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Peter Sneath revolutionized the practice of bacterial taxonomy over a 30-year period. He was the first to apply Adansonian principles to bacterial taxonomy, arguing that a robust system required that bacteria should be subjected to many phenotypic (phenetic) tests, all given equal weight, with analysis of the subsequent binary test scores being used to derive groups that could be given taxonomic rank (taxa). The procedures came to be known collectively as 'numerical taxonomy'. A further innovation was the realization that the then embryonic discipline of computing could be harnessed to derive taxa from these very large sets of data. Computer-aided numerical taxonomy became the method of choice for classifying bacteria by the early 1960s. Much of Peter's effort as Director of a Medical Research Council (MRC) Research Unit in Leicester in the 1960s and early 1970s was to reassess the taxonomy of most of the medically important bacteria. This information was then interrogated to determine the minimum number of tests required to identify new isolates reliably. The tests available in commercial identification kits in use today directly reflect these original numerical analyses. Later, after appointment to the Foundation Chair of Medical Microbiology at the University of Leicester, he carried out, together with colleagues, the most important revision of bacterial nomenclature for more than a century, the 1980 'Approved lists of bacterial names'. He was also a member, Vice Chairman and then Chairman of Bergey's Trust, the organization responsible for *Bergey's manual of determinative bacteriology* (later *Bergey's manual of systematic bacteriology*), the definitive account of bacterial taxonomy and properties. He continued to edit volumes and contribute sections right up to his death.

FAMILY BACKGROUND AND EARLY LIFE

Peter Henry Andrews Sneath was born at Richmond College, Galle, Sri Lanka, the second child of Alec Andrews Sneath and Elizabeth Maud (*née* Adcock). His father, a Methodist

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minister, missionary and teacher, was at that time Principal of Richmond College, and his mother taught at the adjoining college for girls.

The Sneaths were of yeoman farmer stock from south Lincolnshire. Peter's grandfather, Henry Andrews Sneath, was a prominent farmer and corn and straw merchant in the village of Thurlby-by-Bourne in Lincolnshire. Peter's father read history at the University of Manchester and then entered the Methodist ministry. In this he followed in the steps of his great-uncle Henry Andrews, who served as a missionary in Trinidad until his death in 1853. He is commemorated in the family name Andrews. Another ancestor, Henry Andrews of Royston (1744–1820), was a schoolmaster and bookseller and was also calculator to both the Astronomer Royal, Nevil Maskelyne, and the *Nautical almanac*.

Peter's mother came from a background of trade and education in Leicestershire. Her father, Thomas Draper Adcock, was the first headmaster of Desford Industrial School. She trained as a teacher at Homerton College. Her brother was Sir Frank Ezra Adcock, Fellow of King's College and Professor of Ancient History in the University of Cambridge. As well as being a distinguished historian, Peter's uncle was also involved with intelligence work in both World War I and World War II. During World War I he was an occupant of the famed Room 40 in the Admiralty, the section most identified with the British naval cryptoanalysis effort. At the end of the war this subsequently merged with the British Army Intelligence Unit and relocated to Bletchley Park.

Peter's parents first met when a young girl from Thurlby-by-Bourne, Lincolnshire (a maid in the Adcock household in Leicester), took Peter's mother to visit the village, where they met Peter's father Alec. They were married some years later in Ghana, where Peter's father served in the Methodist mission at Cape Coast. Peter's sister Barbara died at the age of four years when Peter was a baby. He was very close to his younger brother, Frank, who became a lecturer in psychology at Birkbeck College, London, and who sadly predeceased him in 1978.

Early years and National Service

Peter's early education was at Richmond College, Sri Lanka. It was there, surrounded by the rich diversity of the plants and animals of Sri Lanka, that he began to develop what would become a lifelong interest in natural history. In 1932, when his parents came home on leave, he attended Thurlby village school. On their return to Sri Lanka in 1933 he went to a preparatory school (Ryeford School, Stonehouse, Gloucestershire) until 1936 and then to Wycliffe College until 1941. From 1939 the school was evacuated to St David's College, Lampeter, south Wales. During this time Peter was Head Scholar. Peter spoke warmly of the excellent scientific education he received at Wycliffe, especially the many opportunities to do small experiments and observe the plants and animals of Gloucestershire and south Wales. It is possible that it was during his time at Lampeter that Peter developed his abiding interest in early Welsh literature.

In 1941 he went to King's College, Cambridge, as a Foundation Scholar. Uncertain of what career to follow he was persuaded by his college tutor to read medicine. After three years of preclinical study he graduated with a second-class degree in pathology. He then did his clinical studies at King's College Hospital Medical School in south London and was awarded the prize for pathology in 1947 on graduating from London University, later graduating MB BChir (Cantab.) in 1948. After the usual series of house jobs he stayed on at King's College Hospital until 1950 to train as a pathologist in the Royal Army Medical Corps, awaiting National Service. In that year he was commissioned and posted to Malaysia to do two years' National Service—one year in Singapore and one year in Kuala Lumpur. As a Medical Officer, Peter was responsible for pathology and some medical wards. In this capacity he was telephoned one evening by the Chief Medical Officer and directed to administer penicillin to the sick child of a fellow officer. That child, then aged about eight years, was Joanna Lumley, the actress. Peter used to relate this incident with amusement, adding, 'she did not cry'.

