of the immigrants.

The present report deals with an experiment in which we have studied the effect of prophylactic immunisation, with a suitable bacterial vaccine, in modifying the course of events in our experimental herds.

As in many of our previous experiments, the infection selected for study was mouse typhoid, due to infection with *Bact. aertrycke*. There is abundant evidence that the active immunisation of mice with killed suspensions of this organism results in an increased resistance to subsequent experimental infection with living cultures (Loeffler, 1906; Wolf, 1908; Yoshida, 1909; Brückner, 1911; Webster, 1922; Ornstein, 1922; Neufeld, 1924; Lange and Yoshioka, 1924; Topley, Wilson and Lewis, 1925). The immunity so induced has, however, usually been of a low order. A proportion of the immunised mice have resisted a subsequent experimental infection, and those which have succumbed during the experimental period have, on the average, lived longer than the unvaccinated controls, but fatal infections have not been prevented, and, in most experiments, a considerable proportion of the vaccinated mice have died from the disease. Some evidence has also been obtained that such active immunisation may exert an inhibitory effect on the epidemic spread of mouse typhoid (Lynch, 1922; Topley and Wilson, 1923; Topley, 1926). The few adequately controlled experiments so far recorded deal only with epidemics running their course in closed communities; and the results suggest that, even under these conditions, immunisation must be carried out *before* exposure to infection, and must be applied to the *whole* of the population at risk, if any significant degree of herd protection is to be attained. Our main object, in the experiment here reported, has been to provide data which will allow us to compare the behaviour of normal with that of artificially immunised mice during the course of a long-continued epidemic, and, in particular, to compare as far as possible the effect of artificial immunisation before admission to the infected herd with that of the natural immunisation, which occurs during the

earlier period of exposure to risk. The opportunity has been taken of assessing the relative value of different bacterial vaccines, and an attempt has been made to compare the immunising effect of various antigenic components, and to test the prophylactic value of purely non-specific antigens.

The work of Felix and his colleagues (Felix, 1924; Robertson and Felix, 1930), of Arkwright (1927), of Ibrahim and Schütze (1928) and of Schütze (1930) has already provided a considerable body of evidence in favour of the view that the somatic antigens of the normal smooth form of bacilli of the typhoid-paratyphoid group (the so-called O antigens) are far more significant immunologically than the flagellar (H) antigens, or than the somatic antigens of rough variants (the so-called Ø or R antigens). As will be seen, our own results are entirely confirmatory of this view. A brief account of this aspect of our enquiry, dealing only with the earlier phases of our experience, has already been recorded elsewhere (Topley, 1929).

One other point in relation to antigenic structure has been investigated. Schütze (1928) has noted that one serological type of *Past. pseudotuberculosis* possesses a somatic antigen which is related to that of *Bact. aertrycke*. Such relationships are of obvious importance in epidemiological enquiries. Antigenic specificity is fundamentally chemical in nature, and only specific in the bacteriological sense as a result of the actual distribution of antigenic components among different bacterial species. It would accord quite well with our knowledge of immunity in general to find that infection, or immunisation, with one bacterial species, increased resistance of the host to any other pathogenic bacterium, which shared with it an immunologically significant antigenic factor.

As a preliminary to the description of the happenings in our herd of mice, we note the nature of the vaccines employed, and certain additional data with regard to their immunological properties.

Vaccine A. This consisted of a saline suspension of *Staphylococcus albus*, killed by the addition of 0·25 per cent. formalin followed by heating at 55° C. for 1 hour. A single batch of vaccine was prepared shortly before the commencement of the experiment, and was employed throughout the period 1. v. 28 to 27. xi. 28. This vaccine was selected as an example of an entirely non-specific immunising agent. The mice inoculated with this vaccine are referred to as the *A* mice.

Vaccine B. A suspension of a rough strain of *Bact. typhosum* in saline containing 0·25 per cent. formalin, steamed at 100° C. for 30 minutes. Selected as a material containing the cosmopolitan rough somatic antigen, but neither the H nor O antigens of the normal smooth *Bact. aertrycke*. One suspension was used from 1. v. 28 to 27. xi. 28. The mice inoculated with this vaccine are referred to as the *B* mice.

Vaccine C. A suspension of a smooth strain of *Bact. aertrycke* in 0·25 per cent. formol saline, heated at 55° C. for 1 hour. This vaccine contained organisms in the type and group phase, and thus contained the O antigen and the two types of H antigen corresponding to the two alternative phases. One suspension was used from 1. v. 28 to 9. vii. 29. The mice inoculated with this vaccine are referred to as the *C* mice.

Vaccine D. A suspension of a completely rough strain of *Bact. aertrycke*, prepared in 0·25 per cent. formol saline, and heated at 55° C. for 1 hour. It contained the R, or Ø,

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rough somatic antigen and the H antigen of the type and group phases, but did not contain the smooth somatic antigen in detectable amount. One suspension was used from 1. v. 28 to 27. xi. 28. The mice inoculated with this vaccine are referred to as the *D* mice.

Vaccine E. A broth culture of *Bact. aertrycke*, in the normal smooth phase, incubated for 24 hours at 37° C. and then killed by the addition of 0·25 per cent. formalin, followed by heating to 55° C. for 1 hour. It contained the O antigen, and the H antigen in the type and group phase. One suspension was used from 1. v. 28 to 27. xi. 28. The mice inoculated with this vaccine are referred to as the *E* mice.

Vaccine F. A saline suspension of *Bact. paratyphosum* B smooth in the group phase, killed by the addition of 0·25 per cent. formalin followed by heating at 55° C. for 1 hour. It contained the O antigen, common to *Bact. paratyphosum* B and to *Bact. aertrycke*, and the H antigen shared by these species in the group phase. One suspension was employed between 1. v. 28 and 27. xi. 28. The mice inoculated with this vaccine are referred to as the *F* mice.

Vaccine G. Similar to *F*, except that the strain selected was in the type phase. The only antigenic constituent of this vaccine represented in *Bact. aertrycke* was, therefore, the O somatic antigen. One suspension was used between 1. v. 28 and 27. xi. 28. The mice inoculated with this vaccine are referred to as the *G* mice.

Vaccine J. A saline suspension of *Past. pseudotuberculosis*, of the type showing a serological relationship to *Bact. aertrycke*[1], killed, as above, with formalin and heat. The antigenic structure of this strain will be briefly considered below. A single suspension was used between 4. xii. 28 and 5. ii. 29. The mice inoculated with this vaccine are referred to as the *J* mice.

Vaccine K. A saline suspension of *Bact. aertrycke*, prepared in January 1929, in exactly the same way as vaccine *C*, and containing the same antigenic factors. One suspension was used between 19. ii. 29 and 9. vii. 29. The mice inoculated with this vaccine are referred to as the *K* mice.

In every case the suspension to be inoculated was diluted to contain 1000×10^6 bacilli per c.c., and 0·5 c.c. of this was injected intraperitoneally. One week later the injection was repeated, using the same dose, and the mice were added to the experimental cage on the seventh day after the second inoculation.

An experimental epidemic of mouse typhoid was started on 4. i. 28, by infecting fifty mice with *Bact. aertrycke*, adding to them fifty normal mice and, thereafter, adding three normal mice a day until the conclusion of the experiment (17. ix. 29). The inoculated mice, corresponding to the various vaccines employed, were added in batches every seventh day, and with them were added a numerically equal batch of normal mice, referred to hereafter as the *N* or normal mice.

Thus, from 1. v. 28 to 27. xi. 28, ten mice of each of the vaccinated groups *A*, *B*, *C*, *D*, *E*, *F*, *G*, and ten normal mice were added to the cage every seventh day.

From 4. xii. 28 to 5. ii. 29, twenty *C* mice, twenty *J* mice, and twenty normal mice were added to the cage every seventh day.

From 19. ii. 29 to 9. vii. 29, twenty *C* mice, twenty *K* mice, and twenty *N* mice were added to the cage every seventh day.

The addition of three normal mice a day was continued until 17. ix. 29 in

[1] For a culture of this strain we are indebted to Dr Schütze.

order to keep the conditions as comparable as possible until the last of the vaccinated mice added had survived in the cage for 60 days.

Thus, during the period 1. v. 28 to 27. xi. 28, we were able to compare the immunising values of: (1) a non-specific stimulus—Group *A*; (2) the rough somatic antigen alone—Group *B*; (3) the rough somatic antigen combined with the H antigen in both the type and group phase—Group *D*; (4) the smooth O antigen alone—Group *G*; (5) the smooth O antigen combined with the H antigen of the group phase—Group *F*; (6) the complete antigenic combination (Smooth O + H type + H group)—Group *C*; and (7) the same combination together with any other antigenic constituent which might be present in a broth culture, but absent from a saline suspension—Group *E*.

During the period 4. xii. 28 to 5. ii. 29 we were able to compare the immunising value of a *Past. pseudotuberculosis* vaccine (Group *J*) with that of a *Bact. aertrycke* vaccine (Group *C*).

During the period 19. ii. 29 to 5. vii. 29 we were able to compare the immunising value of a freshly prepared *aertrycke* vaccine (Group *K*) with that of a similar vaccine which was some 15 months old at the commencement of this period (Group *C*).

The data for the whole period are, of course, available for our main object—the comparison of the fate of artificially immunised mice with that of normal mice (*a*) on entry to the cage, and (*b*) after various periods of exposure to risk.

Certain ancillary experiments have been carried out, and certain additional observations have been made, to determine more exactly the nature of the reagents which we have employed. These may be summarised as follows.

The inherent toxicity of the vaccines employed.

Certain of the vaccines possessed an appreciable toxicity for mice in the doses in which they were administered, so that a proportion of the mice died during the 14 days elapsing between the inoculation of the first dose of vaccine and addition to the cage. In order to have sufficient mice available for addition we inoculated twelve to fifteen of each batch, instead of the ten actually required.

The vaccination death-rate for the various groups is shown in Table I.

Table I.

Group	Total no. vaccinated	Deaths during 14 days following first vaccination	Percentage mortality
A	390	10	2·56
B	403	13	3·23
C	1224	96	7·84
D	396	17	4·29
E	423	44	10·40
F	398	30	7·54
G	394	13	3·30
J	240	13	5·42
K	509	45	8·84

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THE ANTIGENIC CHARACTER OF THE VARIOUS VACCINES EMPLOYED, AS JUDGED BY THE ANTIBODY RESPONSE IN MICE.

The vaccination of a number of mice in excess of that required for addition to the cage left us, each week, with a small number of surplus vaccinated mice. These were anaesthetised and bled from the jugular vein. The serum so obtained was tested against formalinised broth suspensions of *Bact. aertrycke* in the group and type phase to determine the titre of H agglutinins, and against an alcoholised suspension of *Bact. aertrycke* to determine the titre of O agglutinins. In the case of Groups *A* to *G*, the majority of the agglutination tests were carried out at a commencing titre of 1:20. Table II shows the number of sera tested in each group, and the number of the sera which agglutinated these suspensions to a titre of 1:20 or over. It may be noted that a high proportion of the sera showed a titre of 1:640 (the highest dilution tested) against the H suspensions, while no serum showed a titre of 1:160 or over against the O suspension.

Table II.

		No. of sera agglutinating different suspensions of *Bact. aertrycke* at 1:20 or over			
		H			
Group	No. of sera tested	Type	Group	O and H	O alone
A	70	0	0	0	0
B	72	0	0	0	0
C	60	58	59	4	0
D	61	59	36	0	0
E	66	65	64	5	0
F	52	0	52	10	0
G	62	0	0	0	5

It will be seen that the vaccines behaved in the way which was expected. The staphylococcus vaccine (*A*) showed itself entirely devoid of the antigenic factors with which we are concerned. The rough typhoid vaccine (*B*) was equally devoid of these factors. (The presence of agglutinins acting on the rough somatic antigen was not determined.) The rough *aertrycke* vaccine *D* stimulated the formation of H antibodies, but not of O antibodies. The paratyphoid B vaccine in the type phase (*G*) stimulated the formation of O antibodies alone, so far as *Bact. aertrycke* was concerned. A similar vaccine in the group phase gave rise to O antibodies, and to H antibodies of the group variety. The *aertrycke* vaccines *C* and *E* caused the formation of both H and O agglutinins.

It will be obvious that the production of O agglutinins is, in all cases where both are formed, far less copious than that of H agglutinins. It seems to us probable, in view of the results to be described later, that it would be unjustifiable to assume that the production of O antibodies is, in fact, confined to those mice in which agglutinins acting on alcoholised suspensions are demonstrable in the serum. It seems more likely that the presence of such

agglutinins to a demonstrable titre in a proportion of the mice concerned should be taken as evidence that the corresponding stimulus has been provided, while it may well be that mice which show no such demonstrable agglutinins may have made a specific response which has altered their resistance to infection.

During the latter part of the experiment, the testing of sera against the formalinised suspensions was discontinued, in order that we might employ the small amount of serum available from each mouse in testing for O agglutinins at a lower titre (1:5). The results of these tests are set out in Table III.

Table III.

