

face. From measurement of shadow-length these steps are found to  $50 \pm 10$  Å. in height. The micrograph therefore resolves structure in two crystallographic directions, namely, along  $a$  and along  $c$  on the crystal face. It is further evident from the micrograph that the molecules in the crystal are arranged in successive columns parallel to the  $b$ -axial direction, and this is confirmed by the fact that cross-shadowing does not improve resolution along  $b$ . It can be seen that the individual columns are in some instances incomplete; the inset enlargement gives two examples of this type of edge dislocation in the crystal lattice.

A direct comparison of the data from X-ray analysis and from electron microscope examination is now possible for the first time for this protein. Since the crystals of  $\beta$ -lactoglobulin were of necessity dried before examination, the results from them can be compared only with the X-ray diffraction results<sup>7</sup> from air-dried preparations. Such results are now given again in the following communication from Dr. D. P. Riley. The periodicity agrees well with previously recorded values for the  $c$ -axial length<sup>7,8</sup>, as does the height of the molecular steps with the  $a$ -axial value. The concept of molecular packing in columns is supported by the (100) Patterson section given in the accompanying letter.

I wish to thank Prof. J. M. Robertson for his interest and encouragement in this work, the Rockefeller Foundation for an equipment grant to the Department, and Imperial Chemical Industries, Ltd., for a research fellowship. I am grateful to Mrs. D. Hodgkin for the specimen of  $\beta$ -lactoglobulin and for making available to me the X-ray data published in thesis form.

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<sup>1</sup> Wyckoff, R. W. G., *Acta Cryst.*, **1**, 292 (1948).

<sup>2</sup> Cosslett, V. E., and Markham, R., *Nature*, **161**, 250 (1948).

<sup>3</sup> Wyckoff, R. W. G., "Electron Microscopy", chapter 10 (Interscience Publishers, New York, 1950).

<sup>4</sup> Crowfoot, D., and Riley, D. P., *Nature*, **141**, 521 (1938).

<sup>5</sup> Dawson, I. M., and Vand, V., *Nature*, **167**, 476 (1951).

<sup>6</sup> Dawson, I. M., and Vand, V., *Proc. Roy. Soc., A*, **206**, 555 (1951).

<sup>7</sup> Riley, D. P., D.Phil. thesis, University of Oxford (1942).

<sup>8</sup> Senti, F. R., and Warner, R. C., *J. Amer. Chem. Soc.*, **70**, 3318 (1948).

### Structure of Dry $\beta$ -Lactoglobulin Crystals

I AM encouraged by Dr. Dawson's most interesting communication to present some crystallographic results on  $\beta$ -lactoglobulin which have hitherto only been available in a thesis<sup>1</sup> or in articles<sup>2</sup> mainly of a review character. Attention will be confined to the dry orthorhombic crystals, often described as 'tabular'.

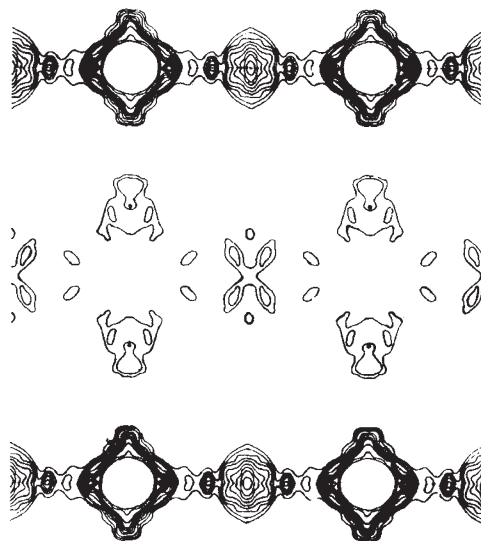
Although I have not examined the actual batch used by Dawson, the habit of his crystals is essentially the same as that of crystals which I have investigated from several other sources and may be written as: tabular {100} elongated along [010]; strongly developed {100} with subsidiary {001} and indefinite {0kl}. The crystals show a pseudo-uniaxial interference figure and appear isotropic when viewed along  $c$  parallel to  $a$ .