During his clinical studies in London, Peter had developed an interest in human blood groups while learning to do blood grouping for the hospital blood transfusion service. Hoping to continue this interest in his 'spare time' while in Malaysia, he contacted the haematologist Dr Arthur Mourant (FRS 1966) of the Blood Group Reference Laboratory at the Lister Institute in Chelsea Bridge Road, London. Dr Mourant, also renowned as a biological anthropologist (Misson *et al.* 1999), suggested some work on the indigenous people, particularly the negritos, whose possible African origin was then much discussed, and provided Peter with a generous supply of antiserum and an introduction to Professor Ivan Polunin of the Anthropology Department, University of Singapore. In addition to his work on the negritos Peter did some work on the blood groups of the Sea Dyaks of Sarawak, which he visited when on leave. These later studies, published with Polunin in 1953 (1)*, showed striking differences in ABO frequencies in different villages and aroused suspicion that the data reflected genetic drift, a view to which Peter did not wholly subscribe. In Peter's opinion, the more interesting finding from his blood-group work in Malaysia was the high level of the Rhesus factor Rho(D) in Malaysian negritos. After discussing the results with Arthur Mourant, they suspected from the reactions with different anti-D sera that it may have been a variant Rho(D). It seems that this work was never published.

Peter's visit to Arthur Mourant at the Lister Institute in 1950, and again on his return from Malaysia in 1952, had a very happy consequence. He was introduced to Joan Sylvia Thompson, a young graduate chemist working in the MRC Blood Group Research Unit in the same building. They were married in the summer of 1953, soon after Peter had completed his studies for the Diploma in Bacteriology at the London School of Hygiene and Tropical Medicine. Joan and Peter had three children (Barbara, Catherine and David) and enjoyed a happy, mutually supportive marriage for 52 years until Joan's death in 2005. Their home in Leicester was a focus of exceptional warmth and hospitality for their colleagues and many friends.

Peter's interest in human blood groups did not cease on his return to the UK. In 1955 he co-authored a paper with Joan on the adsorption of Lewis antigens on human red blood cells (2).

Research and writings in London

In 1953 Peter was employed as a research scientist by the MRC at the National Institute for Medical Research, Mill Hill, north London, in the Division of Microbial Physiology under Martin Pollock (FRS 1962). His main areas of study at Mill Hill were bacterial physiology and genetics. In 1958 he was awarded a Rockefeller Research Fellowship to study bacterial genetics with the future Nobel laureate Professor Joshua Lederberg (ForMemRS 1979) at the University of Wisconsin.

* Numbers in this form refer to the bibliography at the end of the text.

It was, however, at Mill Hill that Peter became seriously interested in bacterial systematics. When in Malaysia, he had studied some purple-pigmented bacteria that he had isolated from soil and water and, unexpectedly, from infected wounds and one fatal infection in humans. When he returned to the UK in 1952 he brought the Malaysian strains with him and continued and extended his studies on these (then and now named as *Chromobacterium violaceum*) and another group of very similar purple-pigmented bacteria (*Chromobacterium lividum*, now *Janthinobacterium lividum*). Comparing the properties of these strains led him to ponder how bacteria could be classified into stable groups that could be named so that future isolates could be identified with much more confidence. These studies would eventually revolutionize bacterial systematics and establish him as a scientist of international note.

In the 1950s, current methods for classifying bacteria were seriously inadequate. Different workers used different criteria depending largely on their field of interest, for example medical, agricultural or food bacteriology. This led to conflicting, unstable classifications. Because the characterization of all bacteria at that time was, of necessity, based on phenetic (phenotypic) characters, Peter reasoned that the greater the number of phenetic characters tested, the greater the possibility of reflecting the genomic composition of each bacterial strain.

In his first study of bacterial classification Peter included the original 42 strains of the purple-pigmented chromobacteria mentioned above, additional strains that showed some resemblance to this group and, most unusually for the time, a few well-characterized reference strains. The inclusion of this last group is now recognized as a must for all taxonomic studies.

The strains were all subjected to a very large battery of morphological, cultural and biochemical tests—a far greater number and variety than was common at that time. The results indicated that the genus *Chromobacterium* was sharply divisible into two distinct groups that could be equated with the species *Chromobacterium violaceum* and *Chromobacterium lividum*. The work was presented as a dissertation for the degree of Doctor of Medicine at the University of Cambridge, which was awarded in 1958. The bulk of the study was also published in detail in *Iowa State Journal of Science* in 1960 (6).

Later, when Peter began to analyse and assess the large body of test results generated in the study he realized that bacterial species consisted of clusters of strains that shared many properties, although no single property was necessarily always constant. Accordingly, for purposes of classification, bacterial strains had to be grouped in a way that took this into account, the degree of similarity between strains being based on an appropriate number of characters rather than relying on one or a few key characters. Consequently, a technique was required to identify and define the clusters by comparing each strain with all the others in a study to find those strains that had the most characters in common. He then faced the problem of how to weight different characters. Some characters might be more constant than others, some possibly reflecting a large portion of the genome, others reflecting a single gene. After much deliberation he concluded that the Adansonian principle that all characters be given equal weight was the only solution. Peter claimed that this method of weighting occurred to him while he was travelling on a London bus. This claim is in keeping with our knowledge of Peter. He rarely stopped thinking about an abstract or concrete problem until it was resolved. Peter introduced the world of microbiology to these concepts at the 24th General Meeting of the Society for General Microbiology at the Royal Institution, London, in April 1957 (3). By this time he had already prepared his first two papers on the use of numerical methods to classify bacteria, and these widely quoted and classic works appeared later in the same year in *Journal of General Microbiology* (4, 5).