Group	No. of sera tested	No. of sera agglutinating an O suspension of *Bact. aertrycke* at 1:5 or over
A	8	0
B	8	0
C	118	8
D	8	0
E	3	0
F	6	0
G	8	1
J	27	0
K	44	2

The results are very similar to those obtained with a serum dilution of 1:20. The *Past. pseudotuberculosis* vaccine (*J*) shows no evidence of being able to stimulate the formation of O agglutinins in the mouse. The immunological properties of this vaccine are further considered below. We may add that we have tried to stimulate a more regular and copious formation of O agglutinins in mice by repeated injections of vaccines *C* or *E*, but without success.

THE IMMUNISING VALUE OF CERTAIN OF THE VACCINES EMPLOYED, AS TESTED BY THE INTRAPERITONEAL INJECTION OF LIVING *BACT. AERTRYCKE* IN VACCINATED MICE.

It seemed desirable to test the effectiveness for active immunisation against a subsequent single measured dose of virulent *Bact. aertrycke*, of certain of these vaccines which, as will be seen later, produced a significant change in the resistance to natural infection in our experimental cages. At the same time opportunity was taken of confirming the ineffectiveness of the *Past. pseudotuberculosis* vaccine. In each experiment the immunised mice received two doses of vaccine, each containing 500×10^6 bacilli, with a week's interval between them. They were tested, 1 week after the second dose of vaccine, by the intraperitoneal inoculation of 1000 *Bact. aertrycke*, of a virulent strain. An equal number of normal unvaccinated mice were injected with the same dose and by the same route to serve as controls. All mice were kept under observation for 28 days. The results are summarised in Table IV.

Whether we take as our test of increased resistance the number of mice which survive for 28 days after the test inoculation, or the mean survival time

limited to 28 days, it is clear that a suspension of a smooth strain of *Bact. aertrycke*, killed by the addition of formalin followed by heating at 55° C. for 1 hour, is a relatively effective immunising agent, as judged by these particular experiments. The *Past. pseudotuberculosis* vaccine (*J*) is without appreciable effect.

Table IV.

Exp.	Vaccine	No. of mice	Average survival time—limited to 28 days	No. died within 28 days	No. survived 28 days	No. of survivors with positive spleen cultures
A	*C* (see above)	50	21·3	27	23	7
	K ,,	50	20·7	30	20	12
	J ,,	50	7·9	50	0	—
	Unvaccinated controls	50	7·1	49	1	1
B	Similar to *K*	50	22·4	29	21	12
	Unvaccinated controls	50	5·1	50	0	0
C	Similar to *K*	44	20·8	25	19	15
	Unvaccinated controls	50	5·2	50	0	—

With regard to the ineffectiveness of the *Past. pseudotuberculosis* vaccine as a prophylactic against infection with *Bact. aertrycke*, a few additional points may be noted. We have been able to confirm Schütze's observation, that there is an apparent antigenic relationship between these species, connected in some way with the O somatic antigen. Thus the serum of a rabbit immunised against *Past. pseudotuberculosis* agglutinated a suspension of that organism to 1:80, and an alcoholised suspension of *Bact. aertrycke* to the same titre. It also agglutinated an alcoholised suspension of *Bact. paratyphosum* B, which shares the same O antigen, but had no action on similar suspensions of *Bact. newport*, *Bact. suipestifer* or *Bact. enteritidis*, in which the O antigens are different. An agglutinating serum prepared against an O suspension of *Bact. aertrycke* agglutinated an alcoholised suspension of that organism to 1:5120, and a suspension of *Bact. pseudotuberculosis* to 1:40.

We have not succeeded in demonstrating any absorption of anti-aertrycke agglutinins by *Past. pseudotuberculosis*, or of anti-pseudotuberculosis agglutinins by *Bact. aertrycke*; but we have not pursued this problem beyond a single test, the results of which were entirely negative. The exact nature of the antigenic relationship between these two species has still to be finally determined, and it would, we think, be premature to assume that the characteristic O antigen of *Bact. aertrycke* is present in this type of *Past. pseudotuberculosis*. It may, however, be noted that the anti-pseudotuberculosis rabbit serum showed some power of protecting mice against experimental infection with *Bact. aertrycke*. This protection was of a low order. Only one of thirty mice survived the test inoculation, but those which died lived significantly longer than untreated controls, or than mice which had received normal rabbit serum. Moreover, the protection afforded was little if at all inferior to that given by the same dose of an anti-aertrycke serum containing

a high titre of O agglutinins. We may note that, in our hands, passive protection of mice against infection with bacilli of the enteric group, using rabbit antisera, has proved singularly ineffectual.

The condition of the immunised mice which survived subsequent experimental infection.

A point of some importance is the actual condition of the immunised mice which survived until the twenty-eighth day. The results, in this respect, were confirmatory of all our previous experience. Taking all three experiments there were eighty-three such survivors. All were examined *post mortem*, and a portion of the spleen was transferred to broth. In forty-six cases a culture of *Bact. aertrycke* was obtained; in thirty-seven the broth remained sterile. With few exceptions these surviving mice showed no observable abnormality at necropsy, so that we must regard the survivors with positive spleen cultures as suffering from a persistent latent infection. All these mice were housed, from the day of the test inoculation onwards, in separate small cages, so that there was no possibility of re-infection from other infected mice. This procedure has always been followed by us in experiments of this kind. What would have happened if these mice had been maintained in isolation over much longer periods of time we are, of course, not in a position to say. We think it probable that some, at least, would have subsequently succumbed to an acute exacerbation of their infection, while others would in time have rid themselves of the bacilli which they were harbouring.

The thirty-seven negative spleen cultures suggest that some 19 per cent. of the immunised mice had their resistance increased to a point at which it was completely effective against a single dose of living *Bact. aertrycke*, in the sense that the tissues were freed entirely from living bacilli; but such figures as these may be quite misleading. It would require a detailed and laborious study of very large numbers of surviving mice to ascertain with any exactness the frequency of persistent but quiescent foci of infection throughout the tissues. The point is an important one, as will be seen when we come to describe the fate of the vaccinated mice in our infected herd. Are we to regard the reaction of an immunised mouse to the fluctuating dispersion of infective material within the cage as in the nature of a single decisive event, the first reception of a dose of infective matter being followed by a rapidly fatal illness, a persistent latent infection, or a complete return to the non-infected state, according to the size of the dose received and the resistance of the mouse? Or are we to regard this reaction as a series of events, not necessarily connected in any orderly sequence, of which the initial reception of infection forms merely the first chapter, and in which decisive happenings, of very varying nature, may occur at any period thereafter?

If the establishment of a persistent latent infection is a common reaction—and we have no doubt that it is—the subsequent events which determine ultimate death or recovery *may* have little connection with further risks of

specific infection in the cage. The mouse may have purchased immunity to such risks at the price of a heightened susceptibility to others, such as fatigue, dietetic influences, or other factors, which might upset the equilibrium on which this infection immunity depends, and precipitate a fatal illness. It should be noted, however, that this possible indifference to repeated doses of the specific infective material is by no means a necessary consequence of the view that latent infections are common. It is quite likely that a latently infected mouse might at one time be more resistant to specific infection than a normal animal, at another more susceptible.

If, on the other hand, the complete elimination of the infecting bacteria is a frequent sequence to a primary infection of the vaccinated mice, then the frequency and amount of subsequent doses of infective material will clearly be of preponderating importance, as will also any changes in the specific resistance of the host induced by the earlier doses which have been successfully eliminated.

In this connection, also, there falls to be considered a possible source of error in the interpretation of our experimental findings. We have, throughout our investigations, accepted the recovery of *Bact. aertrycke* from the tissues at the necropsy on any mouse as evidence that that mouse died from the enteric infection. No other criterion is, in fact, possible, since many of those mice which die of acute infection, yielding copious growths of *Bact. aertrycke* from the heart blood, show no characteristic lesions detectable by the naked eye. If the vaccinated mice in our experimental herds frequently contracted a persistent latent infection, which seldom led to a fatal result, they might conceivably be recorded as specific deaths, as a result of the persistence of living bacilli within their tissues, though they had in fact died from some quite different cause. The actual findings at necropsy showed quite clearly that this was not commonly the case, since the characteristic lesions of the disease were frequently present in the vaccinated mice; but, in order to determine whether the figures based on our usual criterion had, from this cause, been weighted to any degree against the vaccinated animals, we tabulated, for the later period of the experiment the frequency of the more significant *post mortem* findings of each of the groups exposed to risk. These are set out in Table V and are, we think, decisive.

Table V. *Showing the findings at necropsy in the various groups of mice.*

	H	Daily	*J*	*K*	*C*
Number of mice examined *post mortem*	468	660	143	317	518
Percentage of above from which *Bact. aertrycke* was *not* isolated	9·6	13·5	10·4	12·3	12·5
Number of specific deaths	423	571	128	276	453
Percentage of above in which *Bact. aertrycke* was isolated from spleen *only*	1·9	1·9	1·4	0·7	1·9
Percentage showing no naked-eye lesions	29·3	26·8	30·4	30·4	25·3
Percentage showing gross splenic enlargement	3·5	5·8	4·7	4·0	7·3
Percentage showing necrotic areas in liver	19·6	20·1	15·6	28·6	24·9

It will be seen that the percentage of mice coming to necropsy from which we failed to isolate *Bact. aertrycke* is no higher in the groups inoculated with the effective vaccine (*K* and *C*) than in the unvaccinated groups (*H* and Daily). Coming to those mice from which *Bact. aertrycke* was isolated, we find that the percentage of mice from which that organism was recovered from the spleen culture *only* is sensibly equal in all groups except *K*, where it is insignificantly smaller. It is certain that, if latent infections were common among mice in the vaccinated groups which had, in fact, died from other causes, the percentage of mice showing this state of affairs would be significantly higher in groups *K* and *C* than in groups *H*, Daily, and *J*. The percentages showing no naked-eye lesions confirm this view: there is no significant difference between the vaccinated and unvaccinated. As regards the two lesions most characteristic of enteric infection in the mouse, gross splenic enlargement and necrotic foci in the liver, the vaccinated groups show, if anything, higher frequencies than the unvaccinated. This is in accordance with the increased survival time of the vaccinated mice. Figures which we have obtained from another long-continued epidemic of mouse typhoid show an increase in the frequency of gross splenic enlargement from 1·2 per cent. among mice dying between the sixth and tenth day of exposure to 8·3 per cent. among mice dying on or after the fortieth day, and a corresponding increase from 1·4 to 18·8 per cent. in the frequency of necrotic liver lesions.

The effect of vaccination on herd experience.

We now pass to a discussion of the effect of the vaccinations observed in herd experience. First we must ask ourselves, on the basis of individual experimentation and deduction from such experimentation, what advantages we should *expect* the animals treated with the different vaccines to enjoy in comparison with untreated animals when all are exposed alike to the chances and changes of existence in a tainted herd. In the first place we must note that all the vaccinated animals have been subjected to a mortuary selection which has eliminated from 2·56 to 10·40 per cent. of the animals brought under observation. If we suppose that power to resist the toxic products present in the vaccines employed is *some* measure of power to resist the consequences of natural infection in the herd, then we must suppose that the *E* batch of actual entrants to the herd, which consists of a residue left after winnowing the proposed immigrants to the extent of 10·40 per cent., will exhibit more resistance than the *A*'s who had been selected to the extent of only 2·56 per cent. The precise importance of this we cannot determine; we only note the fact.

Leaving this aspect of the problem, which of the vaccinations should we expect to have been efficacious? There seems no *a priori* ground for expecting that the *A* vaccine will improve the prospect of immigrants, apart from some possible non-specific effect. The *B* vaccine is in much the same category, since all the available evidence suggests that the cosmopolitan rough antigen of the

enteric group is valueless as an immunising agent. For the same reason we should expect the *D* vaccine to have little value, with the reservation that it is impossible, by any laboratory test, to be certain that a rough variant of any particular strain is *entirely* free from any trace of the O antigen characteristic of the strain from which it was derived. The properties of the *J* vaccine have been described in some detail above; in the light of the results recorded we should clearly not expect that it would provide any significant protection. On the assumption that the O somatic antigen is the important factor in immunisation, we should expect the remaining vaccines, *C*, *E*, *F*, *G* and *K*, to be of approximately equal value, noting that, if the antigenic value of a vaccine decreases rapidly with storage, we should expect vaccine *K* to be superior to vaccine *C*, over the last period of the experiment.

In Table VI (see Appendix, pp. 279–289) we have given the life tables of the various batches, in full detail for the first 30 days, thereafter at intervals of 5 or 10 days. This is comparable with our earlier tables. But it may be objected that, while the tables for control mice cover the whole period of the experiment, the various batches of vaccinated mice (except *C*) were added over different periods, so that their life tables are not strictly comparable either *inter se* or with the experience of the controls. To test this point Table VII was prepared which gives the probabilities of surviving five days for the *H* and Added Daily mice in periods strictly comparable with the periods of exposure of the vaccinated mice. For exposures of 35 days or more the variations from column to column are large, but for these exposures the numbers of animals concerned are very small. At the earlier ages the variations are small and inconsistent in sign. It seems, therefore, best to use as controls the whole experience of *H* and Added Daily mice[1].

Table VII.

ALL DEATHS.