The unit-cell dimensions of the air-dry crystals are  $a = 60$  Å.,  $b = 63$  Å.,  $c = 110$  Å. (N.B. The values

given in an earlier note<sup>3</sup> are incorrect.) Values in good agreement with these have been reported since by other workers: Fankuchen<sup>4</sup>,  $a = 60$  Å.,  $b = 62$  Å.,  $c = 111$  Å.; Senti and Warner<sup>5</sup>,  $a = 60.7$  Å.,  $b = 61.0$  Å.,  $c = 112.4$  Å. Perfect agreement would not be expected owing to the differences in residual water-content from crystal to crystal.

The relative intensities of 142  $hkl$  reflexions have been estimated visually and used to calculate the principal Patterson projections and Patterson-Harker sections. That the structure of the air-dry crystals is not very disordered is demonstrated by the fact that X-ray reflexions occur out to a spacing limit of about 4.5 Å. The space group is  $P 2_1 2_1 2_1$ . The density of the air-dry crystals was measured as  $1.27 \pm 0.01$ , but the later figure of McMeekin and Warner<sup>6</sup>,  $1.260 \pm 0.003$ , is more precise.

Dawson's unit-cell dimensions are  $a = 50 \pm 10$  Å.,  $b$  undetermined,  $c = 105 \pm 5$  Å. It is to be expected that these values would be somewhat lower than those given by X-ray measurements on air-dry crystals, as the electron-microscope shadowing technique probably involves further drying in a vacuum chamber. The air-dry crystals still contain<sup>6</sup> 9.78 per cent of water by weight.



Patterson section at  $x = 0$ ,  $P(0, y, z)$ , for air-dry lactoglobulin crystals.  $b = 63$  Å., horizontal;  $c = 110$  Å., vertical. Higher contours around origin not drawn

The agreement between the electron micrograph and X-ray diffraction evidence is not confined to this near coincidence of unit-cell dimensions. The accompanying figure reproduces the Patterson section at  $x = 0$ ,  $P(0, y, z)$ , in which only the higher contours have been drawn, the lowest contour line shown having a value of 10 arbitrary units. For clarity, the very dense region around the origin has been omitted as the contours there rise to a value of 49. This map represents the summation of interatomic vectors lying in the (100) plane and is therefore directly comparable with the electron micrograph. Its main features are the pronounced band of vector density parallel to  $b$  at  $z = 0$  and, conversely, the absence of any very high peaks in the middle of the pattern. This is exactly the Patterson vector-map corresponding to the arrangement of molecules shown in the micrograph, wherein the molecules lie in

columns parallel to  $b$ , the columns being separated, centre-to-centre, by the whole  $c$  cell-dimension. The Patterson section, however, reflects further structure in the (100) layers which the electron micrograph is unable to resolve. There is, first, the fundamental  $b$ -lattice translation. Second, the relatively high peak at  $y = \frac{1}{2}$ ,  $z = 0$  shows that the molecules which constitute the columns parallel to  $b$  are probably placed with their centres  $b/2 = 31.5$  A. apart, that is, there is a pseudo-halving of this cell dimension. Third, the two distinctly resolved peaks on the  $z = 0$  line, at 10 A. and at  $b/2 - 10$  A., indicate the presence of marked intramolecular vectors parallel to  $b$  of length 10 A.

On the basis of eight molecules in the unit cell, the anhydrous molecular weight is 35,800, the errors arising particularly from imprecise knowledge of the water-content. Senti and Warner<sup>5</sup> arrive at the more accurate value of 35,400 from consideration of the wet crystals. The volume of the anhydrous molecule, subject to the same errors, is 44,400 A.<sup>3</sup>, and it can be shown that 85 per cent of the available free volume in the air-dry crystal is occupied by water.

Reliable knowledge of the shape of the molecule with its actual linear dimensions is now clearly very near and should result from a re-examination of the X-ray data in conjunction with further electron micrographs.

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<sup>1</sup> Riley, D. P., D.Phil. thesis, University of Oxford (1942).

<sup>2</sup> Crowfoot, D. M., *Chem. Rev.*, **28**, 215 (1941). Riley, D. P., "Médécine et Biologie", No. 5, 35 (Liège and Paris, 1947).

<sup>3</sup> Crowfoot, D. M., and Riley, D. P., *Nature*, **141**, 521 (1938).

<sup>4</sup> Fankuchen, I., *J. Amer. Chem. Soc.*, **64**, 2504 (1942).

