Measles Endemicity in Insular Populations: Critical Community Size and Its Evolutionary Implication

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Monthly measles case reports from 19 island communities covering periods up to 15 years have been analyzed. Breaks in the continuity of measles transmission were found for all communities of less than 500,000 population. The duration of epidemics was also affected by population density. It is postulated that populations sufficient to support continued propagation of this virus did not exist in primitive societies and that measles virus must have evolved since the development of early civilizations.

Measles virus possesses no reservoir other than the human host and, since permanent immunity follows infection, persistence of the virus is dependent on a continuous supply of susceptible persons. At least 30 new susceptible persons would be needed every year to maintain the disease, if the cases were evenly spaced, but in effect many more cases are actually required to sustain endemicity.

Bartlett (1957, 1960) has considered this problem mathematically and estimated that, in urban areas, about 2500 cases per year is the minimum needed to prevent breaks in continuity of disease transmission. This estimate was checked against data on reported cases from British and American cities, and fade out was found where there were fewer than 4000 to 5000 cases per annum. On this basis Bartlett suggested that fade out would occur in any city with less than 250,000 to 300,000 inhabitants. Two factors that Bartlett recognized, but did not correct for, were: masking of fade out by reintroduction of measles from outside the city and the damping effect of geographic dispersion. The present study of measles in insular communities was made to confirm and refine Bartlett's estimates by considering communities where reintroduction is minimal and where the effect of population dispersion could be observed.

Data on measles incidence in 19 island communities have been compared (Table 1). The period covered was 1949–1964 inclusive, but there were

TABLE 1

Measles endemicity for 19 island communities

Island	Population (thousands)	Annual population input†	% cases reported‡	% of months with measles
Hawaii	550·0	16700	24	100
Fiji	346·0	13400	8	64
Iceland	160·0	4490	45	61
Samoa	118·0	4440	9	28
Solomon	110·0	4060	6	32
Fr. Polynesia	75·0	2690	27	8
New Caledonia	68·0	2600	9	32
Guam	63·0	2200	11	80
Tonga	57·0	2040	28	12
New Hebrides	52·0	1910	9	30
Gilbert & Ellice	40·0	1260	56	15
Greenland	28·0	1190	111	24
Bermuda	41·0	1130	10	51
Faroe	34·0	744	24	32
Cook	16·0	678	51	6
Niue	4·7	225	21	5
Nauru	3·5	167	30	5
St. Helena	5·0	116	54	4
Falkland	2·5	43	—	0

† 1956 births less infant mortality.
‡ Total number of reported cases divided by total input of susceptible children during the period of study.

breaks in continuity of reporting in most areas and the actual number of months covered varied from 102 to 180. Many of these figures were available from World Health Organization reports (1950–1965, and 1952–1962), but I am also indebted to local health officers for numerous items. Completeness of case reporting varied greatly from one community to another. An estimate of completeness was made by comparing the average number of cases reported with number of children reaching their first birthday. This estimate does not correct for changes in general immune status such as have occurred in Greenland during the period of study. Islands where reporting accounted for less than 6% of the susceptible input have been omitted from the tabulation. All populations considered except the Falkland Islands were exposed to measles on at least four occasions during the period of study.

A crude correlation can be seen in Table 1 between annual input of susceptible persons and endemicity of measles. The islands of Guam and Bermuda form exceptions to the pattern. These two islands have relatively large transient military populations and frequent air connections to mainland points. It seems probable that they are insufficiently isolated to be directly

comparable with the other areas. Fade out was seen in all the islands except Hawaii. Travel to Hawaii is even more frequent than to Guam, and it is possible that fade outs may have occurred in Hawaii but been masked by reintroduction. Unfortunately, case reporting from other islands with populations around the half-million mark is poor. Mauritius has an annual input of 23,000 susceptibles, yet had strong swings in epidemicity of measles, considerable gaps without reported cases, and there was local opinion that the disease was occasionally introduced from outside. However, total case reporting of measles in Mauritius accounted for less than 1 % of the annual input and the significance of the data is correspondingly weakened. Fiji, which had a population of 350,000 and an annual input of 13,400 had many clear breaks in continuity of measles.