	Comparable with *A*–*G*		Comparable with *J*		Comparable with *K*	
Cage age in days	*H*	Added daily	*H*	Added daily	*H*	Added daily
0	·9710	·9816	1·000	1·000	·9952	·9932
5	·9635	·9609	·9900	·9762	·9641	·9817
10	·9207	·9121	·8889	·9366	·9206	·8884
15	·7900	·8000	·8011	·8490	·8005	·8508
20	·6919	·6317	·7021	·7178	·7071	·6923
25	·4795	·5795	·5051	·4786	·5238	·5378
30	·5286	·6037	·5600	·5536	·4638	·5124
35	·6486	·6263	·6071	·8387	·5882	·6129
40	·6667	·6290	·6471	·8077	·6333	·6316
45	·7500	·6667	·5455	·8091	·4737	·4500
50	·5833	·8846	·6667	·9412	·8889	·7778
55	·5714	·7826	1·000	·9375	·8750	1·000

With regard to the general course of mortality we find the expected increase to a maximum of mortality in the region of the thirtieth day followed by a

[1] Tables VI A–D (see Appendix, pp. 286–289) provide data for exact comparison should other investigators desire to pursue the subject further.

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recovery towards an asymptotic level. There is no doubt that this is the normal picture of herd mortality under our experimental conditions.

We must now decide what criterion of success is the most suitable. The most obvious test of success is naturally to ascertain whether the supposedly immunised members of a community did actually live longer than the controls. As in these experiments virtually all the animals under observation had died before the statistical analysis was made, this merely involves the comparison of the average lengths of life of the different batches with their probable errors. In Table VII A these are shown. Except that *K* has been less successful than *a priori* considerations would suggest, the results are not discrepant with our anticipations. As we have noted before, however, utilising all the data has the disadvantage that a few mice who lived very long might play too prominent a part in determining the general average. In the fourth column of the table the comparison is limited to the first 60 days of observation. By the end of 60 days in all batches fewer, usually far fewer, than 10 per cent. of the exposed to risk are still alive. A comparison on this basis, *i.e.* averaging a variable restricted to the range 0–60, improves the relative position of *K* but leads us to the same general result. We think that these simple and direct comparisons establish the proposition that certain of the vaccines have, appreciably and—in the statistical sense—significantly, lengthened the lives of the exposed to risk. Taking the *H* mice as the standard then the *E*, *F* and *G* mice, which differ insensibly among themselves, show an ad-

Table VII A. *Experiment* 1.

EXPECTATION OF LIFE.

	Total deaths				Specific deaths			
Group	Unlimited	Standard error	Limited to 60	Standard error	Unlimited	Standard error	Limited to 60	Standard error
H	26·27	0·567	25·28	·331	27·93	0·595	26·38	·347
A	33·55	2·068	28·51	·682	36·60	2·164	29·86	·714
B	31·67	1·869	27·50	·683	35·43	2·003	29·28	·732
C	34·24	0·956	30·12	·402	38·74	1·028	32·10	·432
D	35·85	2·747	28·14	·734	39·33	2·885	29·44	·771
E	39·07	2·321	32·38	·780	44·16	2·515	34·97	·845
F	41·71	2·942	32·63	·778	48·93	3·194	35·06	·845
G	45·84	3·466	31·99	·803	52·12	3·681	33·71	·853
J	25·75	1·075	24·77	·715	27·30	1·127	25·87	·750
K	32·62	1·235	29·44	·620	35·39	1·300	30·82	·653
Added daily	29·70	0·769	25·86	·274	33·24	0·809	27·07	·288
Period 1. v. 28–27. xi. 28 to compare with *A* to *G*.								
H	26·45	1·271	24·90	·606	29·06	1·345	26·26	·641
C	39·08	2·103	32·61	·805	46·29	2·309	35·31	·884
Added daily	27·26	0·980	25·29	·439	30·08	1·040	26·66	·466
Period 4. xii. 28–5. ii. 29 to compare with *J*.								
H	26·89	1·266	25·58	·705	28·41	1·313	26·25	·731
C	32·26	1·601	29·82	·740	34·29	1·688	31·14	·780
Added daily	34·64	2·679	27·88	·830	38·29	2·773	28·58	·859
Period 19. ii. 29–9. vii. 29 to compare with *K*.								
H	25·99	0·620	25·51	·481	27·05	0·648	26·48	·502
C	31·64	1·257	28·58	·565	35·01	1·339	30·16	·602
Added daily	28·37	1·072	26·13	·506	30·61	1·131	27·37	·534

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vantage of 28 per cent. The *C* mice, over the same period of exposure, show an advantage of the same order. If the mice added daily are the standard, the advantage is not materially less, 25 per cent. But even the most favoured group only enjoyed slightly more than half the possible life span, 60 days, and one of us (Greenwood, 1928) showed that, of a sample of mice reared under specially favourable conditions, none died in the first 50 days, while of mice under rather less exceptional conditions and observed from the age of 6 months, 89 per cent. were still alive after 60 days' exposure. Were these valid controls, it is obvious that our immunised mice had not been brought into approximately the same state as healthy animals, but it was arbitrary to suppose that the controls *were* valid. We therefore carried out a strictly comparable control experiment. Twenty normal mice were placed in a cage of precisely the type of those used in the experiments on 4. x. 29; for 3 days one mouse was added daily, then for 3½ months three mice were added daily. In all 329 mice were used, of which 273 survived at the end of the experiment. Of the 56 deaths, 15 were classed as not examined, 41 were examined and not found to be specifically infected. The expectation of life at entry limited to 60 days was found to be 56·79 days. In other words, taking round numbers, unprotected mice in our infected herd had an expectation of 25 days, mice immunised as efficiently as we were able to immunise them had an expectation of 32 days and mice living under conditions in all respects the same, save non-exposure to the specific risk, had an expectation of 57 days, respectively 42, 53 and 95 per cent. of the maximum possible. We shall, in a moment, discuss the objections to which this comparison is subject, but, to anticipate a little, we may say that the objections do very little to weaken the essential force of the comparison. Most members of the general public and some scientific writers use language which implies that it is reasonable to hope that bacterial vaccines, or similar immunising agents, may be found which will place the vaccinated, *vis-à-vis* with some particular risk, let us say dying of typhoid fever or of scarlet fever, or of smallpox, precisely in the (mythical) position of King Mithradates who could consume the most deadly poisons as table beverages. So far as these persons are concerned, *that* element of the environment, dosage of infective material in food or drink, contact with infectious persons, is simply eliminated. Naturally these conditions have never been realised (with the possible exception of vaccination against small-pox for a limited period after vaccination) in practice, but it has been believed that their realisation is practically possible.

The results we have obtained in this experiment strengthen our suspicion that they are unrealisable. We have at least succeeded in providing conditions of exposure which overcome the protection afforded by two massive doses of a vaccine containing the antigenic factors that should produce an efficient immunising response. These conditions, too, are conditions of natural infection from member to member of the herd, not of some massive artificial inoculation. So far as antibacterial immunity is concerned there seems to be a critical limit

to the response of the organism to immunisation, whether by artificial inoculation or by sublethal natural infection. This has been overlooked because statistically controlled herd experimentation has been neglected.

This direct comparison is subject to the criticism that it is based upon deaths from all causes, and there is no theoretical reason why the vaccinations should have improved the prospects of the vaccinated when confronted with some cause of death other than aertryckial infection; one should compare the mortality experiences with respect to the specific infection alone. The practical importance of this objection is less than might have been supposed. It appears (see Table VIII) that more than half, perhaps as many as 90 per cent. of all the deaths *were* really attributable to the specific infection against which we attempted to immunise our animals, so that the elimination of the non-specific deaths should not make a very important difference. The pure comparison is, however, made in the right-hand half of Table VII A. The sampling errors of the expectations given there are only approximations. When one is dealing with mortality from all causes in a population, all members of which have been observed from entrance to death or to a particular terminus, the expectation of life is the arithmetic mean of the frequency distribution of the ages at death (or the terminal age), and the standard error of the mean is simply the standard deviation of the frequency divided by the square root of the number of deaths and survivors to the terminal age. If, however, we wished to learn what would be the average length of life of members of a herd subject to one only of the causes of mortality which actually operated, we shall not reach the right answer by taking the average age at death of the members of the herd which, under the real conditions, died of this particular disease. They would then form only a part of the number of deaths and, owing to the mortality from other causes, there would be too few survivors to later ages, the average longevity shown would be too small. What we should have to do would be to construct, from the death-rates of the special disease, a new, fictitious life table setting out how the population would have died had only this cause been operating. The d_x column of this table will *not* be the deaths at ages from the specific cause of the original table but those deaths respectively multiplied by factors which increase with x. When we took all deaths,

Table VIII.

Group	Proportions of deaths certainly due to *Bact. aertrycke*	Proportions of deaths probably due to *Bact. aertrycke*
A	64·8	91·3
B	62·3	87·1
C	65·2	86·4
D	58·7	90·6
E	61·9	85·2
F	63·2	84·8
G	61·5	88·7
H	64·6	90·9
J	67·5	91·0
K	66·9	90·2
Added daily	64·5	90·4

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the expectation of life was an unweighted average; now we have a weighted average with weights substantially correlated with the variables. The standard error of such an average is difficult to calculate and is evidently larger, it might be *many* times larger, than that of the unweighted average. We know of no arithmetically simple device for approximating to the value. In our particular case the difficulty is more apparent than real, because so large a proportion of the deaths was really due to the specific factor that the difference between the actual mean age at death and the correctly determined expectation of life, although distinct enough, is not very large. We have computed a standard error by using as standard deviation that obtained from the all causes data and as n the number of animals in each group which did actually die of the specific cause, but, for the reasons just given, this is *certainly* an underestimate and the inexactitude increases as the proportion of specific deaths decreases. The comparison appears in the right-hand half of Table VII A. Confining ourselves as before to the limited expectation, it will be seen that this comparison does not modify the conclusions to be drawn from that of the total mortality. Vaccination confers a substantial benefit, but altogether fails to produce a solid immunity.

Having reached this very important conclusion, we must seek to understand the nature of the limitation of the benefit conferred.

We proved in earlier researches that exposure to natural infection within a herd leads to the production of an immunity which, like that under notice, is substantial but far from perfect. We have given reasons for thinking that this immunisation, rather than mortuary selection, explains the decreasing rate of mortality with increasing cage age. It is tempting to suppose that the effect of vaccination would be to place immigrants at entrance into the same position as elder survivors of natural exposure, so that, for instance, if we were comparing death rates, we ought to find that $q'_x = q_{x+s}$, where q'_x is the probability of surviving a day from age x of a vaccinated animal, while q_x is the survivorship function for the unvaccinated animals and s is a constant. An examination of Tables IX and X, which give the probability of surviving

Table IX. *Experiment* 1. *Probability of survivorship.*

Cage age in days	ALL DEATHS. A	B	C	D	E	F	G	J	K	H	Added daily
5	·990	·990	·996	·987	·987	·984	·994	·995	·993	·988	·987
10	·980	·974	·975	·980	·984	·993	·987	·970	·988	·966	·966
15	·947	·923	·949	·923	·944	·960	·967	·902	·922	·912	·901
20	·863	·822	·887	·852	·937	·911	·881	·759	·847	·800	·811
25	·724	·727	·810	·703	·793	·845	·779	·682	·783	·702	·660
30	·629	·648	·624	·560	·711	·688	·662	·489	·690	·510	·545
35	·554	·551	·643	·720	·693	·623	·692	·568	·621	·502	·592
40	·629	·712	·664	·687	·788	·792	·772	·520	·694	·613	·690
45	·795	·690	·635	·739	·683	·750	·817	·538	·693	·644	·759
50	·806	·621	·806	·794	·750	·825	·828	·857	·634	·574	·745
55	·760	·889	·828	·926	·762	·809	·875	·833	·879	·704	·880
60	·895	·875	·903	·920	·844	·789	·905	1·0	·862	·789	·884

Table IX A. *Experiment* 1. *Probability of survivorship from life tables.*

Cage age in days	Specific deaths. *A*	*B*	*C*	*D*	*E*	*F*	*G*	*J*	*K*	*H*	Added daily
5	1·0	·9968	·9979	·9935	1·0	·9935	·9968	1·0	1·0	·9937	·9919
10	·9902	·9772	·9926	·9804	·9902	1·0	·9935	·9798	·9904	·9732	·9706
15	·9533	·9263	·9624	·9300	·9634	·9669	·9735	·9166	·9319	·9226	·9113
20	·8795	·8591	·9068	·8716	·9574	·9241	·9237	·7898	·8643	·8260	·8307
25	·7403	·7668	·8334	·7339	·8289	·8634	·7859	·6874	·7992	·7164	·6781
30	·6413	·6800	·6508	·5889	·7408	·7341	·6744	·5050	·7101	·5423	·5825
35	·5625	·5984	·6629	·7302	·7172	·6734	·7254	·5878	·6434	·5172	·6226
40	·6531	·7270	·6982	·6866	·7981	·8210	·7822	·5448	·7091	·6264	·7088
45	·8197	·6905	·6542	·7559	·6951	·7738	·8169	·5385	·6933	·6438	·7686
50	·8375	·6552	·8230	·7941	·7842	·8246	·8276	·8571	·6698	·5936	·7508
55	·7600	·8889	·8276	·9259	·7857	·8278	·8750	·8333	·9063	·7037	·8796
60	·8947	·8750	·9292	·9200	·8710	·8373	·9274	1·0	·8621	·7895	·8937

through the next 5 days at intervals of 5 days for our observations down to day 60[1], shows that no mere shifting vertically of the columns would produce agreement. If, for instance, we shift the entries under *F* downwards we shall not find that any such movement will make them agree with *H*[2]. Comparison shows that, at first, all the probabilities are approximately equal, that then those of the vaccinated groups diverge more and more from the controls to a maximum difference round about 30, *i.e.* the probability of surviving from day 25 to day 30, and thereafter the probabilities of survivorship of the vaccinated groups again approximate to those of the controls. For the purpose of studying the matter more closely Table X has been constructed. The vaccinated groups *E*, *F*, *G* (on the whole the most successful groups) are confronted with the weighted average of the controls (the added daily group being twice as large as the *H* group its probabilities have been given twice the weight of the

Table X. *Probability of surviving* 5 *days.*

Cage age in days	Specific deaths. *E*, *F*, *G*	Controls	Difference	Column 2 / Column 3	Graduation of col. 5
0	·9968	·9925	·0043	1·004	1·001
5	·9946	·9715	·0231	1·024	1·009
10	·9679	·9151	·0528	1·058	1·039
15	·9351	·8291	·1060	1·128	1·113
20	·8261	·6909	·1352	1·196	1·217
25	·7164	·5691	·1473	1·259	1·274
30	·7053	·5875	·1178	1·201	1·229
35	·8004	·6813	·1191	1·175	1·126
40	·7619	·7270	·0349	1·048	1·046
45	·8121	·6984	·1137	1·163	1·011
50	·8295	·8210	·0085	1·010	1·002
55	·8786	·8590	·0196	1·023	1·000

[1] Thus the entry ·9968 against cage age 0 means that 99·68 per cent. of the *B* animals survived 5 days from entrance. The next entry ·9772 means that 97·72 per cent. of the animals which survived 5 days survived a further 5 and so on.

