ACTA STEREOL 1987; 6/SUPPL II: 5–10
ISS COMMEMORATIVE-MEMORIAL VOLUME
EDITORIAL

PREFACE

by Roger E. Miles (ISS President, 1984–7)

This volume, "Twenty-five years of Stereology", has been produced at this time to mark two events:

I The 25th birthday of the International Society for Stereolgy.

II The death of the ISS's Founder and Honorary President, Hans ELIAS, on 11 April 1985. It also marks the recent deaths of Honorary Members Hennig, Rhines and Saltykov.

Stereology has as many definitions as there are stereologists. To me it is concerned with the investigation of the spatial structures of (usually) irregular and opaque materials, on the basis of the observable data carried by plane sections, thick or thin (lamellar) sections, serial (lamellar) sections, projections through the material onto an image plane, and other such geometric probes. It may be *qualitative*, applying logical geometric thought processes to such data; some people seem to possess a strong feeling for such 'spatial relationships' — Elias was famous in this respect. More usually in the ISS it is *quantitative*, and then it becomes necessary for the sections and other probes to be appropriately random — usually uniform and isotropic — relative to the material; thus either the material is regarded as non-random, so that it must be arranged that the sections etc. are appropriately random, *or* (and this is a big step!) the material is regarded as sufficiently homogeneous and/or isotropic that it may be regarded as the realization of a homogeneous and/or isotropic stochastic process, in which case sections etc. need only be 'arbitrary'. Such models typically permit the application of various statistical techniques, especially sampling theory, and the derivation of unbiased estimates of spatial characteristics of the material — mean values, even full distributions — from lower-dimensional information.

The history of stereology is of some interest. There seems to be reasonable agreement that stereology proper, as a practical applicable technique, began with Delesse in 1847 ($A_A = V_V$). However, Cruz Orive points out below that in the seventeenth

century Cavalieri developed a formula for volume in terms of the intercepted areas on equi-spaced serial sections. Between these two pioneers Buffon initiated geometric probability (1777), but without stereological intent. Progressively more useful versions of Delesse's formula appeared over the next century: $L_L = V_V$ (Rosiwal, 1898), $P_P = V_V$ (Thomson, 1930). An isolated, but the very first specifically mathematical stereological theory, was produced by Wicksell (1925, 1926) in his consideration of the by now classical spherical (and ellipsoidal) particles and plane section problem, which continues to inspire new developments. In the same statistical journal — *Biometrika* — another isolated and only recently re-discovered paper, relating to fundamental aspects of stereological sampling, is due to Thompson (1932). The next significant advance, by Saltykov (1945), truly entered into the geometry, showing that surface area per unit volume, S_V, is estimated by sectional length per unit area L_A by the formula $L_A = (\pi/4)S_V$; he also derived the further fundamental stereological formulae $P_L = (1/2)S_V$, $P_A = (1/2)L_V$.

Meanwhile, Hans Elias, from his biological background, had in the '50's become increasingly interested in qualitative stereology, an interest that became more mathematical through a close collaboration with August Hennig. Elias discovered a mutual biological morphometric interest in encountering Ewald Weibel at a meeting in Boston in 1958, and then, at the International Anatomy Congress at New York in 1960, Elias discovered, through Weibel, a further neurobiological 'fellow-traveller' in Herbert Haug.

> " The time has come, I believe, that people who do such things should get together"
>
> (H. Elias)

True to his word, the Feldberg Mountain (in the West German Black Forest region) meeting of 11 scientists took place in May 1961, from which the word 'stereology' emerged. A notice he inserted in *Science* prior to this meeting unearthed further kindred spirits, notably Erv Underwood. The gathering momentum manifested itself in the 1st International Congress for Stereology in Vienna, 1963. Haug's and Weibel's papers in this volume document in far greater detail the wave of activity at that time.

The appearance of this volume in 1987 marks a quarter-century from a time between the landmark Feldberg meeting at which it was decided to launch an international society for stereology, and the Vienna meeting at which the process was essentially completed. Thus the greatest achievement in stereology — the creation of the ISS — was mainly due to the vision and energy of one man, Hans Elias.