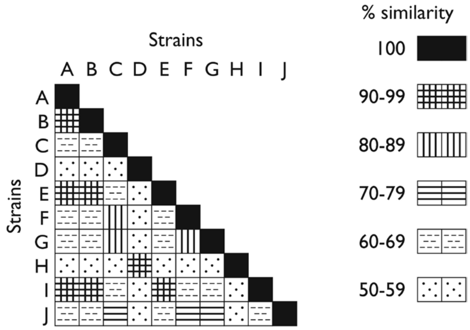

Figure 1. Similarity matrix between strains A to J before rearrangement. The squares are shaded to represent the degree of similarity between strains. (Redrawn from (9).)

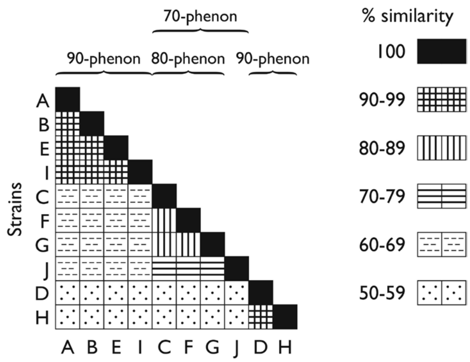

Figure 2. Similarity matrix between strains A to J after rearrangement. The strains have been placed in the new order by cluster analysis. The phenons of different value are indicated by brackets. (Redrawn from (9).)

In his first study, Peter resorted to visual methods to estimate similarity by using photographic images on X-ray film in which strains were tabulated against positive and negative tests (scored as transparent circles and rectangles, respectively, against the black background of the film) so that films could be overlaid to determine the degree of similarity between different strains. These data were then converted into a similarity table of features that could be analysed to give a numerical value for overall similarity (*S* value) between every strain and every other (strains were referred to as operational taxonomic units (OTUs), reflecting the applicability of the procedures outside bacteriology). This numerical *S* value is simply the proportion of these two-state data that have the same state (both negative and positive) and is derived from the simplest of all the matching procedures known as the single linkage procedure. Any characters for which either or both OTUs have a missing entry are ignored.

Figure 1, taken from Peter's seminal review published in 1962 (9), is a similarity matrix diagram in which several hypothetical OTUs are compared with each other for a series of hypothetical tests and in which the squares have been shaded to represent similarity values between different hypothetical OTUs. These shaded diagrams could be rearranged so that closely related OTUs were placed adjacent to each other in groups (figure 2).

Such similarity matrices were thus useful for identifying the main phenotypic groups (phenons); this could be done by eye in simple instances, but more objective methods,

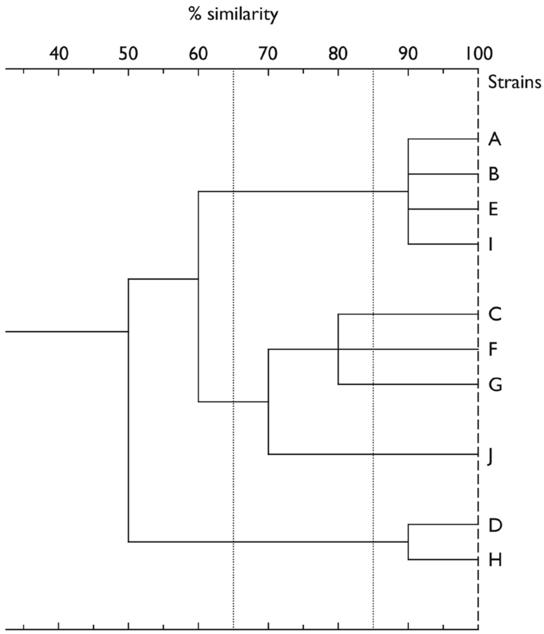

Figure 3. Taxonomic hierarchy obtained from figure 2. The dotted lines indicate similarity levels that have been considered appropriate to different (but unspecified) ranks. (Redrawn from (9).)

collectively known as cluster analyses, were developed by Peter. Clustering methods begin by finding the pair of closest OTUs. This pair then forms a group or cluster. The similarities between this group and each of the remaining OTUs are determined and the process cycles back, treating the newly formed group as an OTU, to find the next highest similarity. The new highest similarity may thus be either between two single OTUs or between an OTU and the group formed during the previous clustering cycle. The process finishes when all the OTUs have joined the cluster analysis. The cluster analysis could then be converted into a hierarchical taxonomic tree (dendrogram or phenogram) that summarized the salient points of the cluster analysis and from which potential taxonomic rank could be determined. Figure 3 shows the dendrogram derived from the cluster analysis shown in figure 2.

Variants of the method arise over the definition of the similarity between an OTU and a group or between two groups. The commonly used single linkage procedure first used by Peter defines the similarity between two groups as the similarity of the two most similar OTUs, one in each group. Average similarity takes the average of all the similarities across the two groups. Unweighted average linkage (unweighted pair group method with arithmetic mean; UPGMA), probably the most commonly used variant, is the simple arithmetic average of the similarities across the two groups, each similarity having equal weight. Matching procedures have since been devised that allow, for example, multi-state characters to be used in the construction of the original similarity matrix or allowing matching negative characters to be ignored.