[2] It must be noted that the fact that a simple translation does not produce agreement does not prove that the hypothesis suggested above is false, since, during the first days of exposure risk of death is relatively small for *all* mice. All that is demonstrated is that the simplest form of that hypothesis is inexact.

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H group). After day 40 the differences are irregular, but they suggest a rise to a single maximum and then a decline. Taking now the ratios of the survivorship probabilities of the vaccinated to the unvaccinated group, we have the figures of the fifth column. The suggestion they convey is that the relative advantage of the vaccinated increases to a maximum at somewhere about the epoch in herd life when the specific mortality rate itself is at a maximum. It looks as if vaccination gave the vaccinated an extra reserve of resistance, which responded to the increasing demands made upon it up to a point and then wore away. Is this capable of quantitative appraisement? A fundamental difficulty is that, owing to the rapid decrement of the exposed to risk, the standard errors of such ratios increase very fast. In fact calculation shows that, for day 45 onwards, the standard errors of the ratios are of the same order of magnitude as the differences of these ratios from unity. They are therefore wholly unreliable as data for the determination of the "law" of change of the ratio. A long shot can, however, be made in the following way. Let us suppose that the ratio starts at unity—no difference between vaccinated and unvaccinated—in respect of mortality in the first 5 days of herd life—and gradually approaches unity again in symmetrical fashion. Then we might suppose that the differences of the several ratios from unity should be approximately represented by areas of a normal curve. As, however, the limit of this curve towards increasing x is ill-determined, any approximation to its constants must be imperfect. A first attempt was made by the plan of assuming that the first few values formed the tail of a normal curve and deducing the constants of the whole curve from this stump by a method devised by Pearson. The graduations so obtained were not, however, satisfactory. They greatly exaggerated the advantage of the vaccinated at a part of the course where the observed values depend upon reasonably large numbers and are, therefore, fairly trustworthy. A second attempt was then made by directly fitting a normal curve to the seven values from 0·058 to 0·048 inclusive. This, it will be seen, leads to a much better result. Only where the observations are scanty is the divergence gross. Having regard to the necessarily crude method of analysis from a biometric point of view and to the biological, or epidemiological, probability that any "law" *must* be blurred in operation by extraneous factors, we seem justified in saying that a feasible explanation of our results is that suggested. An analogy may help to make the point clear. Suppose that a mouse of a particular category were being bombarded with lethal missiles and his chance of not being hit by any one missile were q ($p + q = 1$), then if n bullets were aimed at him, his chance of escaping would be q^n. For a mouse of different category the chance might be q', and under the given circumstances his chance of escape would be q'^n. Let q' be greater than q. Then the ratios of survivorship will be $(q/q')^n$ which will decrease with n without limit. If, however, q and q' both differ very little from unity, the limit as n increases will not be zero but e^{-k}, where k is a constant and e the base of the natural logarithms, while, when n is small, the ratio will differ

little from unity. Now, if we supposed that in successive intervals of 5 days the value of n varied, was first small, then increased and then again decreased, we should find the ratios of survivorship first near unity, then increasing to some limit and then again falling towards unity. We should have a result having some resemblance to what we find. For reasons set out at length in our last paper, we are satisfied that this scheme is far too simple to be adequate, but it is sufficient to illustrate the general line of argument.

At this point it will be convenient to correct an error published in our last paper. In that paper (Greenwood, Newbold, Topley and Wilson, 1930, p. 257) we printed two tables (Tables VIII and IX) from which we drew the conclusion that the asymptoting of q_x, which characterises all our experiments, including the present one, was attributable to an insensitiveness of the inhabitants to variations of the environment *after* the first few days of their residence. Table IX, which was a direct comparison of survivorships under contrasting conditions, is not, we think, open to objection and, so far as it goes, sustains the conclusion drawn. But Table VIII is logically invalid. The correlations contained in it were not based as, we think, they should have been upon the individual observations, but upon the *means* of small groups. No doubt if the batches used in each calculation had been of the same size, the coefficients of correlation would have been comparable although, even then, we do not think the method would have been satisfactory. But actually the batches decreased in size. The methodological error involved is this. Suppose we start with two variables x and y, in our case x is the prevailing death-rate in the cage, and y the length of time a mouse exposed to that death-rate survived after the date to which the death-rate refers. There will be a certain degree of correlation between x and y. Now suppose we take the table showing for each value of x the various associated values of y, *i.e.* the arrays of y for each value of x, and form a new variable y' by dividing up at random the n_x values of y corresponding to the particular x into, say, k sets and taking the k means as our new variable y', the correlation of x with y' will be numerically larger than the correlation of x with y. This is easy to demonstrate algebraically, but it will be sufficient to note that if the array is reduced to a single value by taking the mean of the array as variate, then, if the regression be linear and x and y are correlated, the correlation of x with y' must be perfect. Hence the decreasing absolute values of the coefficients of correlation in the table might merely be expressions of the fact that as the batches used decreased in size one was approaching the value of the proper variate correlation of x and y, y' was becoming the same as y.

An obvious check was to compare the *regression* coefficients, which would not be affected by the procedure and we found that these did not, having regard to errors of sampling, show any significant or regular decrement. We think therefore that the support Table VIII of the last paper appeared to give to the conclusion was illusory. Using the material of the present experiment we have studied the proper measure, viz. the correlation of prevailing death-

rate and individual survivorship and found it both for vaccinated and control mice to be insignificant. We have also prepared a table (Table XI) comparable in form with Table IX of the previous paper. This does not confirm the suggestion of that table. It must be noted, however, that the contrasting levels of mortality are not the same as before. The position is that our previous surmise may be correct, but that the evidence we tendered before and the material we have derived from this experiment do not justify it. Biologically, the surmise still commends itself to us as a reasonable one, but it is *not*, as we suggested, statistically established.

Table XI. *Cage* 1.

Cage age x	Mean length of after life from day x: Low death-rate (under ·025) just before day x	Mean length of after life from day x: High death-rate (over ·035) just before day x	Difference	Numbers of groups: Low death-rate	Numbers of groups: High death-rate
		Group *C*			
0	43·37	32·60	10·77	13	16
5	34·37	26·33	8·04	26	6
10	30·11	26·31	3·80	11	13
15	31·92	21·59	10·33	12	16
20	22·82	15·95	6·87	18	11
25	22·32	8·85	13·47	16	6
30	27·32	12·05	15·27	6	19
35	48·27	16·94	31·33	8	19
40	42·97	32·33	10·64	18	10
		Group *H*			
0	25·35	27·20	−1·85	13	16
5	22·48	20·35	2·13	26	6
10	16·20	19·21	−3·01	11	13
15	13·37	15·26	−1·89	12	16
20	11·33	9·82	1·51	18	11
25	11·88	10·23	1·65	16	6
30	9·25	15·08	5·83	6	19
35	29·43	9·05	20·38	7	16
40	32·81	14·73	18·08	17	6

From the results obtained in the present experiment we conclude that the protection afforded by vaccination is neither absolute, nor independent of subsequent happenings in the infected herd. It increases the average resistance, *vis-à-vis* with the particular risk concerned, and in so doing it increases the probability that the first reception of a dose of infective material will result in a latent infection associated with a further immunising response; but the value accruing from the artificial immunisation will depend in large part on the magnitude of the doses of bacilli subsequently received, and on the intervals between these doses. If the bombardment to which a mouse is subjected is intense and continuous, the relative increase in its resistance will be of little avail.

Incidentally, this way of thinking of artificial immunisation enables us to think of such vaccination as a communal measure in a more sensible way. Suppose the members of our herds had been dispersed after some 30–40 days of communal existence, farmed out, perhaps in little groups of twos and threes. At this time the number of surviving vaccinated animals would (assuming

equal numbers of entrants of the two groups) be more than double the number of surviving controls. Under the new conditions a good many would die of the acquired infection but, in comparison with the mortality rate of the herd, very few. The advantage conferred by vaccination would *approximate* to a saving of 50 per cent. of deaths. The value of the immunisation when a herd is exposed to temporary but intensely unfavourable conditions is enormous. But, if the herd conditions persist, although the vaccinated animals have an advantage it is not, from the point of view of the community, a very great one. If we intend to expose a herd—whether troops on active service or hospital attendants—to transitory but intense risks of infection, a method of vaccination may be expected to render good service. The vaccination of 100 per cent. of a community steadily, from generation to generation, exposed to risk of infection, will no more eliminate the disease than, as we showed in an earlier paper, will the exclusion of infected immigrants to a community, in which the disease has existed and still smoulders, lead to elimination.

We have now discussed the broad results of this experiment, so far as concerns the effect of immunisation with the most efficient of the vaccines employed. The subsidiary question of the relative efficiency of the eight different vaccines employed may be dealt with very briefly. Table VII A sets out the relevant data.

The results show clearly that those vaccines which contain the smooth O antigen (*C*, *E*, *F*, *G* and *K*) are all effective, in the sense outlined above, and that their efficiency differs insignificantly *inter se* when comparisons are made over the same period of time. It is clearly immaterial whether the H components are present (vaccines *C*, *E* and *K*), incompletely represented (vaccine *F*) or altogether absent (vaccine *G*). Nor is a killed broth culture (vaccine *E*), which might contain bacterial products not present in the bacterial suspensions, superior to the saline suspensions of bacilli (vaccines *C*, *F* or *G*). The inefficacy of the H components is confirmed by results obtained with vaccine *D*, containing the H, but not the O, antigens of *Bact. aertrycke*. There is a suggestion that a minor degree of protection may result from entirely non-specific immunisation. The *A* mice, vaccinated with a staphylococcal suspension, and the *B* mice, vaccinated with a rough strain of *Bact. typhosum*, show a slight advantage over the H, and the Added Daily mice. It will be noted that the *D* mice fall into the same category. The *J* mice, vaccinated with *Past. pseudotuberculosis* show no advantage; their expectation of life is less than that of any other group. For this we can offer no explanation.

There is a suggestion, falling far short of demonstration, that the efficacy of the *C* vaccine diminished slightly on storage. Taking the three periods, 1. v. 28 to 27. xi. 28, 4. xii. 28 to 5. ii. 29, and 19. ii. 29 to 9. vii. 29, it will be noted that the relative advantage of the *C* over the *H* mice showed a progressive diminution; during the last period the freshly prepared vaccine *K* gave slightly better results than vaccine *C*, which had at that time been stored for slightly more than a year.

CONCLUSIONS.

(*a*) *With regard to the effectiveness of different vaccines.*

1. The efficacy of a *Bact. aertrycke* vaccine, as an immunising agent, appears to be determined by its content in the O somatic antigen. We have obtained no indication that other components have any significant effect.

2. There is a suggestion that the effectiveness of a vaccine containing the O antigen may diminish slightly on storage; but such loss is very slight over a period of 1 year.

3. There is a suggestion that the injection of bacteria unrelated to *Bact. aertrycke* may result in a minor increase in resistance to infection with that organism; but such increase is trivial in comparison with that which follows the injection of the specific O antigen, and is not obtained with all non-specific agents.

(*b*) *With regard to the influence of efficient vaccination on herd infection.*

4. Vaccinated mice show a significant advantage as compared with unvaccinated mice in respect of their expectation of life, unlimited or limited to 60 days.

5. This advantage is not uniform over the whole period of exposure. As judged by the chance of survival over the succeeding 5 days, it is not apparent on the day of entry, or during the first week of exposure, probably because the risk of dying of a fatal infection within the first 10 days or so of residence in the cage is in any case slight. The advantage of the vaccinated mice, on this test, increases to a maximum between the twenty-fifth and thirtieth days of cage life and thereafter declines, so that a vaccinated mouse which has survived exposure for a considerable period (50–60 days in this experiment) enjoys no significant advantage over an unvaccinated mouse which has survived for the same period.

