WHY CHRISTEN A SALMONELLA?

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The Enterobacteriaceae Subcommittee of the Nomenclature Committee of the International Association of Microbiological Societies has published the Minutes agreed at its last meeting (1958), in which the concept that the family Enterobacteriaceae should be divided into large groups comparable, but not identical, with genera, and smaller groups down to serotypes, comparable, but not identical, with species and subspecies, needs careful consideration in order to understand the arguments suggested by Kauffmann (1959) in favour of the use of the term "groups" rather than the terms "genus" and "species".

The term "group" is not subject to the rules of nomenclature which govern the use of the terms "genus" and "species"; for this reason many would prefer to use "group", as being less restrictive. It is an ideal term for indicating that members of the group have many similarities. Subsequent research may indicate that they have important differences, and re-grouping will not be affected by the laws of nomenclature. In ordinary life, the situation is similar to the use of the term "boy-friend" and "betrothed" - the former is care-free, the latter is a legal state with defined responsibilities.

Cowan (a, 1959), has pointed out some difficulties in bacterial classification, and the family Enterobacteriaceae is no exception; it was defined in the Report (1958), which stated that the family "is made up of a series of interrelated bacterial types and segregation of these into groups often is difficult because the transition from group to group is gradual, and intermediate forms exist in all instances". During the past few years, new groups have been described and de-
fined. These groups have brought together organisms which were intermediate between groups already described. The grouping has depended on the results of various generally-accepted fermentative and other biochemical tests. At this juncture, the groups may be compared with the genera of a Linnaean Code. The next traditional step in classification within these groups has been the identification of the antigenic complex of each organism. Quite empirically the somatic, the flagellar and some surface antigens have been used to define a particular serotype, but other antigens, such as the mucoid and fimbrial antigens, have not been used for purposes of serotype designation. A number of antigens have been described which, though identical, have been demonstrated in different biochemical groups; for example, the biochemical groups Salmonella, Escherichia and Citrobacter have been defined; within each of these a number of antigens have been described, some of which, although given different symbols, are identical, e.g. Salmonella somatic antigen (O) 35 = Escherichia 0.111. Other Salmonella antigens, such as surface antigen Vi, somatic antigen 6 and flagellar antigen 1,2 may be found in a number of different biochemical groups. Nevertheless, the complete complex of a Salmonella serotype is not found in other biochemical groups; the 9,12:Vi:d of Salmonella typhi is found only in the Salmonella group.

Hybridization between different biochemical groups was first demonstrated by Luria and Burrous (1957) using Shigella, Escherichia and phage. This work has now been extended to include various groups of enterobacteria. Intergroup hybridization does not occur readily, and some characters cannot be transmitted, which suggests that incomplete genetic homology exists between biochemical groups.

Many endeavours have been made to extract the toxic principle of Salmonella and other groups of enterobacteria; the toxic extracts have been tested in a number of ways in a variety of experimental animals, but no differences have been demonstrated in the effect of the toxic substance extracted from S. typhi, S. typhimurium and other members of the family Enterobacteriaceae.

The intergroup relationship is demonstrated by the examples quoted of identity of antigens, results of hybridization, and the toxicity tests.

Within a single biochemical group, such as Salmonella,
it is easy to demonstrate a number of antigens which weave through the group in such a way as to stress the sameness of organisms which may differ in their additional antigens. For example, the 'O' antigen 1 is found in the 0.4, the 0.9, 0.19, and a number of other serological groups, and this antigen may be added to existing complexes by the use of phage (Iseki and Kashiwagi, 1955), and is then found in subsequent generations of the organism. The relation of phage to antigens in Salmonellae of the E serological group has been described earlier by Iseki and Sakai (1953). It is believed that this experimental demonstration of antigen addition, which has also been described in another serological group by Baron et al (1957), indicates that both the giving and receiving organisms are very closely related. Zinder and Lederberg (1952), and Lederberg and Edwards (1953), in their classical papers, demonstrated that phage could effect a change in certain strains of non-motile Salmonellae, such strains becoming motile, the flagellar antigens being the same as those of the motile parent strain when such were available for testing, and both the motility and flagellar antigens were inherited by subsequent generations of the organisms. Similarly, it is possible, by the use of phage, to change at will the flagellar antigens of certain Salmonella strains which are already motile. The phages capable of effecting these changes have been isolated from Salmonellae, will act only on certain Salmonella serological groups and will not act on other biochemical groups, even though they contain Salmonella antigens. These phage-induced changes between Salmonellae occur readily, suggesting genetic homology.

