Letter to the Editor

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A survey of education in crystallography in the USA

Sir,

To plan its future activities better, the subcommittee on Interdisciplinary Activities of the USA National Committee for Crystallography (of the National Research Council) decided to examine the current status of formal education in this field. This seemed especially appropriate at this time. Improved detection schemes are under active development and there are new intense sources such as rotating anodes. National facilities for even more intense X-radiation (synchrotron sources) are being developed. A national small-angle neutron scattering facility is commencing at Oak Ridge National Laboratory and there is continued development of an intense pulsed neutron source at Argonne National Laboratory. Centers in these areas exist already in several places outside the USA and others are under development. These laboratories are opening areas of study, and making previously extremely difficult experiments almost routine. The increased activity stimulated by these new developments will greatly enhance the need for many scientists and engineers to understand the new results, even if they are not directly in the field.

Crystallographers generally consider themselves to be practitioners of an interdisciplinary science, and the extent that this is taken into account in formal training was of interest, as well as the numbers of students being trained. The results might also be useful to the American Crystallographic Association in planning meetings in the future, to better foster the interdisciplinary activities of actual interest and to arrange more clearly to serve the future crystallography community.

Accordingly, in the winter of 1976–77 a thirteen-page questionnaire was prepared by the author, reviewed by the committee, and distributed to 456 people in academic institutions. The names were chosen (by a secretary unfamiliar with the field to avoid bias other than the interest in crystallography expressed by membership in ACA) to include one member in each department, in each university or college listed in the ACA directory. In addition, questionnaires were sent to those involved in the field listed in the *Metallurgy/Materials Education Yearbook* (ASM, 1976) as this group is not yet well represented in the ACA membership. Fol-

Table 1. *Results of survey on education in crystallography in the USA*
Texts given under 16, and 25 are Cullity (1978), Stout & Jensen (1968). Blundell & Johnson (1976), Warren (1969) and Hirsch, Howie, Nicholson, Pashly & Whelan (1965).

1. Area	Biology, Biomedical Engineering, Biophysics, Biochemistry	Chemistry, Chemical Engineering	Geology, Geophysics, Earth Sciences	Materials Science and Engineering (Metallurgy, Ceramics, Polymers)	Physics	Miscellaneous Other Fields (Design, Computer Systems)
2. Questionnaires sent	70	162	30	96	33	22
3. % returns	51	60	77	57	39	55
4. % of returns teaching in area	56	66 (½ as small parts of other courses)	83	76	62	0
5. # of faculty doing research in this area (in No. 3)	38	120	38	128	13	
6. # postdoctorates	48	62	6	58	6	
7. # graduate students	38	181	75	304	19	
8. # undergraduates	3	2	---	---	---	
9. Equipment (% of No. 4)	83% modern automated units and film equipment, one E.M. only, 25% film only.	9% film only 51% 1 or more automated diffractometers	most had well-equipped laboratories including automated units, film techniques	most have electron microscopes; 69% had extensive x-ray equipment with cameras, diffractometers. Equipment old; little use of computer controls	only 38% of No. 4 had adequate laboratories	
10. Complete undergraduate courses,%	0	14 (one with 2 courses)	79 (5 with 2 or more courses up to 4)	100	25	
11. % of No. 10 including extensive labs	graduate courses open to undergraduates	56	53 (powder and single crystal)	95	1 school	
12. % of No. 10 including other than x-ray diffraction		33	47 (spectroscopy, E.M., optics) tensor properties	21	0	
13. % of No. 10 on electrons or neutrons solely		0	0	12 (mostly E.M.)	0	
14. % of No. 10 including modern structure methods		91	13	17	100	
15. % of No. 10 including reciprocal space		(no department had both undergrad. and grad. courses) 100	33	24	100	
16. Dominant texts (% of No. 10)		None	None	Cullity	---	
17. Course size		10	21	19	9	
18. % of No. 4 recommending courses in other departments	10	11	5	19	25	
19. Graduate courses % of No. 4 on diffraction	50	40 (2 with 2)	68 (3 with 3-4 courses)	81	63	
20. % of No. 19 with extensive labs	50 (5)	31	62	82	0	
21. % of No. 19 including modern structure methods	100	100 (This was the essential content of all courses; little else including powder diffraction was covered)	40	32	40	
22. % of No. 19 including dynamical theory	0	0	0	26	40	
23. % of No. 19 including electrons and neutrons	10 (1) (4 covered fiber patterns, SAS)	12	15	24	20	
24. % of No. 19 offering graduate courses other than x-rays (i.e. neutrons, electrons)	0	4	0	62 (mostly E.M) 2 schools neutrons	0	
25. Dominant texts	Stout & Jensen (4), Blundell & Johnson (5)	Stout & Jensen (16 courses)	none	Warren; Hirsch et al., on E.M.	none	
26. No. of schools offering two or more graduate courses at graduate level	3	2	2	20 (up to 6 courses in 3 schools)	1	
27. Average course size	5	11	9	12	5	
28. % of students in all courses from other departments	35	24	23	16	46	

low-up letters were sent to those who had not replied on March 23, and April 8, 1977 urging that the questionnaires be filled out and returned, or passed to someone in the department who was more active in teaching. At the end of June when returns essentially ceased, there were 236 replies, representing active groups with over 400 faculty and over 800 research students. While no such survey can ever be complete, this would seem to represent the major portions of the actual activities in this field in the universities and colleges in the USA.