6. The protection afforded is in no sense absolute. Judged from the experience in this herd of mice it might be regarded as of little account, in that it has little if any influence on the ultimate mortality from the specific disease. Our results offer no suggestion that antibacterial immunisation, with the most efficient available vaccine, will afford protection against severe and prolonged exposure to infection, or will, under such conditions, ameliorate the course of events in an infected herd. The vaccinated mice, in the presence of infection, are never placed in the same position as normal mice in a non-infected herd. This conclusion does *not* involve the deduction that vaccination is useless. Under other conditions of exposure—especially where the risk of infection is limited in time—the advantage afforded by vaccination might well make the difference between effective immunity and death.

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APPENDIX

Table VI.

SPECIFIC DEATHS.

Cage age in days	*C* mice				*D* mice			
	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x
0	10000·00	10·37	·0010373	38·74	10000·00	—	—	39·33
1	9989·63	—	—	37·78	10000·00	64·52	·0064516	38·33
2	9989·63	—	—	36·78	9935·48	—	—	37·57
3	9989·63	10·40	·0010406	35·78	9935·48	—	—	36·57
4	9979·23	—	—	34·81	9935·48	—	—	35·57
5	9979·23	—	—	33·81	9935·48	—	—	34·57
6	9979·23	—	—	32·81	9935·48	32·47	·0032680	33·57
7	9979·23	20·99	·0021031	31·81	9903·01	64·94	·0065574	32·68
8	9958·24	21·01	·0021097	30·88	9838·08	64·94	·0066007	31·89
9	9937·24	31·61	·0031813	29·94	9773·14	32·47	·0033223	31·10
10	9905·62	63·50	·0064103	29·04	9740·67	97·41	·0100000	30·20
11	9842·12	74·16	·0075350	28·22	9643·26	129·88	·0134680	29·50
12	9767·96	53·09	·0054348	27·43	9513·39	97·41	·0102389	28·90
13	9714·88	106·52	·0109649	26·58	9415·98	194·81	·0206897	28·19
14	9608·35	74·98	·0078038	25·87	9221·17	162·34	·0176056	27·78
15	9533·37	128·83	·0135135	25·07	9058·82	98·11	·0108303	27·27
16	9404·54	118·77	·0126292	24·40	8960·71	164·72	·0183824	26·56
17	9285·77	205·87	·0221704	23·71	8795·99	99·58	·0113208	26·05
18	9079·90	151·69	·0167064	23·24	8696·42	265·54	·0305344	25·34
19	8928·21	283·09	·0317073	22·62	8430·88	535·29	·0634921	25·12
20	8645·12	263·30	·0304569	22·35	7895·58	501·84	·0635593	25·79
21	8381·82	374·48	·0446780	22·03	7393·74	436·90	·0590909	26·51
22	8007·33	288·35	·0360111	22·04	6956·84	407·23	·0585366	27·14
23	7718·98	244·69	·0317003	21·84	6549·61	477·58	·0729167	27·80
24	7474·29	269·75	·0360902	21·54	6072·04	277·58	·0457143	28·95
25	7204·54	508·16	·0705329	21·33	5794·46	453·78	·0783132	29·31
26	6696·38	524·76	·0783646	21·91	5340·67	501·81	·0939597	30·76
27	6171·62	643·60	·1042830	22·73	4838·87	509·35	·1052632	32·90
28	5528·03	499·38	·0903361	24·32	4329·51	476·98	·1101695	35·71
29	5028·65	339·93	·0675991	25·69	3852·53	440·29	·1142857	39·07
30	4688·71	353·42	·0753769	26·51	3412·24	110·07	·0322581	43·04
35	3108·26	230·69	·0742188	33·66	2491·50	223·12	·0895522	52·88
40	2170·16	178·72	·0823529	42·19	1710·58	37·19	·0217391	71·11
45	1419·74	26·29	·0185185	58·33	1293·08	76·06	·0588235	88·29
50	1168·51	67·16	·0574713	65·32	1026·86	38·03	·0370370	105·61
55	967·04	—	—	73·52	950·79	—	—	108·86
60	898·53	—	—	73·95	874·73	—	—	113·11
70	744·66	28·10	·0377359	78·24	684·57	—	—	132·78
80	614·72	—	—	83·84	646·54	38·03	·0588235	130·26
90	600·08	15·00	·0250000	75·75	570·48	—	—	137·30
100	540·07	30·00	·0555556	73·50	532·44	—	—	137·00
110	465·06	—	—	74·99	418·35	—	—	162·50
120	420·06	31·12	·0740741	72·25	418·35	—	—	152·50
130	357·83	—	—	—	418·35	—	—	—
140	309·67	—	—	—	418·35	—	—	—
150	277·07	—	—	—	418·35	—	—	—
160	244·48	—	—	—	342·29	—	—	—
170	206·87	—	—	—	342·29	—	—	—
180	150·45	—	—	—	342·29	—	—	—
190	150·45	—	—	—	304·25	—	—	—
200	128·96	—	—	—	266·22	—	—	—
210	128·96	—	—	—	190·16	—	—	—
220	128·96	—	—	—	190·16	—	—	—
230	103·16	—	—	—	190·16	—	—	—
240	—	—	—	—	152·13	—	—	—
.					.			
270	—	—	—	—	152·13	38·03	·2500000	—
280	—	—	—	—	114·10	—	—	—
.					.			
320	—	—	—	—	114·10	—	—	—

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Table VI (*cont.*)

SPECIFIC DEATHS

Cage age in days	*E* mice				*F* mice			
	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x
0	10000·00	—	—	44·16	10000·00	32·26	·0032258	48·93
1	10000·00	—	—	43·16	9967·74	—	—	48·09
2	10000·00	—	—	42·16	9967·74	—	—	47·09
3	10000·00	—	—	41·16	9967·74	—	—	46·09
4	10000·00	—	—	40·16	9967·74	32·57	·0032680	45·09
5	10000·00	—	—	39·16	9935·17	—	—	44·24
6	10000·00	—	—	38·16	9935·17	—	—	43·24
7	10000·00	—	—	37·16	9935·17	—	—	42·24
8	10000·00	32·68	·0032680	36·16	9935·17	—	—	41·24
9	9967·32	65·57	·0065789	35·27	9935·17	—	—	40·24
10	9901·75	—	—	34·50	9935·17	32·79	·0033003	39·24
11	9901·75	32·90	·0033226	33·50	9902·38	32·79	·0033113	38·36
12	9868·85	131·58	·0133333	32·61	9869·59	131·16	·0132890	37·49
13	9737·26	98·69	·0101351	32·05	9738·43	33·01	·0033898	36·99
14	9638·57	99·37	·0103093	31·37	9705·42	99·04	·0102041	36·11
15	9539·21	67·18	·0070423	30·69	9606·39	99·04	·0103093	35·48
16	9472·03	100·77	·0106383	29·91	9507·35	66·02	·0069444	34·84
17	9371·26	33·95	·0036232	29·22	9441·33	231·89	·0245614	34·08
18	9337·31	136·31	·0145985	28·33	9209·44	165·64	·0179856	33·93
19	9201·00	68·16	·0074074	27·74	9043·80	166·86	·0184502	33·54
20	9132·84	206·00	·0225564	26·94	8876·94	234·49	·0264151	33·16
21	8926·84	379·13	·0424710	26·55	8642·45	133·99	·0155039	33·05
22	8547·71	173·73	·0203252	26·71	8508·46	368·48	·0433071	32·56
23	8373·97	527·77	·0630252	26·25	8139·98	201·82	·0247934	33·01
24	7846·20	285·32	·0363636	26·98	7938·17	273·73	·0344828	32·84
25	7560·89	322·50	·0426540	26·98	7664·44	479·03	·0625000	32·99
26	7238·38	716·67	·0990099	27·16	7185·41	523·21	·0728155	34·16
27	6521·71	217·39	·0333333	29·09	6662·20	317·25	·0476190	35·80
28	6304·32	327·97	·0520231	29·07	6344·95	430·17	·0677966	36·57
29	5976·35	368·91	·0617284	29·65	5914·79	288·53	·0487805	38·19
30	5607·44	336·45	·0600000	30·56	5626·26	365·34	·0649351	39·13
35	4021·78	309·37	·0769231	36·63	3788·81	236·80	·0625000	51·83
40	3209·69	117·43	·0365854	40·39	3110·56	163·71	·0526316	57·66
45	2231·13	79·68	·0357143	52·08	2406·98	168·91	·0701754	68·76
50	1749·64	83·32	·0476190	60·74	1984·71	168·91	·0851064	78·03
55	1374·71	—	—	71·60	1642·86	86·47	·0526316	88·93
60	1197·33	44·35	·0370370	76·76	1375·60	45·85	·0333333	100·81
70	886·91	—	—	91·50	1238·04	45·85	·0370370	101·77
80	798·22	—	—	90·83	871·21	—	—	132·94
90	709·53	—	—	91·31	779·51	—	—	137·93
100	665·18	44·35	·0666667	87·17	687·80	—	—	145·66
110	532·15	—	—	97·50	596·09	—	—	157·30
120	443·46	—	—	106·30	550·24	—	—	159·78
130	399·11	—	—	—	550·24	—	—	—
140	354·77	—	—	—	550·24	—	—	—
150	354·77	—	—	—	453·95	—	—	—
160	310·42	—	—	—	453·95	—	—	—
170	266·07	—	—	—	453·95	—	—	—
180	266·07	—	—	—	453·95	—	—	—
190	266·07	—	—	—	403·51	—	—	—
200	221·73	—	—	—	403·51	—	—	—
210	177·38	—	—	—	353·07	—	—	—
220	177·38	—	—	—	353·07	—	—	—
230	177·38	—	—	—	302·63	—	—	—
240	177·38	—	—	—	302·63	—	—	—
250	177·38	—	—	—	302·63	—	—	—
260	177·38	—	—	—	252·19	—	—	—
270	177·38	—	—	—	252·19	—	—	—
280	177·38	—	—	—	189·15	—	—	—
290	133·04	—	—	—	189·15	—	—	—
300	133·04	—	—	—	189·15	—	—	—
310	133·04	—	—	—	189·15	—	—	—
320	—	—	—	—	189·15	—	—	—
330	—	—	—	—	189·15	—	—	—
340	—	—	—	—	189·15	—	—	—
350	—	—	—	—	189·15	—	—	—
360	—	—	—	—	189·15	63·05	·3333333	—
370	—	—	—	—	126·10	—	—	—
380	—	—	—	—	126·10	—	—	—
390	—	—	—	—	126·10	—	—	—
400	—	—	—	—	126·10	—	—	—

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Table VI (*cont.*)

SPECIFIC DEATHS.

Expectation of life limited to 60 days ahead.

Cage age in days	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*	*K*	Added daily
0	29·86	29·28	32·10	29·44	34·97	35·06	33·71	26·38	25·87	30·82	27·07
1	28·92	28·34	31·22	28·52	34·09	34·31	32·86	25·43	24·90	29·89	26·16
2	27·99	27·41	30·31	27·79	33·20	33·45	32·00	24·45	23·93	28·97	25·26
3	27·06	26·56	29·39	26·87	32·31	32·58	31·14	23·51	22·96	28·04	24·37
4	26·13	25·62	28·50	25·96	31·42	31·70	30·38	22·53	21·99	27·12	23·47
5	25·19	24·68	27·58	25·14	30·53	30·94	29·52	21·63	21·02	26·19	22·55
6	24·26	23·74	26·67	24·22	29·64	30·06	28·65	20·67	20·05	25·27	21·64
7	23·33	23·02	25·74	23·28	28·75	29·18	27·79	19·73	19·08	24·34	20·79
8	22·47	22·16	24·88	22·50	27·86	28·31	26·92	18·83	18·40	23·47	19·93
9	21·61	21·36	24·00	21·73	27·04	27·43	26·15	18·04	17·43	22·60	19·23
10	20·74	20·49	23·16	20·87	26·30	26·56	25·37	17·22	16·55	21·77	18·39
11	19·94	19·75	22·37	20·14	25·39	25·76	24·50	16·36	15·83	21·05	17·66
12	19·14	19·20	21·61	19·49	24·57	24·97	23·87	15·63	15·11	20·49	16·95
13	18·39	18·33	20·80	18·75	23·99	24·41	23·07	15·03	14·38	19·81	16·31
14	17·83	17·70	20·10	18·22	23·32	23·60	22·28	14·33	13·71	19·28	15·64
15	16·97	17·20	19·32	17·61	22·65	22·96	21·63	13·52	12·97	18·53	15·15
16	16·44	16·50	18·65	16·87	21·90	22·29	21·21	12·98	12·29	17·70	14·64
17	15·74	16·11	17·95	16·25	21·22	21·54	20·85	12·35	11·75	17·43	14·16
18	15·03	15·42	17·42	15·51	20·39	21·16	20·06	11·59	10·92	16·63	13·70
19	14·89	15·10	16·78	15·05	19·77	20·64	19·34	11·10	10·80	16·36	13·38
20	14·25	14·86	16·39	15·12	19·00	20·11	18·89	10·87	10·74	16·31	13·00
21	13·77	14·59	15·95	15·27	18·52	19·75	18·84	10·59	10·52	16·04	12·74
22	13·42	14·41	15·76	15·28	18·41	19·15	18·52	10·05	10·06	15·97	12·70
23	13·41	14·44	15·40	15·30	17·88	19·10	18·78	9·77	9·89	15·55	12·80
24	13·63	14·22	14·97	15·57	18·15	18·69	19·06	9·67	9·99	15·35	12·94
25	13·66	14·05	14·60	15·30	17·92	18·44	19·14	9·31	9·66	15·19	13·34
26	13·86	14·10	14·76	15·67	17·81	18·75	19·18	9·30	9·98	15·47	13·79
27	14·02	14·78	15·07	16·36	18·83	19·31	20·18	9·73	10·72	15·68	14·49
28	14·50	14·43	15·88	17·36	18·57	19·38	21·51	9·94	11·18	15·75	15·13
29	14·84	14·84	16·53	18·59	18·69	19·41	22·17	10·28	11·98	15·91	15·79
30	15·47	15·15	16·82	20·09	19·01	19·53	23·36	10·45	12·35	15·98	16·90
35	21·55	20·02	19·98	22·53	21·39	24·45	27·87	12·98	15·04	19·19	21·83
40	28·06	22·73	23·90	28·47	22·32	25·45	32·12	15·05	21·45	22·28	26·36
45	30·39	28·69	32·11	33·89	27·49	28·52	36·55	18·02	34·45	27·32	30·46
50	32·46	39·58	35·47	39·41	31·09	30·79	41·82	25·27	37·33	36·22	36·92
55	39·23	41·49	39·85	39·56	35·70	33·67	45·63	31·41	41·56	36·42	38·96
60	40·97	45·02	40·17	40·18	37·39	36·90	47·54	36·47	39·23	38·83	40·77

Table VI (*cont.*)

SPECIFIC DEATHS.