Since then International Congresses for Stereology have been held every four years, alternately in Europe and the U.S.A.; and the ISS has increased in size, to 400 members hailing from 35 countries and many disciplines. Between congresses, many ISS meetings and ISS-sponsored sessions at meetings of cognate societies have done much to facilitate developments and 'spread the word'. In particular, regular intensive practical courses

have been staged under ISS auspices. Hopefully, basic stereological theory will eventually become standard elsewhere, e.g. in university mathematics/probability/statistics courses.

A milestone in recent years was the launching of the journal *Acta Stereologica* in 1982, for which we must thank its Editor-in-Chief, Miro Kališnik, who continues to stringently guide its affairs. Currently *Acta* is experiencing an explosion since it is not only publishing this volume, but also over 1000 pages of the proceedings of the 7th ICS, a special issue on Instrumentation, in addition to its regular issues! It is possible that in due course publication of *Acta*, which is published 'on behalf of the ISS' may be taken over by an international publisher — an event that might well have major implications for the running of the ISS. The *Journal of Microscopy*, which is our 'official journal', continues to carry selected high quality articles on stereology, which are a mainstay of the journal, and serve as a fine 'shop window' for us. The efforts of successive stereological editors Weibel, Gundersen and Howard are appreciated. I personally find that the two journals nicely complement each other.

The past 25 years have seen many stereological developments:

1) The realization of the relevance of much pre-existing theory from geometrical probability and integral geometry, together with the active participation of mathematicians and statisticians in the ISS. Tangible evidence of this is the choice of myself as ISS president, after the first five had hailed from biology (3) and metallurgy (2). In these days of super-specialization, our society offers a breath of fresh air! I am glad to see signs that the ISS is beginning to serve as a much wanted focus for work in stochastic geometry.

2) The realization that, just as a Gallup poll sample of a human population is governed by statistical sampling theory, so too are the various stereological probes. Sampling theory results carry over, with the geometric structures of both specimen and sample adding a new exciting element to the theory. Thus in a sense stereology may be regarded as geometric sampling theory. The importance of adopting appropriate models has been slowly realized, witness the current 'design-based' and 'model-based' approaches.

3) The development of 'big machine' image analysers since the '60's and the necessary accompanying logical 'mathematical morphology' developed by the Fontainebleau school of Matheron, Serra and others. Although strictly speaking not stereological, image analysis can be a key step in much stereological analysis, and is a self-contained mathematical discipline in its own right. It may be significant that, in an ISS vote in 1984, the society voted fairly decisively to retain its name, rather than add "and Image Analysis". The increasing automation of stereological procedures is reflected by the existence of the ISS Special Interest Groups on Instrumentation and Software.

4) The realization that, due to the inevitable error due to the particular section or sections taken, even results obtained by use of precision image analysers suffer a substantial error, and that superior results are often possible without their use by *more extensive sampling* of the specimen, with only a limited number of observations. This has been pushed hard by Gundersen and others. However, big and smaller image analysers will always be required for the continuous sampling of materials in quality control lines, etc.; and also, *par excellence*, for the investigation of *two*-dimensional structure (e.g. analysis of Landsat pictures), where it can achieve far more than stereology may for three-dimensional structures.

5) Mandelbrot's books have done much to popularize fractal curves and surfaces, and much effort these days is expended on estimating fractal dimensions, where classical geometry fails in the modelling of structures.

Thus we have come a long way in the last 25 years, building upon and sometimes re-discovering the scattered foundations which existed pre-1960. What will the next 25 years have to offer? Undoubtedly more and more computer infiltration. Very probably newly developed probing machines, like the TSRLM (tandem scanning reflected light microscope), which may well render obsolete many of the tedious current methods. Possibly computerized tomography techniques, if their expense can be substantially reduced; however, it should be noted that stereology in practice is most usually carried out at the microscopic level on lamellar specimens, which may resist the application of such techniques. Whatever the technical developments, the mathematical theory of stereology will always remain true, and be of intrinsic interest.

THIS VOLUME. And so to this volume, the idea for which originated with the dynamic Erv Underwood.

In the first of its four sections, the dead are honoured. Intimate insights into Elias' working methods at Chicago, and his twilight years at San Francisco, are presented by *Pauly* and *Hyde*. The reader is also referred to the detailed obituaries of Elias written by Haug [Anat. Anz., Jena 161 (1986) 185–195] (see also [Acta Stereologica 4 (1985) 109]) and Pauly [Anat. Record 216 (2) (1986) 243–244]. Then follow brief obituaries of Honorary Members Hennig, Rhines and Saltykov.

