

REFERENCES

References

- Abraham, E. P. & Robinson, R. (1937). *The crystallization of lysozyme*. *Nature (London)*, **140**, 24.
- Alderton, G., Ward, W. H. & Fevold, J. (1945). *Crystallization of lysozyme chloride*. *J. Biol. Chem.* **157**, 43–58.
- Arndt, U. W., North, A. C. T. & Phillips, D. C. (1964). *Adaptation of a linear diffractometer to measure three X-ray reflections quasi-simultaneously*. *J. Sci. Instrum.* **41**, 421–425.
- Arndt, U. W. & Phillips, D. C. (1961). *The linear diffractometer*. *Acta Cryst.* **14**, 807–818.
- Arndt, U. W. & Riley, D. P. (1952). *Side-window proportional counters*. *Proc. Phys. Soc. London A*, **65**, 74–84.
- Bijvoet, J. M. (1954). *Structure of optically active compounds in the solid state*. *Nature (London)*, **173**, 888–891.
- Blake, C. C. F. (1968). *The preparation of isomorphous derivatives*. *Adv. Protein Chem.* **23**, 59–120.
- Blake, C. C. F., Fenn, R. H., North, A. C. T., Phillips, D. C. & Poljak, R. J. (1962). *Structure of lysozyme. A Fourier map of the electron density at 6 Å resolution obtained by X-ray diffraction*. *Nature (London)*, **196**, 1173–1178.
- Blake, C. C. F., Johnson, L. N., Mair, G. A., North, A. C. T., Phillips, D. C. & Sarma, V. R. (1967). *Crystallographic studies of the activity of hen egg-white lysozyme*. *Proc. R. Soc. London Ser. B*, **167**, 378–388.
- Blake, C. C. F., Koenig, D. F., Mair, G. A., North, A. C. T., Phillips, D. C. & Sarma, V. R. (1965). *Structure of hen egg-white lysozyme. A three-dimensional Fourier synthesis at 2 Å resolution*. *Nature (London)*, **206**, 757–761.
- Blake, C. C. F. & Phillips, D. C. (1962). *Effects of X-irradiation on single crystals of myoglobin*. In *Biological effects of ionizing radiation at the molecular level*. Brno, Czechoslovakia: International Atomic Energy Agency, Vienna.
- Blow, D. M. (1958). *The structure of haemoglobin. VII. Determination of phase angles in the non-centrosymmetric [100] zone*. *Proc. R. Soc. London Ser. A*, **247**, 302–336.
- Blow, D. M. & Crick, F. H. C. (1959). *The treatment of errors in the isomorphous replacement method*. *Acta Cryst.* **12**, 794–802.
- Blow, D. M. & Rossmann, M. G. (1961). *The single isomorphous replacement method*. *Acta Cryst.* **14**, 1195–1202.
- Bluhm, M. M., Bodo, G., Dintzis, H. M. & Kendrew, J. C. (1958). *The crystal structure of myoglobin IV. A Fourier projection of sperm-whale myoglobin by the method of isomorphous replacement*. *Proc. R. Soc. London Ser. A*, **246**, 369–389.
- Buerger, M. J. (1959). *Vector space*. New York: Wiley.
- Canfield, R. E. & Liu, A. K. (1965). *The disulfide bonds of egg white lysozyme (muramidase)*. *J. Biol. Chem.* **240**, 1997–2002.
- Carlstrom, D. (1962). *The polysaccharide chain of chitin*. *Biochim. Biophys. Acta*, **59**, 361–364.
- Cheetham, J. C., Artymiuk, P. J. & Phillips, D. C. (1992). *Refinement of an enzyme complex with inhibitor bound at partial occupancy*. *J. Mol. Biol.* **224**, 613–628.
- Collins, J. F. & Richmond, M. (1962). *A structural similarity between N-acetyl muramic acid and penicillin as a basis for antibiotic action*. *Nature (London)*, **195**, 142–143.
- Corey, R. B., Donohue, J., Trueblood, K. N. & Palmer, K. J. (1952). *An X-ray investigation of air-dried lysozyme chloride crystals: the three-dimensional Patterson function*. *Acta Cryst.* **5**, 701–710.
