

SPECIAL ARTICLES

THE SIZE OF STREPTOCOCCUS BACTERIOPHAGES AS DETERMINED BY X-RAY INACTIVATION

INFORMATION about the particle size of bacteriophages has been obtained chiefly by ultrafiltration and centrifugation methods. Data of various authors, as collected by Elford,¹ seem to indicate that the particles of each phage are homogeneous in size; and that particle size is a characteristic property of each phage. Coli-dysentery phages have particles ranging from 8–20 μ (phage "S13") to 50–75 μ diameter (phage "C16"). Staphylococcus phage "K" has a diameter of about 50–70 μ . The largest phage at present known has particles of 80–120 μ (Subtilis phage).

While the particle size values as given above are usually accepted, it must be mentioned that diffusion studies² have suggested that phage particles may be much smaller and inhomogeneous in size.

A new method has recently been developed,³ which, on the basis of radiation experiments, seems to give useful information about the particle size of bacteriophages.

When suspended in a suitable medium the sensitivity to x-rays of a phage strain, measured by the percentage of active phage which remains after a certain amount of radiation has been given, is a highly reproducible property of that strain, and appears to be a function only of the size of its particles. The irradiation experiments interpreted in terms of the "hit theory" indicate that a phage particle is inactivated by a single ionization (or excitation) process. In order to be effective this process must take place within a "sensitive volume," the size of which can be calculated from the rate of inactivation. This volume is found for each strain of phage to be of the same order of magnitude as the volume of the phage particle itself, as determined by ultrafiltration and centrifugation.

We have now used this method to obtain information about the particle sizes of three streptococcus bacteriophages, which had not previously been measured. These phages have been described by A. C. Evans.⁴ They are distinguished by their serological specificity, by bacterial host specificity and by the type of plaque they produce on solid medium.

Samples of the bacteriophages suspended in peptone

¹ W. J. Elford, in Doerr and Hallauer, *Handbuch d. Virusforschung*, p. 126, Julius Springer, Wien, 1938.

² J. Bronfenbrenner, *Jour. Exp. Med.*, 45: 873, 1927; D. M. Hetler and J. Bronfenbrenner, *Jour. Gen. Physiol.*, 14: 547, 1931; J. H. Northrop, *Jour. Gen. Physiol.*, 21: 335, 1938.

³ E. Wollman, F. Holweck and S. Luria, *Nature*, 145: 935, 1940; D. E. Lea, *Nature*, 146: 137, 1940.

⁴ A. C. Evans, U. S. Public Health Reports 49: 1386, 1934.

broth in small celluloid tubes were exposed to x-rays (475 kv equivalent constant potential, 13 ma, .25 mm Cu plus .45 mm Al filter, 960 roentgens/min. measured in air at 37 cm focal distance, absorption and scattering corrections negligible). Afterward the phage content of each sample was determined by plaque count. The results are shown in Fig. 1.

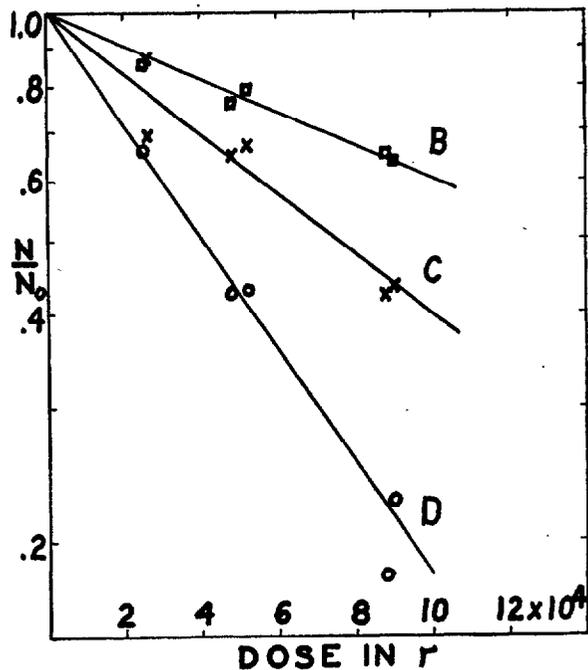


FIG. 1. Inactivation curves for three streptococcus bacteriophages. Abscissas: dose of x-rays in roentgens. Ordinates: proportion of bacteriophage particles remaining active after irradiation.

It is evident that in each case the experimental points can be fitted by an exponential curve (straight line on semi-logarithmic plot) within the limits of the experimental errors, which in plaque counts with streptococcus phages are likely to be rather large. Having established the exponential relation with great precision for other phages,⁵ we shall assume it to apply here.

Table I gives the diameters of the "sensitive volumes," calculated from the curves in Fig. 1 by Lea's method.³ Assuming that the relationship which exists for other phages between size of sensitive volume and particle size is also valid for the streptococcus phages we can tentatively consider the values of Table I as estimates of particle size. It should be mentioned that the recognized uncertainties in the absolute measurement of x-ray dosage at 500 kv are not large enough

⁵ S. E. Luria and F. M. Exner, *Proc. Nat. Acad. Sci.*, 27: 370, 1941.

TABLE I

| Bacteriophage | Streptococcus strain | Inactivation dose in r* | Sensitive volume diameter μ |
|---------------|----------------------|-------------------------|---------------------------------|
| B | 563 | 200,000 | 26 |
| C | 594 | 110,000 | 33 |
| D | 693 | 60,000 | 43 |

* Dose giving inactivation ratio $\frac{N}{N_0} = 1/e$.

to influence the present results, since particle diameters depend (through volumes) on cube roots of inactivation rates.

A comparison with previously measured phages⁵ shows that phage D is a medium size phage; phage C falls among small phages (like C13 Burnet); and phage B is still smaller.

The classification of these three phages as separate entities, based up to now on their different biological properties,⁴ finds further justification in their different particle sizes.

A general relationship of inverse proportionality has been shown to exist between the size of phage particles and the size of the plaques they produce on agar (Elford, Burnet). Such comparisons are definite only for plaques produced in presence of the same host strain of bacteria, which was not the case in our experiments. Nevertheless, it is probably not meaningless that the smallest phage B is a "large plaque forming" strain, whereas the larger phage D produces very small plaques.

We hope soon to check the particle size values as given here by other methods (ultra-centrifugation, electron microscope).

We are indebted to Dr. A. C. Evans for supplying the strains of bacteriophages and of host bacteria. Only three out of four strains were studied, owing to difficulty in obtaining reproducible counts of the plaques formed by phage A.

FRANK M. EXNER
S. E. LURIA

DEPARTMENT OF CANCER RESEARCH AND
THE BACTERIOLOGICAL LABORATORIES OF
THE DEPARTMENT OF SURGERY,
COLLEGE OF PHYSICIANS AND SURGEONS,
COLUMBIA UNIVERSITY