These procedures could be performed manually when the study involved a relatively small number of OTUs and tests. However, Peter had by now come to the conclusion that very little confidence could be placed on an *S* value based on fewer than 50 character tests, and it was not uncommon to subject at least that number of OTUs to the test regime. It was clear that there was a need for some mechanical aid in sorting the data. Peter's analysis of a large number of test results was done before the wide availability of computers. His attempt to analyse the data by punch cards and a punch card-sorter proved inadequate; the process became much more complicated than simple sorting. The advent of computers made a great deal of difference. Peter was extremely fortunate in the support he received from Elliot Automation, one of the early computer firms situated near the National Institute for Medical Research. It was with Gerald Mills, an employee of the firm, that Peter wrote a computer program for the single-linkage cluster-generating procedure described above. In keeping with the thoroughness of his approach to all his work, Peter arranged to attend a computer course. He often referred to the first lecture he attended when the lecturer commented, 'If you think you need not think any more, and computers will do it all, let me tell you that your thinking days are just beginning.'

It is likely that these words were responsible for Peter's emphasis on the necessity of careful planning, especially in the choice of program in all computer-aided studies. His early papers (4, 5) on the application of computers in taxonomy constitute classic discourses on the newly developing field.

Initially, the analyses were intended to *produce* taxonomic groups and not to *identify* the groups. However, Peter was well aware that inspection of the data could, in theory, identify the tests most useful for identification. This was to be a major consideration in his later work at Leicester. The selection of taxonomic rank was also a matter of concern. Consideration of figure 3 indicates that there are two similarity levels that might be appropriate to different (but unspecified) ranks. Peter deduced that inclusion of selected type strains as reference points was the key to deciding the taxonomic rank of other strains or taxa. This again was to prove crucial in the taxonomy and nomenclature of bacteria over the next 30 years.

Numerically assisted taxonomy, or numerical taxonomy as it is now known, was not welcomed by all bacterial taxonomists. Peter did, however, receive support from many colleagues at Mill Hill and from workers such as Sam Cowan, Director of the National Collection of Type Cultures at Colindale, North London (Cowan 1970).

In 1958 the Mill Hill virologist Christopher (later Sir Christopher) Andrews, who was a keen entomologist, told Peter that there was another man 'mad enough to classify organisms numerically'. This was the American entomologist Robert Sokal (deceased 2012), who had published in *Proceedings of the 10th International Congress of Entomology* on the classification of bees (Sokal 1958). This was to prove a momentous moment for the development of numerical taxonomy. Sokal was not convinced by Peter's claim that he had been initially alerted to Sokal's work by Christopher Andrews. He believed that Peter had independently noted the obscure reference as a result of what Sokal referred to as 'his signal characteristics—Peter, the meticulous biographer', an acknowledgment of Peter's remarkable depth of knowledge and exceptional retention of precise detail. Whether or not this was so, there is no doubt that Peter was a meticulous collector and collator of references that had a bearing on his research. This was the start of what was to become a long and immensely productive collaboration with Sokal (figure 4).

In 1958 Peter took up his Rockefeller Research Fellowship to work with the geneticist Joshua Lederberg (ForMemRS 1979) in Madison, Wisconsin. In March 1959 Lederberg moved to Stanford University, California. To relocate to Stamford, Peter decided to buy a second-hand Plymouth car to transport his very young family across the USA in what they referred to as the Great Trek. (One of Peter's ancestors had married a Mormon and had indeed

Figure 4. Peter and Robert Sokal in 1990. (Courtesy of Bergey's Manual Trust.) (Online version in colour.)

taken part in the Great Trek to Utah.) The car itself they dubbed the 'Mile Eater'. It made not only the journey to California but also, at the end of his Fellowship, the return journey to New York.

On the journey to California, Peter planned a one-day visit to Lawrence, Kansas, to meet Robert Sokal in person. However, the visit lasted significantly longer because shortly after their arrival the worst ice storm in decades struck Lawrence and for three days it was not possible to enter or leave the city. This gave lots of time to talk about their work and make vague plans to collaborate. Shortly after Peter's return to the UK, Sokal received a National Science Foundation senior postdoctoral fellowship (1959/60) to study biometry at the Galton Laboratory, University College, London. It was during this period, in the spring of 1960, that Sokal and Peter made firm plans for collaborative work. In 1962 they published a discussion of the state of numerical taxonomy in the journal *Nature* (8), a precursor to their first book in 1963, *Principles of numerical taxonomy* (10). Their joint work led to their recognition as the founding fathers of numerical taxonomy. Shortly after Peter's death Robert Sokal wrote, 'We two came from such different backgrounds that it is a wonder we became such close friends and colleagues. It would have been all too easy to become vociferous competitors claiming credit for every inch of new discovery and disparaging the other's contribution.'

In a similar vein, Joe Felsenstein, the distinguished evolutionary geneticist at the University of Washington, the author of the widely used PHYLIP package of programs for inferring phylogenies (Felsenstein 1982) (which, in part, have their roots in the numerical procedures developed by Peter and Sokal), wrote just after Peter's death (Felsenstein 2011): 'The smartest thing Sokal and Sneath did was not to fight over who invented numerical taxonomy but to join together to promote it.'

After establishing the principles of numerical taxonomy applied to bacterial classification in 1957, Peter published extensively in other fields for the next few years, including bacterial genetics, antibiotics and even contamination precautions in space travel (7), but bacterial classification was never far from his mind.

In 1964, on the basis of Peter's research studies in microbial systematics, the MRC established a Microbial Systematics Research Unit with Peter as Director at the University of Leicester. At that time the university was building up its science, and his first laboratories were in a wing of one of the oldest buildings on the site—originally a mental hospital after World War I. Although hardly ideal (the autoclave was on a landing on a steep staircase, the main laboratory had the distinct character of a hospital ward, and there was a padded cell in close proximity!), Peter coped without complaint until new facilities were provided a few years later. Peter remained as Director until the Unit was dissolved in 1975 on his appointment to one of the Foundation Clinical Chairs (Clinical Microbiology) in the new Medical School at Leicester University.