The communities listed in Table 1 include several with similar populations which showed measles prevalence variation not attributable to frequency of reintroduction. Much of this variation depended on the duration of individual epidemics and this in turn correlated inversely with population density. Seven communities of comparable population (annual susceptible inputs of 1900 to 4500) have been placed on a graph in Fig. 1 to illustrate this correlation. The plot of the inverse root of the number of susceptibles added per
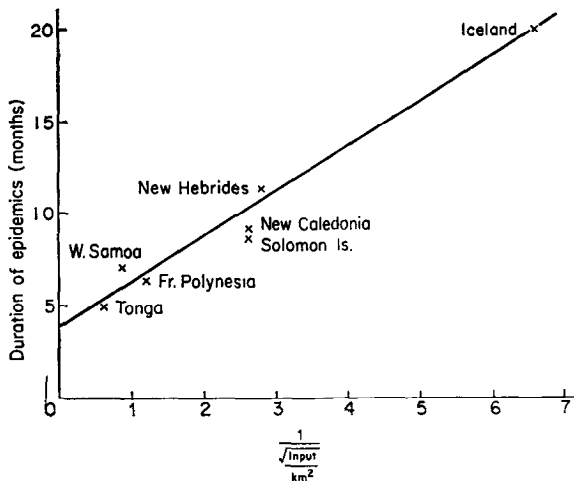

FIG. 1. Relation between average duration of measles epidemics and dispersity of population in areas with about 2000 to 4000 new susceptible children per year. The ordinate plot of the inverse root of the number of new susceptibles introduced annually per km² represents the mean distance between new susceptible persons.

km² of total land area is equivalent to the average distance between infants added to the population each year. Only epidemics involving 100 or more

cases were used in calculating the epidemic extinction time. Smaller outbreaks were often stopped artificially by local quarantine. The graph suggests that with maximal crowding, an epidemic would burn itself out in about four months in a population of this size.

Other factors such as social structure and custom doubtless contribute to the duration of epidemics and endemicity of measles but the critical population would seem to be similar to, or a little higher than, that found by Bartlett in Western cities. Measles may fade out in a community as large as 350,000 and possibly over 500,000 if closely settled. If the community is dispersed, the disease might persist in smaller populations but probably not under 200,000 population or 5000 annual input.

This large critical community size is in distinct contrast to the small community size that appears to suffice for maintenance of varicella. While similarly extensive records on varicella incidence are not available, it seems clear from the studies of Hope-Simpson (1954) in the Shetlands and from observations in Iceland by the author that the critical size for varicella is less than 1000 persons. Hope-Simpson (1965) has attributed this fact to a propensity of the virus to remain latent in man, a phenomenon never observed with measles. He suggests that this capability was essential to survival of varicella in primitive society and, conversely, the same line of thought suggests that measles must be a relatively new organism, arising late on the evolutionary scale.

On an evolutionary scale, human population groups of several hundred thousand are relatively recent developments and did not predate the rise of the great river valley civilizations some 5000 to 6000 years ago. Measles, then, could not have existed before this time in its present form unless it moved continually across social and geographical barriers. It is improbable that it would have been capable of such movement. When measles was first introduced into the Americas it did not sweep the continents but affected one area at a time. Where primitive tribes exist today in north Canada and in Australasia there are still groups untouched by measles in spite of modern communications (Black, 1962; Adels, Francis & Gajdusek, 1962).

The tribal structure of monkey populations apparently protects them from measles for, although they are fully susceptible, they do not become infected in nature except where they live in close association with man (Meyer, Brooks, Douglas & Rogers, 1962; Bhatt et al., 1965). No natural non-primate host for measles is known, although it has been sought for.

It seems necessary to presume, therefore, that measles virus evolved sometime within the past 6000 years. It may be that it derived from either rinderpest or canine distemper. These two viruses are antigenically related to measles (Adams & Imagawa, 1957) and are physically indistinguishable

from measles (Palm & Black, 1961; Cruickshank *et al.*, 1962). They persist now in wild host populations which pre-date human civilization and also in animals that were domesticated shortly before human populations reached critical size.

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