- Cox, E. G. & Jeffrey, G. A. (1939). *Crystal structure of glucosamine hydrobromide*. *Nature (London)*, **143**, 894–895.
- Crick, F. H. C. & Magdoff, B. S. (1956). *The theory of the method of isomorphous replacement for protein crystals. I*. *Acta Cryst.* **9**, 901–908.
- Cullis, A. F., Muirhead, H., Perutz, M. F., Rossmann, M. G. & North, A. C. T. (1961). *The structure of haemoglobin VIII. A three-dimensional Fourier synthesis at 5.5 Å resolution: determination of the phase angles*. *Proc. R. Soc. London Ser. A*, **265**, 15–38.
- Cullis, A. F., Muirhead, H., Perutz, M. F., Rossmann, M. G. & North, A. C. T. (1962). *The structure of haemoglobin IX. A three-dimensional Fourier synthesis at 5.5 Å resolution: description of the structure*. *Proc. R. Soc. London Ser. A*, **265**, 161–187.
- Dauben, C. H. & Templeton, D. H. (1955). *A table of dispersion corrections for X-ray scattering of atoms*. *Acta Cryst.* **8**, 841–842.
- Dickerson, R. E., Kendrew, J. C. & Strandberg, B. E. (1961). *The crystal structure of myoglobin: phase determination to a resolution of 2 Å by the method of isomorphous replacement*. *Acta Cryst.* **14**, 1188–1195.
- Dickerson, R. E., Reddy, J. M., Pinkerton, M. & Steinrauf, L. K. (1962). *A 6 Å model of triclinic lysozyme*. *Nature (London)*, **196**, 1178.
- Fenn, R. H. (1964). *An X-ray crystallographic study of some mercury compounds and their use in protein structure analysis*. Davy Faraday Research Laboratory, The Royal Institution, London 182.
- Fenn, R. H., Phillips, D. C. & Oldham, J. W. H. (1963). *Crystal structure of $(CH_3)_3S.HgI_3$ and the configuration of the HgI_3^- ion*. *Nature (London)*, **198**, 381–382.
- Fleming, A. (1922). *On a remarkable bacteriolytic element found in tissues and secretions*. *Proc. R. Soc. London Ser. B*, **93**, 306–317.
- Ford, L. O., Johnson, L. N., Machin, P. A., Phillips, D. C. & Tjian, R. (1974). *Crystal structure of a lysozyme-tetrasaccharide lactone complex*. *J. Mol. Biol.* **88**, 349–371.
- Furnas, T. C. (1957). *Single crystal orienter instruction manual*. General Electric Company, Milwaukee, USA.
- Green, D. W., Ingram, V. M. & Perutz, M. F. (1954). *The structure of haemoglobin IV. Sign determination by the isomorphous replacement method*. *Proc. R. Soc. London Ser. A*, **225**, 287–307.
- Green, D. W., North, A. C. T. & Aschaffenburg, R. (1956). *Crystallography of the β-lactoglobulins of cows' milk*. *Biochim. Biophys. Acta*, **21**, 583–585.
- Hadfield, A. T., Harvey, D. J., Archer, D. B., MacKenzie, D. A., Jeenes, D. J., Radford, S. E., Lowe, G., Dobson, C. M. & Johnson, L. N. (1994). *Crystal structure of the mutant D52S hen egg white lysozyme with an oligosaccharide product*. *J. Mol. Biol.* **243**, 856–872.
- Hamaguchi, K. & Imahori, K. (1964). *Optical measurements of the secondary structure of lysozyme*. *J. Biochem. (Tokyo)*, **55**, 388–391.
- Hamilton, W. C. (1955). *On the treatment of unobserved reflexions in the least-squares adjustment of crystal structures*. *Acta Cryst.* **8**, 185–186.
- Hamilton, W. C., Rollett, J. S. & Sparks, R. A. (1965). *On the relative scaling of X-ray photographs*. *Acta Cryst.* **18**, 129–130.
- Handoll, H. H. G. (1985). *Crystallographic studies of proteins*. DPhil thesis, University of Oxford.
- Harker, D. (1956). *The determination of the phases of the structure factors of non-centrosymmetric crystals by the method of double isomorphous replacement*. *Acta Cryst.* **9**, 1–9.