It was at Leicester that we first met Peter; one of us (D.J.) was a member of Peter's staff at the MRC Microbial Systematics Research Unit, the other (W.D.G.) was the first university staff member appointed to the Department of Microbiology.

Research and writings at Leicester

At Leicester, Peter extended and expanded his earlier studies on the characterization of bacteria of medical importance and their classification by numerical methods. Initially the work was performed with the help of his small MRC-funded team. In the team, Peter was fortunate to have the assistance of the computer programmer M. J. Sackin, who contributed to Peter's work on the development of appropriate computer algorithms and statistical methods. In the late 1960s, as the numerical approach to classification gained general acceptance, Peter's team was augmented by visiting workers, postdoctoral fellows and postgraduate students, not all of them bacteriologists.

Much of the work that Peter initiated in the 1960s and early 1970s was focused on revising the classification of a range of bacteria of medical importance. These included studies on the genera *Yersinia*, *Bordetella*, *Haemophilus* and *Listeria*. Other studies were done on larger groups of bacteria that contained pathogenic and non-pathogenic forms such as the enterobacteria and coryneform bacteria, in attempts to define taxa within the groups and clarify the relationship of the component taxa to each other. The results of these studies produced robust groupings of predictable taxonomic rank when evaluated against other available evidence on the same organisms. Together with the results of numerical taxonomic studies from other laboratories, they placed the classification of bacteria on a new, firmer scientific footing.

In assessing the results of these early numerical phenetic studies, Peter was the first to identify and publish on factors important in their planning and execution. These included such problems as the growth rate of the strains under study, the choice and number of bacterial strains and phenetic tests to be included in each study, test reproducibility and significance tests for the groupings derived from such studies. Patently, strains that grew slowly under the conditions chosen for a particular study could distort the results. As noted above, Peter realized the importance of including well-documented reference strains appropriate to the study in hand. Of particular importance were the type strains; that is, the reference strains for groups such as species and subspecies. If reference strains were not included—and it was surprising how frequently they were not—evaluation of the results against other numerical taxonomies or taxonomies based on different criteria was difficult. Peter also noted the importance of including a sufficient number of strains and tests in the definition of a particular taxon; he suggested, empirically, 10 strains per taxon at species level and recommended the use of 50 or more tests per strain (9). He was also the first person to advocate internally monitoring a particular study by splitting several strains into two cultures.

Well-designed numerical phenetic studies involved the handling of large numbers of bacteria. To cope with the maintenance of such large collections of bacteria, Peter devised an ingenious, simple, cost-effective and reliable solution based on the use of bacterial suspensions, with a glycerol cryoprotectant, frozen in small (2 mm) glass embroidery beads, which held a small amount of culture in the hole in the centre of the bead. These were contained in screw-capped vials stored in commercial deep freezers at temperatures between −60 and −76 °C (21). The main advantages of the method were ease of preparation of the material, the ability to store hundreds of strains for long periods in a small space, and, on recovery, only one or a few beads containing a portion of the culture would be removed and thawed, the rest remaining frozen. The stability of the phenotype was comparable to that achieved by conventional freeze-drying procedures. Beads of different colours could be used for various groups of bacteria and good levels of viability were maintained for at least ten years (25). In recent years the method has been exploited commercially, alas not by Leicester University because, as was common at the time, no thought was given to obtaining intellectual property rights.

Simple statistical principles indicated that many tests were needed to obtain a high overall similarity between strains. To deal with the heavy workload of large numbers of strains subjected to numerous tests, it became clear that rapid methods of testing were required. At first Peter used square dishes divided into compartments all containing the same substrate to be tested. These were inoculated with several different bacterial strains (one per compartment) by means of another device devised by Peter—a multipoint inoculator (13). The results eventually led to the development of automated or semi-automated highly standardized miniaturized tests produced by commercial firms with much encouragement from Peter, such as the BIOLOG identification system and the API identification kits still widely used in hospital diagnostic laboratories.

A chance remark made by an MRC assessor on the lack of information on the error rates of microbial tests prompted Peter to persuade an informal group of workers, the *Pseudomonas* Working Party of the Society for General Microbiology, to study the problem (19). Chosen strains were distributed, and members did the strictly standardized tests in triplicate. Anonymity was ensured by identifying participating laboratories by numbers known to only one assessor. Inspection of the results allowed the estimation of test error between different laboratories and of that between the replicates in each laboratory. These proved to be illuminating. There was little difference between the laboratories but some tests were extremely unreliable, much more so than had previously been assumed. A few were extremely consistent, so it was possible to list the tests in order of reliability and decide that some phenetic tests were best excluded from systematic studies (18).

At a very early stage in his work, Peter emphasized the importance of choosing an appropriate program to derive groupings when planning numerical studies. The most widely used of his and Sokal's algorithms is the UPGMA clustering method, followed by the single linkage procedure, although many different computer programs have since been written for numerical taxonomic studies (Jones & Sackin 1980; Sackin 1987).

A logical extension of bacterial classification is the identification of unknown organisms with named, well-characterized groups such as existing bacterial species. Areas such as hospital microbiology are almost entirely concerned with identification. Peter had always viewed the information-rich groupings derived from numerical taxonomic studies as ideal sources for the identification of new isolates. The construction of such identification schemes drew much from the earlier development of standardized miniaturized tests together with the construction of computer identification programs. It was clear that it would be impracticable for diagnostic laboratories to perform all the tests used in the original taxonomic studies to identify a new isolate. However, Peter realized that information on bacterial groups was stored as an identification matrix in a form that could be interrogated to determine the minimum number of tests required for the reliable identification of a new isolate (22). Algorithms for identification are now standard in automated laboratory instruments and the particular tests available in identification kits are a reflection of this kind of analysis of the original taxonomic studies.