The second section contains articles of a historical nature. *Weibel* comprehensively reviews the history of stereology, and points the way for the future, indicating the need for an effective theory of 'form' and 'design'. His co-early pioneer *Haug* gives a detailed

account of stereology in the 1960's. *Cruz Orive* reveals Stoyan's amazing discovery that, even in the 19th century, 'STEREOLOGY' was a well-established (art or) science, with a rather different meaning to the familiar one; he also surveys modern approaches to estimating particle number and size, and finishes with a historical note on geometer Cavalieri (1598–1647), whose work is most relevant to serial sectioning stereology. Next Anna-Mary *Carpenter*, Honorary Member and for many years ISS Treasurer, presents some interesting statistics on the ISS, including a reasonably complete 'roll-call'. Then *Bodziony & Hübner* describe the stereological relevance of work of famous Polish mathematician Steinhaus (1887–1972).

The articles in the third section give a good picture of modern-day stereological endeavour. As well as deriving a new type of stereological relation bringing stereology even closer to mathematical morphology, Pamela *Davy* establishes a wide perspective for the true place of stereology in contemporary science. *Baddeley et al.* apply 3-dimensional spatial stereological analysis to 3-dimensional data obtained non-destructively by the TSRLM. *Mecke* solves a mathematical stereological problem: demonstrating that the distribution of a general random line in the plane is determined by knowledge of the probabilities of its intersecting those segments emanating from an arbitrary fixed point in the plane (e.g. the origin). Significantly, his theory is related to that of computerized tomography. Eva *Jensen & Gundersen* explain how sphere size distributions may be estimated directly using the disector. The application of the disector for estimating the Euler characteristic of a general two-phase geometric structure is then presented by *DeHoff*. *Coster et al.* review properties of the four spatial Hadwiger invariants volume V, surface area S, integral of mean curvature and integral of gaussian curvature (= Euler characteristic!) for a spatial two-phase structure, examining in particular their behaviour under digitalization of the structure. Famed integral geometer *Santaló* derives properties of the mosaic (= tessellation) superposition of several randomly positioned mosaics. *Stroeven* points out the plentiful opportunities for the application of stereology in civil engineering — in relation to properties of building materials, and fluid and soil mechanics. *Collan* considers the practical aspects of matching cells in neighbouring serial sections. *Underwood* develops a new relation, $R_s = (4/\pi)(R_L - 1) + 1$, between the profile ($R_L$) and surface ($R_S$) roughness parameters of a fracture surface, and compares its performance with that of previously proposed such relations.

A long-time concern of the ISS has been the establishing of a standard nomenclature for the more common quantities occurring in stereology. For an insight into the activities of the Nomenclature Committee set up in 1979, see Underwood's report in Mikroskopie (Wien) 37 (Suppl) (1980) 476–7. Unfortunately, agreement did not prove possible among committee members, and the committee essentially disbanded in 1983. Past President *Exner* had a lot to do with this question in 1980–3, and his contribution

to this volume throws light on the problems that arose, and also describes two possible nomenclature systems. It seems the alphabet is simply not large enough to accommodate basic quantities in both stereology and image analysis; for example, on pp.487–517 of their 1985 book 'Précis d'analyse d'images', Coster & Chermant present a nomenclature of about 200 items! My own view is that agreement would be much more likely if the ISS simply recognized a modest collection of key quantities and concepts, *rigorously defined; with no attempt to label them.* Labelling would then be at the discretion of the writer, e.g. 'Denote ... (Item 23 in the ISS List of Basic Entities, reference ...) by J'.

Continuing the third section, *Coleman* carries out a detailed stereological investigation of mineral liberation in the case of spherical particles. *Kališnik et al.* recount an empirical comparison, by computer simulation, of various advocated methods of estimating number of spherical particles in a volume. Finally *David* describes how, even in the case of a specific organ — the liver — stereology has, along with 'other approaches', played its part in determining morphology; but how there are still unsolved problems.

In the fourth and final section, the historic *Stereologia* — the Bulletin of the ISS — which appeared from 1962–1966 under editors Underwood, Bach and DeHoff is reprinted in its entirety, with a brief introduction by *Underwood.* Note that, after the hiatus of 1967–8, and thanks to Weibel's strenuous efforts, stereological articles began appearing in the *Journal of Microscopy* in 1969.