- Hart, R. G. (1961). *Refinement of heavy atom parameters other than relative y's*. *Acta Cryst.* **14**, 1194–1195.
- Imoto, T., Johnson, L. N., North, A. C. T., Phillips, D. C. & Rupley, J. A. (1972). *Vertebrate lysozymes*. New York and London: Academic Press.
- Jacobson, R. A., Wunderlich, J. A. & Lipscomb, W. N. (1961). *The crystal and molecular structure of cellobiose*. *Acta Cryst.* **14**, 598–607.
- Jeffrey, G. A. (1990). *Crystallographic studies of carbohydrates*. *Acta Cryst.* **B46**, 89–103.
- Johnson, L. N. (1966). *The crystal structure of N-acetyl-α-D-glucosamine*. *Acta Cryst.* **21**, 885–891.
- Johnson, L. N. (1967). *An interaction between lysozyme and penicillin*. *Proc. R. Soc. London Ser. B*, **167**, 439–440.
- Johnson, L. N. & Phillips, D. C. (1964). *Crystal structure of N-acetylglucosamine*. *Nature (London)*, **202**, 588–589.
- Johnson, L. N. & Phillips, D. C. (1965). *Structure of some crystalline lysozyme-inhibitor complexes determined by X-ray analysis at 6 Å resolution*. *Nature (London)*, **206**, 761–763.
- Jollès, J., Jaurgui-Adell, J. & Jollès, P. (1964). *Amino-acid sequence & S–S bridges of HEWL*. *C. R. Acad. Sci. Paris*, **258**, 3926–3928.
- Jolles, P. (1996). Editor. *Lysozymes: model enzymes in biochemistry and biology*. Basel, Boston, Berlin: Birkhäuser Verlag.

26. A HISTORICAL PERSPECTIVE

- Kendrew, J. C., Bodo, G., Dintzis, H. M., Parrish, R. G., Wyckoff, H. & Phillips, D. C. (1958). *A three-dimensional model of the myoglobin molecule obtained by X-ray analysis*. *Nature (London)*, **181**, 662–666.
- Kendrew, J. C., Dickerson, R. E., Strandberg, B. E., Hart, R. G., Davies, D. R., Phillips, D. C. & Shore, V. C. (1960). *Structure of myoglobin. A three-dimensional Fourier synthesis at 2 Å resolution*. *Nature (London)*, **185**, 422–427.
- Kraut, J., Sieker, L. C., High, D. F. & Freer, S. T. (1962). *Electron density map of chymotrypsinogen at 6 Å resolution*. *Proc. Natl Acad. Sci. USA*, **48**, 1417.
- Lavington, S. (1980). *Early British computers: the story of vintage computers and the people who built them*. Manchester University Press.
- Lemieux, R. U. & Huber, G. (1955). *Can. J. Res.* **33**, 128–133.
- Lipson, H. & Cochran, W. (1968). *The determination of crystal structures*. London: Bell.
- Mo, F. & Jensen, L. H. (1975). *A refined model for N-acetyl- α -D-glucosamine*. *Acta Cryst.* **B31**, 2867–2873.
- North, A. C. T. (1964). *Computer processing of automatic diffractometer data*. *J. Sci. Instrum.* **41**, 42–45.
- North, A. C. T. (1965). *The combination of isomorphous replacement and anomalous scattering data in phase determination of non-centrosymmetric reflexions*. *Acta Cryst.* **18**, 212–216.
- North, A. C. T., Phillips, D. C. & Matthews, F. S. (1968). *A semi-empirical method of absorption correction*. *Acta Cryst. A* **24**, 351–359.
- Perutz, M. F. (1967). *Concluding remarks*. *Proc. R. Soc. London Ser. B*, **167**, 448.
- Perutz, M. F., Rossmann, M. G., Cullis, A. F., Muirhead, H., Will, G. & North, A. C. T. (1960). *Structure of haemoglobin. A three-dimensional Fourier synthesis at 5.5 Å resolution, obtained by X-ray analysis*. *Nature (London)*, **185**, 416–422.
- Phillips, D. C. (1964). *On the design of single crystal diffractometers to measure a number of reflections simultaneously*. *J. Sci. Instrum.* **41**, 123–129.