By the late 1960s it became apparent to Peter that a revised version of the 1963 book *Principles of numerical taxonomy* was required. The publication had stimulated many biologists to expand and improve methods included in the book and had encouraged specialists in other sciences to experiment with numerical methods in their own field. In the year 1967/68, Peter was invited as a Visiting Professor in Biology to the University of Kansas. During this period Peter and Robert Sokal decided to write an entirely new book. Published in 1973, *Numerical taxonomy: the principles and practice of numerical classification* (16), remains the standard text on numerical taxonomy to this day. Indeed, last year, in a tribute to Peter in the publication *Taxon*, Daniel Barker of the Centre for Evolution, Genes and Genomics, University of St Andrews, wrote: 'If the Kew Index [Index Kewensis], funded by money left by Darwin, is the first bioinformatics data base, then Sneath and Sokal (1973) is the first bioinformatics text book' (Barker 2012).

Peter was always keen to extend his methods to other scientific areas. While in Kansas he worked with geologists in the Kansas Geological Survey, and later, as a visiting scientist at Syracuse University in the Department of Geology, he worked on adapting numerical procedures for the comparison of geological maps and stratigraphic sequences and recognizing repetitive sequences (12). Numerical taxonomy in the broad sense has been exploited in many other fields outside biological systematics. In addition to geology, these include ecology, psychometrics and the humanities. Numerical techniques have also been used to track epidemics of infectious disease (15).

Numerical taxonomy continued to underpin microbiology systematics until the advent of nucleic acid pairing (DNA hybridization) and gene sequence comparisons in the 1980s. It still has an important role today in so-called 'polyphasic' taxonomy, in which a mix of traditional tests and gene sequence comparisons are used to classify and identify microbial strains. With very large numbers of molecular sequences now available, very detailed phylogenies can be reconstructed. However, there are still areas where phenetic methods are useful, as in bacteriology, when molecular sequences are not available or when identification may necessarily depend on phenotypic characters alone. Although Peter's approach to the numerical classification of bacteria was based on phenetic characters, he made it clear from the outset that the method indirectly embraced phylogenetics to a considerable extent, because the greater the number of phenetic tests conducted on a particular group of bacteria, the greater would be the reflection of the expression of at least part of the genome (17). Subsequently, he also published papers on the analysis and interpretation of sequence data for bacterial systematics (24). In 1975 he wrote, together with R. P. Ambler and M. J. Sackin, a pioneering paper on detecting recombination between lineages from protein sequences (20).

Peter was also interested in astrobiology, together with the origins of and persistence of life (11, 14). A testament to his innate scientific curiosity and experimental panache in this area is to be found in a little article published in the quarterly journal of the Society for General Microbiology (28). Here he and a colleague from the British Museum describe an experiment that he conducted in a pond in his garden at Oadby in Leicester over a period of 21 years. Samples from four environments (pond water, soil, *Sphagnum* moss, and moss on limestone) were heat-sealed into borosilicate test tubes and then incubated in his garden pond. The question was whether the systems contained enough diversity to allow complete nutrient cycling, given a continual external input of energy, which for both the planet and these miniature ecosystems is sunlight: could such systems survive indefinitely? After 21 years, simple observation indicated that life was still present. The tubes, together with copies of Peter's laboratory notes, are now part of the collections of the Natural History Museum in London. Peter always maintained that simple experiments such as this offered an opportunity to approach much more complex issues in the context of astrobiology and the search for signs of life on other planets.

In 1979 Peter was invited to become a Trustee of Bergey's Manual Trust, a self-perpetuating, non-profit-making organization formed in 1936. The Trustees act as an Editorial Board for *Bergey's manual of determinative bacteriology*, a publication that occupies a unique position in bacteriological literature as the definitive account of bacterial taxonomy and properties at the time of publication. Soon after Peter became a Trustee, the Board made an important decision to change the emphasis of the manual, and the volume(s) became *Bergey's manual of systematic bacteriology*. Peter served as Vice Chairman of the Trust from 1985 to 1990, as Chairman from 1990 to 1994, and as an emeritus member until his death. He was a contributor and had major editorial responsibility for the first edition of the Systematic volumes (prepared between 1984 and 1989) and contributed to the second edition begun in 2001 and finished in 2011. In 1998 he was awarded the Bergey Medal for Distinguished Achievement in Bacterial Taxonomy. Earlier, in 1990, he had been the first recipient of the Van Niel International Prize for Studies in Bacterial Systematics.

Peter became a member of the International Committee on Systematic Bacteriology (ICSB, later the International Committee on Systematics of Prokaryotes (ICSP)) of the International Union of Microbiological Societies (IUMS) in 1962, was its Chairman from 1978 to 1982, and remained an active member until his death. He was appointed a life member in 1986. He served as a member of the Judicial Commission of the ICSB from 1962 to 1994 and was its Chairman from 1966 to 1978. In this capacity, together with other colleagues on the ICSB, especially V. B. D. Skerman and S. P. Lapage, he carried through the most important innovation in bacterial nomenclature for more than a century. A major problem in bacterial systematics in the 1970s was the existence of thousands of names, only a few of which could be equated with well-founded species. The Judicial Commission decided to make a new starting date (1980) for the names of bacteria and produce a new document, the 'Approved lists of bacterial names' (23). Earlier names were declared no longer valid, although provision was made for reviving some old names. New names had to be registered in an official publication. It then became necessary to rewrite the 1975 *International code of nomenclature of bacteria*.