The results are presented in Table 1, and an examination of this summary led to the following observations:

(1) The field is particularly weak in the physics community; there are very few groups, and the equipment is poor. Five schools had graduate courses but the laboratory component was minimal. Only two had breadth in their coverage. Crystallography as a discipline is no longer well represented in physics curricula, despite its past history and new horizons. Only eight of the schools contacted were teaching in the area and only three of the eight were adequately equipped. Staff will be required for the new facilities to develop the equipment and theory needed to optimize their use. There is still time for this community to respond to this need.

(2) The ACA might wish to involve the large activity in the materials community more directly.

(3) The broadest scope of education in the field appears to be available in geology and materials departments.

(4) In the biological and chemical fields, despite excellent available equipment in research groups, there is inadequate laboratory work associated with many courses, and the course content is involved primarily with only structure determination. Students need a broader training, especially since most will undoubtedly work in industrial and government laboratories, where they could be much more helpful if they knew about the vast range of possibilities for information from scattering, such as small-angle studies, particle size, powder work, the specific usefulness of electrons and neutrons, surface studies and the new spectroscopies. Certainly part of the training in structure determination could be carried out informally in each research group, while providing a broader scope for the much larger audience in the classroom. (Such broader courses might even increase the class sizes in these fields.) There are too few courses being offered in biology departments.

(5) There is some weakness in the fundamentals taught in the materials community, as the teaching centers around Bragg's law in scalar form, without reciprocal-space concepts. The training involves many applied topics, such as stress measurement, texture, and analysis, which do seem appropriate because many of the students terminate with a bachelor's degree and are employed in production situations. The more advanced courses are in need of updating, and are perhaps too closely tied to available texts.

(6) There is ample room for developing courses that would be broader in scope (and hence probably of greater interest) if university crystallographers would try to develop appropriate interdisciplinary sequences. Formal departments of crystallography are probably not needed, but the lack of interaction that now exists is surprising. Local interactions could result in joint courses or course sequences with a breadth that does more justice to our entire field. Without such activities we force our students into a narrow mold, which will only deepen the separation of the various aspects of our field in the future, as some of the current students move into the teaching profession.

The questionnaires also indicated that there was extensive training in classical crystallography in geology departments, and good coverage of the powder method and its practical uses, as well as elementary fluorescent analysis in geology and materials. There was some quite brief initial exposure to crystallography and diffraction in many courses in general chemistry and physical chemistry.

The author would like to thank Mrs Kay Jensen for her help in organizing this survey. He also wishes to express appreciation to the other members of the committee for advice and comments throughout this project, (Drs J. Bregman, S. Abrahams, M. Mueller, Q. Johnson, D. Dahm and Professor R. Young).

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Crystallographers

This section is intended to be a series of short paragraphs dealing with the activities of crystallographers, such as their changes of position, promotions, assumption of significant new duties, honours, etc. Items for inclusion, subject to the approval of the Editorial Board, should be sent to the Executive Secretary of the International Union of Crystallography (J. N. King, International Union of Crystallography, 13 White Friars, Chester CH1 1NZ, England).

Dr **David R. Davies,** Laboratory of Molecular Biology, National Institutes of Health, Bethesda, Maryland, and Dr **Isabella L. Karle,** US Naval Research Laboratory, Washington,DC, have been elected to the USA National Academy of Sciences.

Professor **P. P. Ewald** received the Max-Planck Medal of the Deutsche Physikalische Gesellschaft on 3 July 1978.

Dr **Thomas Rundell Lomer,** Senior Lecturer and Departmental Tutor in the Department of Physics, University of Birmingham, died suddenly and prematurely on 21 July 1978. He is best known for his studies of metal soaps, but has published also on other aspects of crystallography and biophysics. He is survived by his widow and four children.

Book Review

Works intended for notice in this column should be sent direct to the Book-Review Editor (J. H. Robertson, School of Chemistry, University of Leeds, Leeds LS2 9JT, England). As far as practicable books will be reviewed in a country different from that of publication.

Crystal growth and materials. ECCG1, Zürich, 1976. Edited by *E. Kaldis* and *H. J. Scheel*. Vol. 2 of the series: **Current topics in materials science.** Edited by *E. Kaldis*. Pp. xvi + 916. Amsterdam: North-Holland, 1977. Price $122.50, Dfl. 300.00.

As the title suggests, this book performs two functions. On one hand, it is a collection of the sometimes extended versions of 28 invited papers which were presented