A Mechanical Cause of Homogeneity of Structure and Symmetry Geometrically Investigated; with special application to Crystals and to Chemical Combination

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IX. *A Mechanical Cause of Homogeneity of Structure and Symmetry Geometrically Investigated; with special application to Crystals and to Chemical Combination.* By WILLIAM BARLOW.*

[Abstract only. Published *in extenso* in *Scientific Proceedings of the Royal Dublin Society*, vol. viii. (n. s.) part vi., no. 62; also in *Groth's Zeitschrift für Krystallographie und Mineralogie*, xxix. 433, 1898.]

THIS paper is to be regarded as supplemental to the geometrical work on the nature of homogeneity by the same author, by which he has shown that every homogeneous structure, whatever its nature, displays one or other of the thirty-two kinds of crystal symmetry †.

The author begins by alluding to the various artificial devices for packing together a number of similar bodies which have from time to time been employed to imitate the different kinds of symmetry displayed by crystals; also to the evidence afforded by stereo-chemical investigations that a regular repetition in space which portrays the homogeneity of structure of crystals should be that of groups composed of two or more individuals rather than that of single bodies, as generally hitherto represented. He then remarks that probably the simplest conceivable kind of closest packing which gives diversity in unity of the elements of the structure, is that of a large number of spheres of two, three, or more different sizes, and argues that the condition of closest packing leads to homogeneity in a great number of such cases.

In order to avoid arbitrariness he suggests the use of elastic deformable balls, differing in material as well as in size, instead of that of rigid undeformable ones; and he points out that if an assemblage of this kind is subjected to some uniform compression which flattens the balls at the places of contact, it can be regarded as equivalent to a flock of mutually-repellent particles occupying the places of the ball-centres, and in equilibrium; provided that repulsion subsists only between near particles whose interaction is represented by the effect on one another of balls which touch.

* Read March 12, 1897.
† See Mineralogical Magazine, vol. xi. p. 119.

For the purpose of imitating two of the principal universal properties of molecular matter, the balls employed to form the assemblages referred to are (1) regarded as suffering contraction or expansion under change of conditions, those of one size, composed of one material, changing at a different rate from those of another material; and (2) it is postulated that ball can be attached to ball by an almost inextensible tie reaching from centre to centre through the place of contact, so that when tied in this way, the centres of two balls cannot get farther and farther apart under change of conditions, and thus the balls have, so to speak, to interpenetrate between tied centres if they expand.

A considerable number of closest-packed arrangements of balls of one, two, or more different sizes, some of which consist of groups of linked balls, and some of undetached ones, are described, and in each case the type of homogeneous structure which an assemblage presents is indicated, and it is further stated to which of the thirty-two systems of crystal symmetry it belongs.

From these examples it is contended that the following proposition is established :—

That assemblages belonging to all of the thirty-two classes of crystal symmetry result from closest-packing of balls of different sizes, when the relations between the different radii take the widest possible range of variety, and cases of packing together of spheres formed into groups in the way premised are included, as well as the cases in which the spheres are unlinked.

Facts with regard to crystal growth are then cited to show that symmetrical arrangement precedes solidification and that the accretion which takes place in cases of growing crystals is consistent with a conception of closest-packing brought about in the way described.

It is next pointed out that under some conditions the necessity for closest-packing will involve the production of *thin* curved assemblages, and the facts concerning thin curved and branched microscopic and other crystals are compared with cases of curved assemblages originated in this way.

The author then proceeds to describe the effect, in various different assemblages, of changing the conditions to which the balls are subjected past a critical point, and the consequent production of dimorphous assemblages, and compares these results with a number of cases of dimorphism and trimorphism occurring in crystals.

In closing the first section of the paper, it is suggested that a *plane of readiest cleavage* is not necessarily a plane the ties crossing which are ties of minimum strength under any given constant conditions, but a plane on the opposite sides of which contiguous parts which face one another are most diverse.

The second section is devoted to the symmetrical partitioning of the artificial assemblages of balls described in the first section, and to the comparison of the properties of the similar groups or units thus obtained with the experimentally ascertained properties of the molecules of the stereo-chemist, considerable space being given to the discussion of enantiomorphously-similar groupings.