Figure 5. Peter with the decanter presented to him at the 1983 Society for General Microbiology Symposium in his honour. (Photograph courtesy of the SGM.)

Peter had been closely involved at all stages but claimed that 'he was only the steersman, others did the rowing'. He was responsible for the 1992 revision of the Code (26). Peter was particularly pleased that the success of the system in bacteriology led workers in botany and zoology to consider whether similar changes should be undertaken in their fields. He was a Council Member of the International Congress of Systematic and Evolutionary Biology (ICSEB) from 1973 to 1985 and a member of the International Committee from 1990 until his death. A member of the International Association for Plant Taxonomy, he was liaison member for ICSB on botanical nomenclature.

At national level, Peter was a founder member (1961) of the Microbial Systematics Group of the Society for General Microbiology (SGM) and Convenor of the Group from 1964 to 1967. In 1983 the SGM held a two-day symposium, 'Twenty-five years of numerical taxonomy' to honour Peter's work. To mark the occasion his friends and colleagues presented him with a decanter engraved with appropriate numerical taxonomic motifs together with six whisky glasses (figure 5). It was entirely appropriate that the first paper at the symposium was given by Robert Sokal.

The Microbial Systematics Research Unit was closely involved in initiating and developing the teaching of basic microbiology in the School of Biological Sciences at Leicester. As Director of the Unit, Peter was successively appointed Reader in Biology (1964–71) and Honorary Professor of Biology (1971–75). In 1975 he was appointed to the foundation Chair of Clinical Microbiology and Head of Department of Microbiology at Leicester University and Honorary Consultant Microbiologist, Leicestershire Health Authority—appointments that he held until his retirement in 1989. His inaugural lecture, given in 1976 and entitled ‘Lessons from Lilliput’, was a most informative and entertaining account of microbiology, past, present and future. As a University Professor, Peter established a Department of Microbiology that was highly regarded at home and overseas. Many graduate students were supervised, and several became distinguished in their own right. Peter was delighted when one former member of the department described a new bacterial genus and named it *Sneathia* in his honour (Collins *et al*. 2001). Peter enjoyed contact with undergraduates and always made time, however busy he was, to accompany second-year Biological Sciences students on their annual one-week trip to London to visit various microbiological institutes.

In contrast to his commitment to research and teaching, Peter did not enjoy administration. Not only did it detract from time ‘better spent’, but in his view much of it was also unnecessary. However, his relaxed style as Head contributed to a happy, productive and united department.

On his retirement he was awarded Emeritus status. At a retirement party he was presented with his portrait in oils commissioned by his friends and colleagues.

Research and writings in retirement

After he retired, Peter came into his office on most days, publishing papers and attending seminars. He continued his work on computer-based identification schemes, developing more refined computer programs to evaluate the quality of databases used in these schemes.

He spent time studying and interpreting the published sequence analyses of bacterial 16S ribosomal RNA (rRNA) and 5S rRNA (29). While impressed by the stability of 16S rRNA analyses and their contribution to understanding the relations between bacteria, Peter was not entirely convinced of the utility of rRNA analysis at the species level, and he was also particularly concerned that species descriptions were frequently based on one bacterial strain.

In two review articles, ‘Thirty years of numerical taxonomy’ (27) and ‘Reflections on bacterial systematics’ (31), both written in retirement, the latter published only months before his death, he reviewed the contribution of numerical taxonomy to bacterial systematics and considered future prospects for both molecular and phenotypic approaches to phylogeny and classification.

He remained very involved with the Judicial Commission of the International Committee on Systematic Bacteriology and with Bergey’s Manual Trust, continuing to contribute to the Manual, including the description of the genus *Brochothrix* for the second Systematic edition in 2009 (30).

A good, clear speaker, Peter was in demand as a lecturer at many meetings, both at home and abroad. He was the plenary lecturer at the International Congress of Systematics and Evolutionary Biology in 1990 and was Clifton C. Garvin Visiting Professor at Virginia Polytechnic Institute and State University (1990–91), where he taught two postgraduate courses: biological systematics and computing in systematic biology.

Peter was not seen in the department as frequently after Joan's death, but when he did appear it was evident how up to date he was with developments in the field of bacterial systematics. It was only in the last year of his life that physical disability prevented him from travelling to the university.

Personality and outside interests

Tall, slim and bespectacled, Peter was friendly but reserved. He enjoyed talking to his friends and colleagues; these came from many different disciplines, reflecting his own wide interests. He was good-natured, only rarely raising his voice or losing his temper. He had a good sense of humour; this, together with his excellent memory, resulted in several amusing anecdotes from the past, which he enjoyed relating as appropriate. He was also an extremely good mimic; the pompous were his usual victims!

A lifelong Methodist, Peter lived by the highest principles of his faith. He was a lay preacher and preached at the small Methodist chapel in the village of Thurlby-by-Bourne, Lincolnshire, at least once a year. The Sneath family had a long association with the village, and Peter maintained a cottage there until his death.

In addition to microbiology and computing, Peter had many other interests and a wide and varied knowledge of many quite obscure subjects. He was an active member of the Leicester Literary and Philosophical Society, and its President from 1989 to 1990.