- Phillips, D. C. (1966). *The three-dimensional structure of an enzyme molecule*. *Sci. Am.* pp. 78–90.
- Phillips, D. C. (1967). *The hen egg white lysozyme molecule*. *Proc. Natl Acad. Sci. USA*, **57**, 484–495.
- Poljak, R. J. (1963). *Heavy atom attachment to crystalline lysozyme*. *J. Mol. Biol.* **6**, 244–246.
- Ramachandran, G. N., Ramakrishnan, G. & Sasisekharan, V. (1963). *Aspects of protein structure*. London: Academic Press.
- Rollett, J. S. (1961). *Least-squares refinement in crystal-structure analysis*. In *Computing methods and the phase problem in X-ray crystal analysis*, p. 122. London: Pergamon Press.
- Rollett, J. S. & Sparks, R. A. (1960). *The correlation of intersecting layers of X-ray intensity data*. *Acta Cryst.* **13**, 273–274.
- Rupley, J. A. (1964). *The hydrolysis of chitin by concentrated hydrochloric acid and the preparation of low molecular weight substrates for lysozyme*. *Biochim. Biophys. Acta*, **83**, 245–255.
- Rupley, J. A. (1967). *The binding and cleavage by lysozyme of N-acetylglucosamine oligosaccharides*. *Proc. R. Soc. London Ser. B*, **167**, 416–428.
- Scouloudi, H. (1960). *Structure of seal myoglobin in projection*. *Proc. R. Soc. London Ser. A*, **258**, 181.
- Scouloudi, H. (1965). *The nature and configuration of the mercuri-iodide ion in the seal myoglobin derivative*. *J. Mol. Biol.* **12**, 17–26.
- Stanford, R. H., Marsh, R. E. & Corey, R. B. (1962). *An X-ray investigation of lysozyme chloride crystals containing complex ions of niobium and tantalum: three-dimensional Fourier plot obtained from data extending to a minimum spacing of 5 Å*. *Nature (London)*, **196**, 1172–1177.
- Steinlauf, L. K. (1959). *Preliminary X-ray data for some new crystalline forms of β -lactoglobulin and hen-egg-white lysozyme*. *Acta Cryst.* **12**, 77–79.
- Stryer, L., Kendrew, J. C. & Watson, H. C. (1964). *The mode of attachment of the azide ion to sperm whale myoglobin*. *J. Mol. Biol.* **8**, 96–104.
- Strynadka, N. C. J. & James, M. G. (1991). *Lysozyme revisited: crystallographic evidence for distortion of an N-acetyl muramic acid residue bound in site D*. *J. Mol. Biol.* **220**, 401–424.
- Tipper, D. J. & Strominger, J. L. (1965). *Mechanism of action of penicillins: a proposal based on their structural similarity to acyl-D-alanyl-D-alanine*. *Proc. Natl Acad. Sci. USA*, **54**, 1133–1141.
- Vernon, C. A. (1967). *The mechanisms of hydrolysis of glycosides and their relevance to enzyme-catalysed reactions*. *Proc. R. Soc. London Ser. B*, **167**, 389–401.
- Waser, J. (1951). *Lorentz factor for precession photographs*. *Rev. Sci. Instrum.* **22**, 563.
- Watson, H. C., Kendrew, J. C., Coulter, C. L. & Brändén, C.-I. (1963). *Progress with the 1.4 Å resolution myoglobin-structure determination*. *Acta Cryst.* **16**, A81.
- Wells, M. (1960). *Computation of absorption corrections on EDSAC II*. *Acta Cryst.* **13**, 722–736.
- Wenzel, M., Lenk, H. P. & Schutte, E. (1962). *Z. Physiol. Chem.* **327**, 13–20.
- Wilson, A. J. C. (1942). *Determination of absolute from relative X-ray intensity data*. *Nature (London)*, **150**, 151–152.
- Wise, E. M. & Park, J. T. (1965). *Penicillin: its basis site of action as an inhibitor of a peptide cross-linking reaction in cell-wall mucopeptide synthesis*. *Proc. Natl Acad. Sci. USA*, **54**, 75–81.
- Yang, J. T. & Doty, P. (1957). *ORD measurements on lysozyme*. *J. Am. Chem. Soc.* **79**, 761.