<sup>5</sup> Senti, F. R., and Warner, R. C., *J. Amer. Chem. Soc.*, **70**, 3318 (1948).

<sup>6</sup> McMeekin, T. L., and Warner, R. C., *J. Amer. Chem. Soc.*, **64**, 2393 (1942).

## SMITHSONIAN INSTITUTION

### ANNUAL REPORT FOR 1949-50

THE report of the Secretary of the Smithsonian Institution for the year ended June 30, 1950\*, points out that increasing pressures on all sides and definite trends in certain countries towards the regimentation of science enhance the importance of the freedom of inquiry which the Institution has always sought to further, and it records that government support of the ten branches of the Institution has not kept pace with modern exigencies, particularly in physical plant and facilities.

Reference is again made to congestion at the National Museum and at the Natural History and the Arts and Industries Building. The task of modernizing exhibits in the museums, which were visited by more than 2,600,000 persons during the year, is now proceeding as rapidly as funds become available for the purpose. The collections at the National Museum were increased by about 793,300 specimens during the year, while, in the field, investigations of the bird life of northern Colombia and of eastern Panama continued. Natural history collections were made on Prince Patrick Island in the Canadian Arctic archipelago, and other work has

\* Report of the Secretary of the Smithsonian Institution and Financial Report of the Executive Committee of the Board of Regents for the Year ended June 30, 1950. (Publication 4020.) Pp. ix+161. (Washington, D.C.: Govt. Printing Office, 1950.) 50 cents.

included a short field study of molluscs inhabiting the salt marshes on the eastern shore of Maryland, botanical field studies on Big Pine Key, Florida, extensive collections of lichens under the auspices of the Arctic Institute of North America, and a study of the origin and occurrence of rare sulphate minerals at the Geysers and Island Mountain, California; four field parties studied problems in invertebrate palaeontology.

The Director of the Bureau of American Ethnology continued his studies of archaeological collections made in Panama, and the survey work of the Bureau for the year has covered twenty-six reservoirs situated in eight States and five river basins. At the end of the year, excavations were completed or under way in thirteen reservoir areas in nine States, and, since the start of this River Basin Survey in July 1946, 120 reports have been issued, the investigations being conducted in co-operation with the National Park Service, the Bureau of Reclamation of the Department of the Interior, the Corps of Engineers and other non-government institutions. Archaeological investigations conducted on Cornwallis Island in the Canadian Arctic have yielded a large collection of artefacts which have thrown considerable light on the prehistoric inhabitants of the region; further studies were made of the Iroquois, especially at the Tonawanda and Alleghany Seneca reservations in western New York, and Dr. J. P. Harrington continued his study of the grammar of the Abnaki language at Old Town, Maine. The Institute of Social Anthropology continued its anthropological teaching and research programmes in Brazil, Colombia, Mexico and Peru, and issued during the year Vol. 5 of the "Handbook of South American Indians".

The International Exchange Service handled 1,009,675 packages of government, literary and scientific publications, an increase of about twenty per cent, and the majority of the publications now being transmitted are current issues. Consignments are now made to all countries except Rumania and China, and ninety-nine sets of United States official publications are now sent abroad in exchange for similar publications of other countries, fifty-nine of these being full sets. A list of depositories of the sets is given in the report. The value of the National Zoological Park has been enhanced by addition of a number of animals never before exhibited there, and research has continued to be an important feature of its operations. At the Astrophysical Observatory the Division of Radiation and Organisms completed its reorganization and reconstruction of its laboratories; and the Division of Astrophysical Research, besides constructing three silver-disk pyrheliometers for institutions in New Zealand, Venezuela and Rumania, and two modified Angström pyrheliometers and a special water-vapour spectroscope for a meteorological institute in Belgium, has calculated that there has been an increase of 0.25 per cent in the radiation emitted by the sun in the two decades 1925-44 from solar-constant determinations at the Chilean station.

Twenty-one scientific workers visited Barro Colorado Island in the Canal Zone Biological Area during the year and worked at various research projects. The Smithsonian Library received 53,035 publications during the year and currently enters 16,961 periodicals, mostly in exchange for its own publications. With the Secretary's report is included the financial report of the executive committee of the Board of Regents.