Peter had a lifelong interest in natural history. As a youngster he had developed an interest in microscopy and had a large collection of stained microscopic slides. These were carefully stored in his study until his death. Interested in gardening, he was very knowledgeable on a wide variety of cultivated and wild plants. He took delight in identifying plants noted on walks in the country that he much enjoyed until prevented by physical disability.

Peter had a great love of literature and read widely. His tastes spanned works from the classics through science fiction to detective novels. He wrote poetry, notably sonnets. On the occasion of his wife Joan's 50th birthday he presented her with a beautifully bound volume of 100 handwritten sonnets, *A century of sonnets for Joan*, on a variety of subjects amatory, locational, political and literary. Later, as he promised Joan before she died, he published these privately together with 16 additional sonnets (not handwritten) under the pen-name Manley Harris (Manly derived from Andrew, and Harris from Henry). We reproduce here the sonnet 'Writing a scientific paper':

Who can tell the source of the idea
That's now incarnate in the printed word,
And flows in power where'er its song is heard?
It comes like wind, like fire, and none can steer
Its path to trammelled courses, tamed and drear.
Wayward it is. Who knows to what related,
Whose son it was, whose daughter shyly mated,
Dreaming in the mind's unruffled mere?
Yet suddenly the concept's there! Its force
Becomes too great, insatiable and deep:–
The passion of its birth is marked by loss
Of all the freedoms, dearer than food, than sleep
Howe'er so much its author turn and toss
It comes to term in sudden labour's course.

Peter was very interested in and knowledgeable about art, especially painting, and was himself a talented amateur artist. His depiction of the Christian emblem Chi Rho (☧) drawn in 1998, which appeared in the order of service at his funeral, is beautifully decorated with carefully painted flowers, insects, birds, rabbits and fish. In retirement, Peter followed Joan's practice of producing postcard-sized watercolours depicting a scene from a holiday destination rather than purchasing a commercially available holiday card. Peter's cards were not as numerous or as well executed as Joan's, but all their cards were cherished by those fortunate enough to receive them.

Although he did not play a musical instrument, Peter appreciated a wide range of music and enjoyed participating in, as well as attending, musical events. He had a good singing voice and was particularly fond of madrigals. At his seventieth birthday dinner he was delighted by the surprise appearance of a madrigal group that had been well hidden in the conservatory of his home until the meal was over. In contrast, he was also well versed in the light operas of Gilbert and Sullivan and could sing an appropriate section of almost any of them to great effect.

Shortly after Joan's death, Peter moved from his delightful house with its large garden in Oadby to a more convenient bungalow on the Leicestershire–Rutland border to be nearer his daughter Kate. While there, he organized occasional coffee mornings that enabled him to keep in touch with some old Leicester friends.

After a relatively short illness Peter died at home in the presence of family. A service of thanksgiving for his life was held in the Methodist Chapel at Thurlby-by-Bourne, and he was interred, like Joan, in Thurlby churchyard, where many earlier members of the Sneath family lie buried.

Peter was a very talented, kind, thoughtful and modest man. As a scientist his contributions to bacterial systematics in the previous century were great and will endure. We end with an extract from a letter written to the Sneath family by Robert Sokal:

> Your father's scientific reputation speaks for itself. The many honours he earned during his career, crowned by the FRS, attest to that in fullness. But scientific acumen is an empty façade when it is not backed up by a complement of scientific ethics. I never heard Peter utter a disparaging word about a colleague, however wrong he might believe that colleague to be. When he strongly disagreed with someone at a scientific meeting, he was not easily perturbed, but would put on a wry face waiting for the errant speaker to fall into the foxhole he had dug for himself. As another example of Peter's character let me reveal that some years ago he was nominated for a prestigious and remunerative prize for the development of NT. He would not accept the nomination unless the sponsors agreed to the splitting of the nomination between us. The sponsors agreed, but in the end neither one of us was chosen for the prize. That is the magnanimous kind of man he was.

Degrees and distinctions

1944	BA Cantab.
1947	MRCS Eng. LRCP Lond.
1948	MB BChir. Cantab.
1953	Dip. Bact. Lond
1959	MD Cantab.
1958–59	Rockefeller Research Fellow
1967–68	Visiting Professor, University of Kansas
1967–70	President, Systematics Association

1972–78 Chairman, Classification Society (European Branch)
1974 Fellow of the Institute of Biology
1976 Hon. DSc, University of Ghent
1978 Honorary Member, Society for Systematic Zoology
1977 Alexander Winchell Distinguished Lecturer, Syracuse University, New York
1980 Visiting Professor, Syracuse University, New York
1981 Honorary member, Society for Applied Microbiology
1986 Watkins Visiting Professor, Wichita State University
1988 Honorary member, American Society for Microbiology
Honorary member, Société Française de Microbiologie
Honorary member, Society for General Microbiology
1989–90 President, Leicester Literary and Philosophical Society
1990 First recipient of the Van Neil International Prize for Studies in Bacterial Systematics
Emeritus Member, Biochemical Society
1990–91 Garvin Visiting Professor, Virginia Polytechnic and State University
1992 Honorary member, Czechoslovak Society for Microbiology
Fellow of the American Academy of Microbiology
1990–94 Chairman, Bergey's Manual Trust

Acknowledgements

Some details of Peter Sneath's early life and subsequent career are drawn from (27) and (31). We are grateful to the Sneath family for permission to quote from the letter from R. R. Sokal and from *A century of sonnets for Joan and additional sonnets*. We are especially grateful to Peter's daughter, Kate, and his grandson, Peter Hill, for providing a curriculum vitae, publications list and other relevant information. We ourselves accept responsibility for other narrative and scientific aspects of this memoir.

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