Cage age in days	*J* mice				*K* mice			
	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x
0	10000·00	—	—	27·30	10000·00	—	—	35·39
1	10000·00	—	—	26·30	10000·00	—	—	34·39
2	10000·00	—	—	25·30	10000·00	—	—	33·39
3	10000·00	—	—	24·30	10000·00	—	—	32·39
4	10000·00	—	—	23·30	10000·00	—	—	31·39
5	10000·00	—	—	22·30	10000·00	—	—	30·39
6	10000·00	—	—	21·30	10000·00	—	—	29·39
7	10000·00	151·52	·0151515	20·30	10000·00	24·04	·0024038	28·39
8	9848·49	—	—	19·61	9975·96	24·04	·0024096	27·45
9	9848·49	50·51	·0051282	18·61	9951·92	48·08	·0048309	26·52
10	9797·98	152·30	·0155440	17·70	9903·85	96·15	·0097087	25·64
11	9645·68	152·30	·0157895	16·97	9807·69	168·68	·0171990	24·89
12	9493·38	152·30	·0160428	16·24	9639·01	120·49	·0125000	24·32
13	9341·08	205·30	·0219780	15·50	9518·52	192·78	·0202532	23·62
14	9135·78	154·84	·0169492	14·83	9325·74	96·39	·0103359	23·10
15	8980·94	206·46	·0229885	14·08	9229·35	48·58	·0052632	22·33
16	8774·48	309·69	·0352941	13·40	9180·78	340·93	·0371353	21·45
17	8464·79	105·15	·0124224	12·87	8839·85	73·67	·0083333	21·26
18	8359·64	630·92	·0754717	12·03	8766·18	344·74	·0393258	20·43
19	7728·72	635·24	·0821918	11·97	8421·44	444·53	·0527859	20·25
20	7093·48	483·65	·0681818	11·99	7976·91	322·05	·0403727	20·35
21	6609·84	325·07	·0491803	11·84	7654·86	398·95	·0521173	20·18
22	6284·76	487·61	·0775862	11·42	7255·91	224·41	·0309278	20·26
23	5797·15	595·97	·1028037	11·34	7031·50	327·63	·0465950	19·90
24	5201·18	325·07	·0625000	11·58	6703·87	328·87	·0490566	19·84
25	4876·11	595·97	·1222222	11·32	6375·00	480·65	·0753968	19·84
26	4280·14	650·15	·1518987	11·83	5894·34	410·04	·0695652	20·42
27	3629·99	440·00	·1212121	12·86	5484·30	334·72	·0610329	20·91
28	3189·99	447·72	·1403509	13·56	5149·58	336·40	·0653266	21·23
29	2742·28	279·82	·1020408	14·69	4813·18	286·19	·0594595	21·68
30	2462·45	391·75	·1590909	15·31	4526·99	364·24	·0804598	22·02
35	1447·37	173·68	·1200000	19·51	2912·49	296·64	·1018518	27·89
40	788·47	—	—	28·63	2065·15	137·68	·0666667	33·56
45	424·56	60·65	·1428571	45·88	1431·83	27·54	·0192308	42·21
50	363·91	—	—	48·44	959·03	—	—	56·64
55	303·26	—	—	52·23	869·12	29·97	·0344828	57·14
60	303·26	—	—	47·23	749·25	—	—	61·00
70	303·26	—	—	37·23	689·31	—	—	55·57
80	161·74	—	—	55·00	536·30	—	—	60·06
90	161·74	—	—	45·00	405·61	—	—	67·45
100	161·74	—	—	35·00	405·61	—	—	57·45
110	161·74	—	—	25·00	338·01	—	—	57·94
120	161·74	—	—	15·00	270·40	—	—	61·42
130	—	—	—	—	270·40	—	—	—
140	—	—	—	—	202·80	—	—	—
150	—	—	—	—	202·80	—	—	—
160	—	—	—	—	162·24	—	—	—
170	—	—	—	—	162·24	—	—	—
180	—	—	—	—	162·24	—	—	—
190	—	—	—	—	121·68	—	—	—
200	—	—	—	—				

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Table VI (*cont.*)

SPECIFIC DEATHS.

Cage age in days	*G* mice				*H* mice			
	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x
0	10000·00	—	—	52·12	10000·00	10·53	·0010526	27·93
1	10000·00	—	—	51·12	9989·47	—	—	26·96
2	10000·00	—	—	50·12	9989·47	21·07	·0021097	25·96
3	10000·00	32·36	·0032362	49·12	9968·40	—	—	25·01
4	9967·64	—	—	48·27	9968·40	31·71	·0031813	24·01
5	9967·64	—	—	47·27	9936·69	10·58	·0010650	23·09
6	9967·64	—	—	46·27	9926·10	21·25	·0021413	22·11
7	9967·64	—	—	45·27	9904·85	42·56	·0042965	21·16
8	9967·64	32·47	·0032573	44·27	9862·29	106·50	·0107991	20·25
9	9935·17	32·47	·0032680	43·42	9755·79	85·20	·0087336	19·46
10	9902·70	—	—	42·56	9670·59	74·64	·0077178	18·63
11	9902·70	98·05	·0099010	41·56	9595·95	149·27	·0155556	17·77
12	9804·66	32·68	·0033333	40·97	9446·68	234·83	·0248588	17·04
13	9771·97	32·68	·0033445	40·10	9211·85	171·18	·0185830	16·46
14	9739·29	98·71	·0101351	39·24	9040·66	118·39	·0130952	15·77
15	9640·58	197·42	·0204778	38·63	8922·27	291·30	·0326481	14·97
16	9443·16	231·94	·0245614	38·43	8630·98	238·25	·0276035	14·46
17	9211·23	33·62	·0036496	38·38	8392·73	152·40	·0181582	13·85
18	9177·61	67·73	·0073801	37·52	8240·34	351·12	·0426099	13·10
19	9109·88	204·72	·0224719	36·80	7889·22	519·32	·0658263	12·66
20	8905·16	379·68	·0426357	36·63	7369·90	467·58	·0634441	12·52
21	8525·48	242·60	·0284553	37·24	6902·32	289·92	·0420032	12·33
22	8282·89	485·19	·0585774	37·32	6612·40	449·82	·0680272	11·85
23	7797·70	450·53	·0577778	38·61	6162·58	541·77	·0879121	11·68
24	7347·17	348·21	·0473934	39·95	5620·81	340·66	·0606061	11·76
25	6998·96	313·39	·0447761	40·91	5280·16	522·34	·0989247	11·48
26	6685·57	591·95	·0885417	41·80	4757·82	651·91	·1370192	11·69
27	6093·62	595·35	·0977011	44·82	4105·91	466·58	·1136364	12·47
28	5498·27	352·45	·0641026	48·61	3639·33	444·68	·1221865	13·00
29	5145·81	425·86	·0827586	50·91	3194·65	331·30	·1037037	13·74
30	4719·95	283·91	·0601504	54·46	2863·35	241·63	·0843882	14·27
35	3423·72	223·29	·0652174	69·11	1480·82	223·99	·1512605	20·08
40	2677·92	226·30	·0845070	82·76	927·57	63·53	·0684932	25·91
45	2187·60	150·87	·0689656	95·99	597·20	76·24	·1276596	34·16
50	1810·42	—	—	110·66	354·51	26·26	·0740741	51·22
55	1584·12	37·72	·0238095	121·01	249·47	26·26	·1052632	66·53
60	1469·08	38·66	·0263158	125·29	196·95	—	—	78·74
70	1314·44	38·66	·0294118	129·53	157·56	—	—	86·80
80	1117·40	—	—	141·36	144·43	—	—	84·28
90	1117·40	—	—	131·36				
100	1117·40	—	—	121·36				
110	1077·49	39·91	·0370370	115·66				
120	1037·59	—	—	110·08				
130	954·58	41·50	·0434783	—				
140	871·57	41·50	·0476190	—				
150	788·57	—	—	—				
160	700·95	—	—	—				
170	657·14	—	—	—				
180	657·14	—	—	—				
190	613·33	43·81	·0714286	—				
200	525·71	—	—	—				
210	438·09	—	—	—				
220	394·28	—	—	—				
230	350·47	—	—	—				
240	300·41	—	—	—				
250	300·41	—	—	—				
260	300·41	—	—	—				
270	250·34	—	—	—				
280	200·27	—	—	—				
290	150·20	—	—	—				
300	150·20	—	—	—				
.	.	.	.	.				
360	150·20	—	—	—				
450	100·14	—	—	—				

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Table VI (*cont.*)

SPECIFIC DEATHS.

Added Daily mice

Cage age in days	l_x	d_x	q_x	e_x
0	10000·00	16·08	·0016077	33·24
1	9983·92	10·73	·0010747	32·29
2	9973·19	21·51	·0021563	31·33
3	9951·69	21·52	·0021622	30·40
4	9930·17	10·78	·0010852	29·46
5	9919·39	16·16	·0016295	28·49
6	9903·23	48·52	·0048993	27·54
7	9854·71	37·80	·0038356	26·67
8	9816·91	129·67	·0132086	25·78
9	9687·25	59·46	·0061384	25·11
10	9627·78	113·65	·0118044	24·26
11	9514·13	135·53	·0142450	23·55
12	9378·60	179·00	·0190862	22·88
13	9199·60	157·96	·0171699	22·31
14	9041·64	267·70	·0296073	21·69
15	8773·95	251·94	·0287141	21·34
16	8522·01	269·58	·0316333	20·96
17	8252·43	286·85	·0347594	20·63
18	7965·58	359·56	·0451389	20·35
19	7606·02	317·38	·0417277	20·29
20	7288·64	375·65	·0515385	20·15
21	6913·00	473·26	·0684597	20·22
22	6439·73	501·87	·0779334	20·67
23	5937·86	469·82	·0791230	21·37
24	5468·04	525·66	·0961337	22·17
25	4942·38	472·35	·0955711	23·47
26	4470·03	480·59	·1075130	24·90
27	3989·44	396·03	·0992701	26·84
28	3593·41	341·67	·0950820	28·74
29	3251·74	372·66	·1146026	30·71
30	2879·08	276·83	·0961538	33·61
35	1792·52	135·89	·0758123	47·63
40	1270·55	99·78	·0785340	61·37
45	976·53	53·88	·0551724	74·24
50	733·16	6·79	·0092593	93·05
55	644·91	6·79	·0105263	100·41
60	576·37	13·72	·0238095	106·98
70	455·86	7·24	·0158730	123·94
80	419·32	—	—	124·32
90	382·53	7·36	·0192308	125·79
100	353·11	—	—	125·98
110	308·97	—	—	133·19
120	293·90	—	—	129·84
130	270·70	—	—	—
140	270·70	—	—	—
150	238·10	—	—	—
160	221·68	—	—	—
170	196·02	8·91	·0454545	—
180	169·29	—	—	—
190	160·38	—	—	—
200	151·47	—	—	—
210	151·47	—	—	—
220	151·47	—	—	—
230	142·56	—	—	—
240	142·56	—	—	—
250	133·65	—	—	—
260	133·65	—	—	—
270	124·11	—	—	—
280	114·56	—	—	—

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Table VI (*cont.*)

SPECIFIC DEATHS.