Tables of all the types of grouping possible are added, also of the number of types obtainable by twofold substitution in these typical groupings.

In the third section the author explains the formation of twinned assemblages of balls consistently with closest-packing, and compares the results with the actual crystal twins ; the properties of many of the modified artificial assemblages described closely resemble many optical and other anomalies of crystals.

Isomorphism, crystalloid structure, and some kinds of diffusion are also dealt with in this section.

In the sections 5, 6, and 7 certain results of closest-packing which resemble some of the incidents of *chemical change* are referred to.

The paper concludes with an Appendix in which the ideas that form the basis of the investigation are stated as definite concepts, and a fundamental *law of closest-packing* is enunciated.

An index is added.

Discussion.

Prof. Herschel said he was particularly pleased with the models. He thought it probable that a wide application would be found for the author's results. There was no doubt much to be learnt from models built up of spheres of two or more sizes, but it would be necessary to learn a great deal more about these symmetrical arrangements before they could be applied with any degree of certainty.

Mr. Fletcher said it was impossible to criticise the paper without long and careful study. From certain hypotheses the author had deduced a law of "closest packing" that seemed adequate to explain many results observed by chemists and crystallographers; at the same time admitting that the law might be presumed from other reasoning. By his models he had tried to present a picture not of the forms of atoms or molecules, but merely analogical representations of the probable structure of particles. Hitherto the research had been confined to determining the possible arrangements of particles all of one kind, but here were examples of packed spheres of various sizes. It was not quite clear how, in an elementary substance, there could be such a structure, although there certainly are cases of polymorphism awaiting explanation, as, for instance, with sulphur. The paper, with its 188 pages of MS., represented a vast amount of clear thinking and many years of admirable work.

Prof. Adams called the attention of Fellows of the Physical Society to the Museum at King's College, where were the original models as made and used by the early investigators of this branch of Physics.

Prof. Miers (communicated too late for reading). The principle of "close packing" was not new, but Mr. Barlow was the first to extend it to explain solution, diffusion, and stereo-chemical problems. His remarks on the growth of curved crystals, vicinal faces, and pseudosymmetrical crystals were open to criticism. With regard to vicinal faces, however, leucite seemed to be a mineral in accord with his hypothesis. The author regarded a crystal as consisting of mutually repellent particles of different sorts; this seemed a very right way of attacking the problem of crystal structure, and would explain some recent observations of Rinne on crystals consisting of water particles and silicate particles. Further, Mr. Barlow had considered the way in which an assemblage might be broken up by the loosening of the ties, and the change of partners, among individual members. That is to say, he had considered crystallization and solution, features quite ignored by ordinary theories. His view of crystal structure failed to explain why crystals should have faces, and gave no hint as to the controlling forces which keep mutually repellent particles together. Nevertheless it suggested, among other striking analogies, those bearing on the relationship between crystal structure and chemical constitution, and the irregularities of crystals. Mr. Barlow had opened up a very promising line of inquiry.

Mr. Barlow, in replying, said he greatly appreciated the interest shown in his work.

X. *Electrical Signalling without Connecting-Wires. By* Prof. Oliver Lodge, *D.Sc., F.R.S., Professor of Physics at University College, Liverpool.**

[Abstract.]

From the nature of the oscillatory disturbances emanating from any of the customary forms of Hertz vibrator, syntony has hitherto been only very partially available as a means for discriminating between receivers. There is, in fact, so rapid a decrease in the amplitude of the vibrations that almost any receiver can respond to some extent. Discrimination by syntony is possible with magnetic systems of space telegraphy, where the magnetic energy much exceeds the electric, *i. e.*, as between two separated inductive coils ; and by the use of such coils, appropriately applied, the author has been able to attain fair syntony even with true Hertz waves—*i. e.*, he has constructed spark-gap oscillators, with sufficient persistence of vibration, and syntonised resonators. The "coherer" principle can be applied to either a purely magnetic or to the Hertzian system. It was first used by the author in devising lightning-guards, and afterwards in his magnetic system of telegraphy by inductive circuits, each in series with a Leyden jar ; a pair of knobs in near contact, or other over-flow gap, being provided in the receiving apparatus. This was the first meaning of a "coherer" in the electrical sense as used by the author : it referred to a

* Read January 21, 1898.