Again, one set of flagellar antigens may be changed to another by the growth of organisms in contact with the appropriate sera. Bruner (1949) changed S. oranienburg, 6, 7:m, t into S. montevideo 6, 7:g, m, s using this technique.

Some strains of Salmonella produced a very mucoid colony, the mucoid material being known as the M antigen of Salmonella. This mucoid colony may be produced by different Salmonella serotypes, such as S. typhimurium, S. paratyphi B, and others, yet this M antigen is the same, irrespective of the Salmonella serotype in which it occurs (Kauffmann, 1954). A mucoid antigen may occur on other Enterobacteriaceae, but the M antigen of Salmonella differs from that of other biochemical groups, such as Escherichia.
from that of other biochemical groups, such as Escherichia.

Fimbriae have been demonstrated in various groups of enterobacteria, such as Escherichia, Shigella and Salmonella, by Duguid and Gillies (1958). Many fimbriate Salmonellae share a major fimbrial antigen, irrespective of the Salmonella serotype, Duguid (personal communication).

In 1956, Kauffmann described the "T1" antigen, a somatic antigen which he had identified in strains of S. paratyphi B, S. typhimurium, and which we have identified in a mutant of a strain of S. senftenberg. These T forms are transient serological forms between smooth (S) and rough (R) forms. The T1 antigen from these three Salmonella serotypes was identical. Kauffmann (1957) also described the T2 antigen in S. bareilly, he regards the T2 antigen as another example of a transient form between S and R.

The biochemical reactions of the Salmonella group are well known, and excluding S. typhi and S. pullorum-gallinarum, are almost identical throughout the 500 serotypes so far described. Of course, minor biochemical variations are encountered between serotypes or between different strains of a single serotype, but these variations are rare in comparison with the typical reactions encountered. The correct position for S. typhi and S. pullorum-gallinarum in the Salmonella or other groups of enterobacteria has led to much controversy at different periods; nevertheless, because of their antigenic and biochemical relationship with other members of the group, I believe it is fair to say that they are now finally accepted as Salmonellae.

DISCUSSION

This account of the various ways in which one Salmonella serotype may be changed to another serotype, the antigens which are identical throughout the whole group, the toxins which are the same irrespective of the particular serotype from which they were derived, and the biochemical reactions, again similar throughout, has been given in order to stress the illogicality of regarding a Salmonella serotype as a species at this time.

The ease with which one serotype may be changed to another by the use of phage or of sera, may be accepted as an example of interfertility which results in a fertile hybrid. In other biological sciences this is regarded as an indica-
tion that the parent types are very similar. In bacteriology, a similar view may be put forward that the serotypes are so similar that they should not be regarded as separate species. Another reason for accepting the Salmonella as a single group is the demonstration of antigens common to all members of very different O groups - the M antigen and the major fimbrial antigens are identical throughout the group, also different strains which are partially degraded have similar antigens - the T1 or T2 antigens already described. The only reason, a reason which is unreasonable, for regarding a serotype as a species is the fact that, by tradition, names have been given to Salmonella serotypes, whereas in other groups of enterobacteria, names are not used, the antigenic structure alone being used. I would agree with Cowan (b, 1959) that if change were essential at the present time, then it would be more logical to regard Salmonella, Shigella, etc. as species.

I would suggest that collections of organisms known as Salmonella, Escherichia, and so on, may at some future period require reconsideration, and possibly the true Linnaean concept applied to them. At present the whole subject is undergoing great changes. We are finding out more and more of the relation of one Salmonella to another, of Shigella to Escherichia, and even of what are regarded as very distantly placed groups within the Enterobacteriaceae. At present the Salmonellae are sub-grouped according to the major antigens in their somatic structure; now we know that a single phage can affect somatic antigens 3, 10., 3, 15., and 3, 19; another phage can affect the flagellar antigens of O groups 4, 12 and 9, 12.

The time may come when the facts discussed here, together with other newer findings, may make a re-grouping and a re-naming of these organisms desirable. Because of rapid advances in knowledge, I firmly believe, with Le Minor (1958), that it would be unwise, at this time, to take such a retrograde step as to use the true Linnaean genus-species naming of Salmonellae. Let us keep them as groups, and avoid the chaotic changes of name that have been imposed upon us within the last few years.
REFERENCES