Cage age in days	*A* mice				*B* mice			
	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x
0	10000·00	—	—	36·60	10000·00	—	—	35·43
1	10000·00	—	—	35·60	10000·00	—	—	34·43
2	10000·00	—	—	34·60	10000·00	32·26	·0032258	33·43
3	10000·00	—	—	33·60	9967·74	—	—	32·54
4	10000·00	—	—	32·60	9967·74	—	—	31·54
5	10000·00	—	—	31·60	9967·74	—	—	30·54
6	10000·00	—	—	30·60	9967·74	97·40	·0097720	29·54
7	10000·00	32·68	·0032680	29·60	9870·34	32·47	·0032895	28·82
8	9967·32	32·68	·0032787	28·70	9837·87	64·94	·0066007	27·92
9	9934·64	32·68	·0032895	27·79	9772·93	32·47	·0033223	27·10
10	9901·96	65·79	·0066445	26·88	9740·46	97·73	·0100334	26·19
11	9836·17	66·01	·0067114	26·06	9642·73	195·46	·0202703	25·45
12	9770·15	99·02	·0101351	25·23	9447·27	32·69	·0034602	24·96
13	9671·13	198·04	·0204778	24·48	9414·58	163·45	·0173611	24·05
14	9473·09	33·12	·0034965	23·98	9251·14	228·83	·0247350	23·46
15	9439·96	231·86	·0245614	23·07	9022·31	130·76	·0144928	23·05
16	9208·11	132·97	·0144404	22·63	8891·55	296·38	·0333333	22·38
17	9075·14	134·45	·0148148	21·96	8595·17	134·83	·0156863	22·13
18	8940·69	470·56	·0526316	21·28	8460·34	337·07	·0398406	21·48
19	8470·13	168·06	·0198413	21·43	8123·27	372·32	·0458333	21·35
20	8302·07	269·99	·0325203	20·86	7750·96	341·45	·0440529	21·35
21	8032·08	340·34	·0423729	20·54	7409·51	375·60	·0506913	21·31
22	7691·74	512·78	·0666667	20·43	7033·91	452·68	·0643564	21·42
23	7178·96	583·93	·0813397	20·85	6581·23	313·39	·0476190	21·86
24	6595·02	448·88	·0680628	21·66	6267·84	324·20	·0517241	21·93
25	6146·15	483·41	·0786517	22·20	5943·64	396·24	·0666667	22·10
26	5662·74	419·46	·0740741	23·05	5547·40	576·35	·1038961	22·64
27	5243·28	492·66	·0939597	23·86	4971·05	184·11	·0370370	24·21
28	4750·62	387·09	·0814815	25·28	4786·93	408·19	·0852713	24·12
29	4363·54	422·28	·0967742	26·48	4378·74	336·83	·0769231	25·32
30	3941·26	387·09	·0982143	28·26	4041·92	604·40	·1495327	26·39
35	2216·96	178·79	·0806452	43·39	2418·64	—	—	37·80
40	1447·83	74·25	·0512821	60·13	1758·38	209·33	·1190476	46·00
45	1186·80	38·28	·0322581	67·93	1214·12	83·73	·0689655	60·75
50	993·91	79·51	·0800000	75·66	745·46	—	—	86·24
55	755·37	—	—	93·97	707·07	—	—	91·52
60	675·56	—	—	99·79	618·69	—	—	99·38
70	636·10	—	—	95·56	574·50	—	—	96·68
80	477·08	—	—	115·00	486·11	—	—	103·44
90	397·56	—	—	126·80	486·11	—	—	93·44
100	397·56	—	—	116·80	397·73	—	—	102·88
110	318·05	—	—	135·00	348·01	—	—	106·64
120	318·05	—	—	125·00	348·01	—	—	96·64
130	318·05	—	—	—	348·01	—	—	—
140	318·05	—	—	—	298·30	—	—	—
150	318·05	—	—	—	298·30	—	—	—
160	278·29	—	—	—	298·30	49·72	·0166667	—
170	238·54	—	—	—	198·86	—	—	—
180	238·54	—	—	—	198·86	—	—	—
190	238·54	—	—	—	198·86	—	—	—
200	198·78	39·76	·2000000	—	149·15	—	—	—
210	119·27	—	—	—	149·15	—	—	—
220	119·27	—	—	—	149·15	—	—	—
230	119·27	—	—	—				
.	.	.	.	.				
300	119·27	—	—	—				

Table VI A.

SPECIFIC DEATHS.

Comparable with *J* mice.

Cage age in days	*H* mice				*C* mice				Added daily			
	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x
0	10000·00	—	—	28·41	10000·00	—	—	34·29	10000·00	—	—	38·29
1	10000·00	—	—	27·41	10000·00	—	—	33·29	10000·00	—	—	37·29
2	10000·00	—	—	26·41	10000·00	—	—	32·29	10000·00	—	—	36·29
3	10000·00	—	—	25·41	10000·00	—	—	31·29	10000·00	—	—	35·29
4	10000·00	—	—	24·41	10000·00	—	—	30·29	10000·00	—	—	34·29
5	10000·00	—	—	23·41	10000·00	—	—	29·29	10000·00	47·62	·0047619	33·29
6	10000·00	—	—	22·41	10000·00	—	—	28·29	9952·38	—	—	32·45
7	10000·00	—	—	21·41	10000·00	—	—	27·29	9952·38	—	—	31·45
8	10000·00	50·00	·0050000	20·41	10000·00	50·25	·0050251	26·29	9952·38	47·62	·0047847	30·45
9	9950·00	50·00	·0050251	19·51	9949·75	—	—	25·42	9904·76	95·24	·0096154	29·60
10	9900·00	50·00	·0050505	18·61	9949·75	50·51	·0050761	24·42	9809·52	95·70	·0097561	28·88
11	9850·00	300·00	·0304609	17·70	9899·24	—	—	23·54	9713·82	95·70	·0098522	28·16
12	9550·00	400·00	·0418848	17·24	9899·24	—	—	22·54	9618·12	47·85	·0049751	27·43
13	9150·00	200·00	·0218579	16·97	9899·24	51·29	·0051813	21·54	9570·27	191·41	·0200000	26·57
14	8950·00	150·00	·0167598	16·34	9847·95	102·58	·0104167	20·65	9378·86	191·41	·0204082	26·10
15	8800·00	350·00	·0397727	15·61	9745·37	153·87	·0157895	19·86	9187·46	287·11	·0312500	25·63
16	8450·00	200·00	·0236686	15·24	9591·49	51·29	·0053476	19·17	8900·35	95·70	·0107527	25·44
17	8250·00	150·00	·0181818	14·60	9540·20	102·58	·0107527	18·27	8804·65	287·11	·0326087	24·71
18	8100·00	253·13	·0312500	13·86	9437·62	102·58	·0108696	17·46	8517·54	239·26	·0280899	24·53
19	7846·88	658·13	·0838710	13·29	9335·04	259·31	·0277778	16·65	8278·28	433·17	·0523256	24·23
20	7188·75	662·79	·0921986	13·46	9075·73	419·69	·0462428	16·11	7845·11	240·65	·0306748	24·54
21	6525·96	308·31	·0472441	13·77	8656·04	419·69	·0484848	15·87	7604·47	529·43	·0696203	24·30
22	6217·64	313·49	·0504202	13·43	8236·36	160·45	·0194805	15·65	7075·04	481·30	·0680272	25·08
23	5904·15	474·44	·0803571	13·12	8075·91	267·41	·0331126	14·95	6593·75	288·78	·0437956	25·87
24	5429·71	159·70	·0294118	13·22	7808·49	374·38	·0479452	14·45	6304·97	673·81	·1068702	26·03
25	5270·01	532·32	·1010101	12·61	7434·11	374·38	·0503597	14·15	5631·16	577·55	·1025641	28·09
26	4737·69	807·56	·1704545	12·97	7059·73	646·69	·0916031	13·87	5053·60	770·07	·1523810	30·24
27	3930·13	664·25	·1690141	14·53	6413·04	986·62	·1538462	14·22	4283·53	389·41	·0909091	34·59
28	3265·88	332·12	·1016949	16·38	5426·42	493·31	·0909091	15·72	3894·12	591·51	·1518987	37·00
29	2933·76	166·06	·0566038	17·18	4933·11	274·06	·0555556	16·24	3302·61	406·47	·1230769	42·53
30	2767·70	332·12	·1200000	17·18	4659·05	328·87	·0705882	16·17	2896·13	206·87	·0714286	47·43
35	1549·91	276·77	·1785714	23·65	2726·09	174·01	·0638298	20·59	1739·19	112·21	·0645161	72·36
40	983·79	115·74	·1176471	31·38	1450·05	116·00	·0800000	31·46	1458·67	112·21	·0769231	80·99
45	636·57	57·87	·0909091	42·76	812·03	58·00	·0714286	49·71	1178·16	—	—	94·77
50	405·09	—	—	61·06	638·02	58·00	·0909091	57·59	953·75	—	—	111·31
55	270·06	—	—	84·83	522·02	—	—	64·94	897·65	—	—	113·05
60	270·06	—	—	79·83	464·01	—	—	67·87	841·54	—	—	115·42
70	270·06	—	—	69·83	406·01	58·00	·1428571	67·21	841·54	—	—	105·42
80	270·06	—	—	59·83	290·01	—	—	82·50	841·54	—	—	95·42
90	180·04	—	—	77·00	290·01	—	—	72·50	729·34	56·10	·0769231	99·56
100	180·04	—	—	67·00	290·01	—	—	62·50	617·13	—	—	107·29
110	180·04	—	—	57·00	290·01	—	—	52·50	561·03	—	—	107·37
120	180·04	—	—	47·00	232·01	—	—	54·50	561·03	—	—	97·37
130	180·04	90·02	·5000000	—	232·01	—	—	—	498·69	—	—	—
140	—	—	—	—	154·67	—	—	—	498·69	—	—	—
150	—	—	—	—					427·45	—	—	—
160	—	—	—	—					427·45	—	—	—
170	—	—	—	—					356·21	89·05	·2500000	—
180	—	—	—	—					267·16	—	—	—
190	—	—	—	—					267·16	—	—	—
200	—	—	—	—					267·16	—	—	—
210	—	—	—	—					267·16	—	—	—
220	—	—	—	—					267·16	—	—	—
230	—	—	—	—					267·16	—	—	—
240	—	—	—	—					267·16	—	—	—
250	—	—	—	—					267·16	—	—	—
260	—	—	—	—					267·16	—	—	—
270	—	—	—	—					267·16	—	—	—
280	—	—	—	—					267·16	—	—	—

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Table VI B.

SPECIFIC DEATHS ONLY.

To compare with *K*.

age in days	*H* mice				*C* mice				Added daily			
	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x
0	10000·00	23·81	·0023810	27·05	10000·00	—	—	35·01	10000·00	22·68	·0022676	30·61
1	9976·19	—	—	26·12	10000·00	—	—	34·01	9977·32	—	—	29·68
2	9976·19	—	—	25·12	10000·00	—	—	33·01	9977·32	—	—	28·68
3	9976·19	—	—	24·12	10000·00	23·87	·0023866	32·01	9977·32	—	—	27·68
4	9976·19	23·81	·0023866	23·12	9976·13	—	—	31·09	9977·32	—	—	26·68
5	9952·38	—	—	22·17	9976·13	—	—	30·09	9977·32	22·78	·0022831	25·68
6	9952·38	47·62	·0047847	21·17	9976·13	—	—	29·09	9954·54	22·78	·0022883	24·74
7	9904·76	47·73	·0048193	20·27	9976·13	23·87	·0023923	28·09	9931·77	—	—	23·79
8	9857·03	119·62	·0121359	19·36	9952·27	—	—	27·15	9931·77	113·90	·0114679	22·79
9	9737·40	95·70	·0098280	18·60	9952·27	23·98	·0024096	26·15	9817·87	22·78	·0023202	22·05
10	9641·70	95·70	·0099256	17·78	9928·29	121·08	·0121951	25·22	9795·09	205·01	·0209302	21·10
11	9546·00	143·55	·0150376	16·95	9807·21	121·08	·0123457	24·52	9590·08	45·78	·0047733	20·54
12	9402·46	167·90	·0178571	16·20	9686·14	72·65	·0075000	23·82	9544·30	229·43	·0240385	19·64
13	9234·56	96·44	·0104439	15·49	9613·49	121·38	·0126263	23·00	9314·87	183·54	·0197044	19·11
14	9138·11	73·10	·0080000	14·64	9492·10	48·93	·0051546	22·29	9131·33	277·41	·0303798	18·48
15	9065·01	219·91	·0242588	13·76	9443·18	147·17	·0155844	21·40	8853·92	162·24	·0183246	18·05
16	8845·10	220·51	·0249307	13·09	9296·01	197·79	·0212766	20·73	8691·67	234·91	·0270270	17·38
17	8624·58	196·57	·0227920	12·41	9098·22	297·49	·0326976	20·17	8456·76	187·93	·0222222	16·84
18	8428·01	420·17	·0498534	11·69	8800·73	272·70	·0309859	19·83	8268·84	305·38	·0369318	16·22
19	8007·85	571·99	·0714286	11·27	8528·03	349·10	·0409357	19·45	7963·45	237·01	·0297619	15·82
20	7435·86	300·44	·0404040	11·10	8178·93	250·12	·0305810	19·26	7726·45	380·38	·0492308	15·29
21	7135·42	325·48	·0456140	10·55	7928·81	378·77	·0477707	18·85	7346·07	286·21	·0389610	15·05
22	6809·95	556·95	·0817844	10·03	7550·05	380·04	·0503356	18·77	7059·86	453·17	·0641892	14·64
23	6253·00	533·79	·0853659	9·88	7170·01	329·36	·0459364	18·74	6606·69	596·27	·0902527	14·61
24	5719·21	357·45	·0625000	9·75	6840·65	205·73	·0300752	18·62	6010·42	552·96	·0920000	15·01
25	5361·75	587·24	·1095238	9·37	6634·91	673·86	·1015625	18·18	5457·46	533·62	·0977778	15·48
26	4774·52	485·11	·1016043	9·46	5961·06	470·61	·0789474	19·18	4923·84	511·88	·1039604	16·11
27	4289·40	526·31	·1226994	9·48	5490·45	653·62	·1190476	19·78	4411·96	560·64	·1270718	16·92
28	3763·10	526·31	·1398601	9·73	4836·82	420·59	·0869565	21·39	3851·32	275·09	·0714286	18·31
29	3236·79	294·25	·0909091	10·23	4416·23	238·00	·0538922	22·38	3576·23	411·65	·1151079	18·68
30	2942·54	214·00	·0727273	10·21	4178·23	425·81	·1019108	22·62	3164·57	340·00	·1074380	20·04
35	1434·96	253·23	·1764706	13·14	2493·90	224·17	·0898876	31·29	1734·39	139·87	·0806452	29·78
40	866·31	28·88	·0333333	15·47	1725·20	151·33	·0877193	39·21	1105·52	58·19	·0526316	40·44
45	548·66	115·51	·2105263	18·08	1104·65	31·56	·0285714	55·04	718·17	29·92	·0416667	55·99
50	259·89	—	—	30·94	820·60	—	—	68·23	566·98	31·50	·0555556	65·35
55	231·02	—	—	29·37	725·91	—	—	71·76	440·98	—	—	78·45
60	202·14	—	—	28·07	692·92	—	—	70·50	440·98	31·50	·0714286	73·45
70	115·51	—	—	34·25	560·93	—	—	75·48	377·98	—	—	75·36
80	—	—	—	—	490·82	—	—	75·48	377·98	—	—	65·36
90	—	—	—	—	455·76	—	—	70·86	377·98	—	—	55·36
00	—	—	—	—	385·64	—	—	72·47	314·99	—	—	55·43
10	—	—	—	—	315·52	—	—	77·57	251·99	—	—	58·55
20	—	—	—	—	315·52	35·06	·1111111	67·57	220·49	—	—	56·55
30	—	—	—	—	280·47	—	—	—	188·99	—	—	—
40	—	—	—	—	245·41	—	—	—	188·99	—	—	—
50	—	—	—	—	245·41	—	—	—	157·49	—	—	—
60	—	—	—	—	245·41	—	—	—	126·00	—	—	—
70	—	—	—	—	163·61	—	—	—				
80	—	—	—	—	122·71	—	—	—				
90	—	—	—	—	122·71	—	—	—				

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Table VI c.

SPECIFIC DEATHS.

Comparable with *A* to *G* mice.

Cage age in days	*H* mice				*C* mice				Added daily			
	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x	l_x	d_x	q_x	e_x
0	10000·00	—	—	29·06	10000·00	32·79	·0032787	46·29	10000·00	15·36	·0015361	30·08
1	10000·00	—	—	28·06	9967·21	—	—	45·45	9984·64	15·38	·0015408	29·13
2	10000·00	64·73	·0064725	27·06	9967·21	—	—	44·45	9969·25	30·86	·0030960	28·17
3	9935·28	—	—	26·23	9967·21	—	—	43·45	9938·39	30·86	·0031056	27·26
4	9935·28	65·36	·0065789	25·23	9967·21	—	—	42·45	9907·53	30·91	·0031201	26·34
5	9869·91	32·79	·0033223	24·39	9967·21	—	—	41·45	9876·61	—	—	25·42
6	9837·12	—	—	23·47	9967·21	—	—	40·45	9876·61	30·96	·0031348	24·42
7	9837·12	65·58	·0066667	22·47	9967·21	33·22	·0033333	39·45	9845·65	77·65	·0078864	23·50
8	9771·54	131·16	·0134228	21·62	9933·99	33·22	·0033445	38·58	9768·00	139·99	·0143312	22·68
9	9640·38	98·37	·0102041	20·91	9900·77	66·67	·0067340	37·70	9628·02	62·22	·0064620	22·00
10	9542·01	65·81	·0068966	20·12	9834·09	—	—	36·96	9565·80	62·32	·0065147	21·14
11	9476·20	32·90	·0034722	19·25	9834·09	66·90	·0068027	35·96	9503·48	140·22	·0147541	20·28
12	9443·30	230·32	·0243902	18·32	9767·19	67·13	·0068729	35·20	9363·27	155·79	·0166389	19·58
13	9212·97	230·32	·0250000	17·77	9700·07	100·69	·0103806	34·44	9207·47	93·79	·0101868	18·90
14	8982·65	132·10	·0147059	17·21	9599·37	33·80	·0035211	33·79	9113·68	297·53	·0326460	18·09
15	8850·55	364·63	·0411985	16·46	9565·57	101·76	·0106383	32·91	8816·15	283·38	·0321429	17·68
16	8485·92	300·68	·0354331	16·14	9463·81	68·33	·0072202	32·26	8532·78	299·67	·0351202	17·25
17	8185·24	101·47	·0123967	15·72	9395·48	172·08	·0183150	31·49	8233·10	348·99	·0423892	16·86
18	8083·77	341·09	·0421941	14·91	9223·40	34·42	·0037313	31·07	7884·11	270·77	·0343434	16·59
19	7742·68	380·22	·0491071	14·54	9188·99	240·91	·0262172	30·18	7613·34	321·24	·0421941	16·16
20	7362·46	593·18	·0805687	14·27	8948·08	174·09	·0194553	29·98	7292·10	472·03	·0647321	15·85
21	6769·28	209·36	·0309278	14·48	8773·99	348·17	·0396825	29·57	6820·07	539·72	·0791367	15·91
22	6559·92	383·82	·0585106	13·92	8425·82	209·77	·0248963	29·77	6280·35	459·14	·0731070	16·23
23	6176·09	628·08	·1016949	13·76	8216·04	141·05	·0171674	29·52	5821·22	460·44	·0790961	16·48
24	5548·02	421·37	·0759494	14·26	8075·00	250·11	·0309735	29·02	5360·78	584·51	·1090343	16·85
25	5126·65	421·37	·0821918	14·39	7824·89	358·94	·0458716	28·94	4776·27	405·06	·0848057	17·85
26	4705·28	748·57	·1590909	14·63	7465·95	582·71	·0780488	29·30	4391·22	358·58	·0820313	18·46
27	3956·71	285·17	·0720721	16·30	6883·24	404·90	·0588235	30·74	4012·64	363·21	·0905172	19·06
28	3671·54	431·95	·1176471	16·53	6478·34	640·30	·0988372	31·63	3649·43	331·77	·0909091	19·91
29	3239·60	509·60	·1573034	17·67	5838·04	384·08	·0657895	34·05	3317·66	319·35	·0962567	20·85
30	2730·00	195·00	·0714286	19·87	5453·96	309·44	·0567376	35·41	2998·31	347·37	·1158537	22·01
35	1475·79	119·66	·0810811	29·39	4177·50	232·08	·0555556	40·38	1883·75	190·28	·1010101	28·73
40	957·27	79·77	·0833333	39·08	3268·30	204·27	·0625000	45·98	1215·63	196·07	·1612903	38·39
45	638·18	39·89	·0625000	52·62	2277·32	—	—	59·92	783·32	120·51	·1538462	53·60
50	478·64	79·77	·1666667	64·67	1982·12	172·36	·0869565	63·45	522·22	—	—	74·38
55	279·20	79·77	·2857143	103·93	1551·22	—	—	75·61	461·96	20·09	·0434783	78·58
60	159·55	—	—	175·75	1421·95	—	—	77·25	378·75	—	—	90·29
70	159·55	—	—	165·75	1151·47	44·48	·0384615	83·76	241·71	—	—	128·28
80	159·55	—	—	155·75	972·99	—	—	88·65	241·71	—	—	118·28
90	119·66	—	—	195·50	972·99	48·65	·0500000	78·65	214·85	—	—	122·00
100	119·66	—	—	185·50	875·69	97·30	·1111111	76·83	214·85	—	—	112·00
110	119·66	—	—	175·50	729·74	—	—	82·03	188·00	—	—	116·93
120	119·66	—	—	165·50	632·44	48·65	·0769231	83·35	188·00	—	—	106·93
130	119·66	—	—	—	486·49	—	—	—	161·14	—	—	—
140	119·66	—	—	—	437·84	—	—	—	161·14	—	—	—
150	119·66	—	—	—	389·20	—	—	—	134·28	—	—	—
160	119·66	—	—	—	291·90	—	—	—	134·28	—	—	—
170	119·66	—	—	—	291·90	—	—	—	134·28	—	—	—
180	119·66	—	—	—	233·52	—	—	—	107·43	—	—	—
190	119·66	—	—	—	233·52	—	—	—	107·43	—	—	—
200	119·66	—	—	—	233·52	—	—	—				
210	119·66	—	—	—	233·52	—	—	—				
220	119·66	—	—	—	233·52	—	—	—				
230	119·66	—	—	—	116·76	—	—	—				
240	119·66	—	—	—	116·76	—	—	—				
250	119·66	—	—	—	116·76	—	—	—				
260	119·66	—	—	—	116·76	—	—	—				
270	119·66	—	—	—	116·76	—	—	—				
280	119·66	—	—	—	116·76	—	—	—				
290	—	—	—	—	116·76	—	—	—				
300	—	—	—	—	116·76	—	—	—				
.	.	.	.	.	.	.	.	.				
380	—	—	—	—	116·76	—	—	—				

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Table VI D.

SPECIFIC DEATHS.

Expectations of life limited to 60 days.

Cage age in days	To compare with J			To compare with K			To compare with A to G		
	H	C	Added daily	H	C	Added daily	H	C	Added daily
0	26·25	31·14	28·58	26·48	30·16	27·37	26·26	35·31	26·66
1	25·28	30·19	27·66	25·57	29·23	26·47	25·27	34·57	25·74
2	24·31	29·23	26·75	24·59	28·29	25·52	24·29	33·71	24·81
3	23·34	28·28	25·83	23·61	27·36	24·56	23·46	32·85	23·93
4	22·36	27·32	24·91	22·63	26·49	23·60	22·47	31·99	23·04
5	21·39	26·36	24·00	21·70	25·55	22·64	21·63	31·13	22·14
6	20·42	25·40	23·20	20·72	24·61	21·73	20·72	30·26	21·17
7	19·44	24·44	22·28	19·83	23·67	20·81	19·73	29·38	20·27
8	18·47	23·48	21·37	18·93	22·78	19·85	18·88	28·60	19·46
9	17·59	22·64	20·56	18·18	21·84	19·11	18·15	27·80	18·75
10	16·71	21·68	19·84	17·37	20·96	18·19	17·35	27·11	17·90
11	15·81	20·82	19·11	16·55	20·26	17·61	16·48	26·23	17·04
12	15·32	29·86	18·38	15·80	19·56	16·73	15·55	25·51	16·32
13	15·00	18·89	17·56	15·10	18·77	16·17	14·95	24·80	15·61
14	14·35	18·02	17·00	14·26	18·06	15·53	14·34	24·16	14·79
15	13·62	17·24	16·43	13·39	17·20	15·05	13·56	23·36	14·30
16	13·20	16·55	16·04	12·72	16·52	14·36	13·14	22·72	13·79
17	12·54	15·67	15·30	12·04	15·93	13·78	12·63	21·99	13·30
18	11·80	14·86	14·90	11·32	15·50	13·14	11·80	21·50	12·90
19	11·20	14·06	14·43	10·89	15·05	12·67	11·31	20·68	12·37
20	11·21	13·47	14·30	10·70	14·73	12·09	10·89	20·34	11·93
21	11·34	13·14	13·85	10·15	14·24	11·74	10·83	19·85	11·75
22	10·92	12·82	13·97	9·62	13·99	11·25	10·18	19·76	11·75
23	10·52	12·10	14·07	9·45	13·78	11·04	9·81	19·38	11·69
24	10·44	11·53	13·82	9·29	13·49	11·15	9·90	18·82	11·70
25	9·80	11·13	14·55	8·89	12·97	11·30	9·70	18·54	12·12
26	9·89	10·73	15·29	8·93	13·46	11·55	9·55	18·53	12·25
27	10·87	10·81	17·13	8·90	13·65	11·92	10·30	19·20	12·36
28	12·02	11·74	17·98	9·09	14·52	12·68	10·09	19·52	12·61
29	12·39	11·92	20·32	9·50	14·96	12·72	10·41	20·78	12·88
30	12·17	11·66	22·36	9·42	14·89	13·43	11·30	21·38	13·27
35	15·29	13·41	32·52	11·62	19·25	18·80	13·94	23·17	15·39
40	19·12	18·96	35·60	13·12	23·01	24·65	15·89	25·39	18·59
45	25·22	29·17	41·19	14·63	31·41	33·69	18·78	32·03	24·25
50	35·73	33·73	48·15	24·22	38·40	39·33	20·80	33·25	32·29
55	50·16	38·50	49·07	22·43	40·22	47·67	30·86	39·37	33·03
60	48·50	40·62	50·51	20·86	39·28	45·17	51·62	40·18	37·21

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