

Optical Rotatory Dispersion.¹

A TRIBUTE TO THE MEMORY OF BIOT (1774-1862).

By Prof. T. M. LOWRY, F.R.S.

LAST year, in Amsterdam and in Paris, we celebrated the jubilee of the foundation in 1874 of the science of stereo-chemistry. The year before, in Paris and in Strasbourg, the centenary of the birth in 1823 of Louis Pasteur was commemorated. This series of celebrations would be incomplete unless it covered also the 150th anniversary of the birth in 1774 of the French physicist, Jean Baptiste Biot. For, apart from Biot's pioneer work on optical rotatory power, there could have been no discovery of molecular dissymmetry by Pasteur; and, apart from the study of molecular dissymmetry, we should have known very little of "chemistry in space."

THE DISCOVERY OF ROTATORY DISPERSION.

One might have supposed that the discovery of optical activity would have preceded that of rotatory dispersion; that, after the rotation of the plane of polarised light had been discovered, further research would have shown that this rotation varied with the wave-length of the light. This, however, is the opposite to what actually happened, for it was the colours resulting from the unequal rotation of light of different wave-lengths by a plate of quartz that first attracted the attention of Arago (*Mém. Inst.*, 1811, 12, 93) and thus led to Biot's discovery of the laws of optical rotation.

In view of the fact that Biot was thus led to a knowledge of optical rotatory power through a study of the phenomena of rotatory dispersion, it is not surprising that he always included measurements of dispersion in his work on optically active substances. The example thus set would probably have been followed generally, but for the discovery in 1866 of the Bunsen burner. This device, which made it easy to produce monochromatic light of one colour, was fatal to the study of dispersion, since no other monochromatic light could be produced with equal ease. The custom therefore arose of measuring the optical rotatory power of organic compounds for one wave-length only; and even physical chemists, seeking to discover the influence of solvent, concentration, temperature or chemical constitution on rotatory power, were content to work with sodium light only, and thus to record a single point on a curve of unknown form. Biot, however, always recognised the supreme importance of dispersion in his studies of optical rotatory power, and this fact alone brings his work into closer relation with the researches of the twentieth century than with those of the nineteenth.

THE LAW OF INVERSE SQUARES.

In his first memoir (*Mém. Inst.*, 1812, 1, 1-372) Biot only recorded the fact that the rotations produced by a plate of quartz decreased progressively with change of colour from violet to red (pp. 256-257). In his second memoir (*Mém. Acad. Sci.*, 1817, 2, 41-136), however, he undertook a more exact "Re-

cherche de la loi des rotations des différens rayons simples dans le cristal de roche," and as a result he was able to announce immediately his well-known Law of Inverse Squares, $\alpha = k/\lambda^2$. For this law Biot was able to claim that "si elle n'est pas la loi de la nature elle en approche du moins assez pour pouvoir lui être substituée dans toutes les observations" (p. 85). It is noteworthy that Biot arrived at this important law in spite of the fact that he had no source of monochromatic light, and that his only wave-lengths were Newton's values for the boundaries of the different colours.

Special interest attaches to the graphical method which Biot used in order to express his Law of Inverse Squares. For this purpose Biot plotted along a horizontal axis the square of the wave-length of the light, and in a vertical direction the thickness of the plates

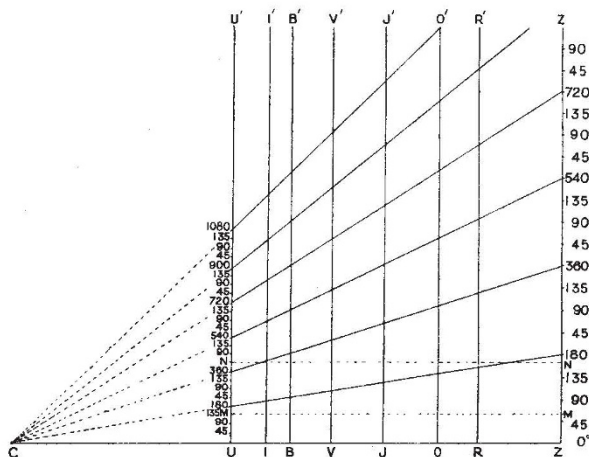


FIG. 1.—Biot's linear diagram. This diagram, in which the reciprocal of the rotatory power of quartz is plotted against the square of the wavelength of the light, is of the same type as those now used in the graphical method of testing for "simple rotatory dispersion."

of quartz required to produce rotations of 180°, 360°, 540°, etc., in light of a given colour. The law of inverse squares was verified (i) by a linear relation between $1/\alpha$ and λ^2 , (ii) by noticing that the line passed through the origin, *i.e.* that on extrapolation to $\lambda^2 = 0$, $1/\alpha$ became 0 also, and α became infinite.

Having established the law of inverse squares for quartz, Biot at once proceeded to apply it to those liquids in which he had just discovered the existence of optical rotatory power, and in particular to oil of turpentine (pp. 91-103), and to an aqueous solution of cane-sugar (pp. 103-114). The method adopted was to balance the rotation of the liquid against that of quartz plates selected so as to produce an equal and opposite rotation in the light transmitted through a piece of deep red glass. In each case the compensation appeared to be exact, proving that the law of inverse squares applied just as well to the liquid as to the rock crystal. Some years later, however, when trying to compensate levorotatory turpentine against a dextrorotatory oil of lemon, either in separate tubes

¹ From a lecture delivered before the Société de Chimie Physique, in Paris, on December 9, 1925.

or mixed, Biot observed "une compensation tres approchée, mais non pas complète, ni surtout générale pour tous les rayons" (*Comptes rendus*, 1836, 2, pp. 542 and 543). A very exact compensation was obtained when cane-sugar and invert-sugar were balanced against one another (*Ann. Chim. Phys.*, 1844, 10, 35), but the experiments with turpentine and oil of lemon proved clearly that the law of inverse squares was not exactly and universally true.

What then must be done in order to find the exact law of rotatory dispersion? Biot had the key in his own hands, and could have solved the problem with certainty if the experimental methods then available had provided data of sufficient exactness for a rigid test of the law. Thus, it is only necessary to plot $1/u$ against λ^2 for a series of optically-active compounds, in order to discover that there is often an exact linear relationship between these two quantities. The straight line does not pass, however, through the origin at $\lambda^2=0$, but intersects the axis of zero rotation at a finite distance from the origin, e.g. at a point given by $\lambda^2=\lambda_0^2$. The true law of rotatory dispersion is therefore not $a=k/\lambda^2$, but $a=k/(\lambda^2-\lambda_0^2)$.

It is a remarkable fact that, although Biot discovered the law of inverse squares in 1818, and discovered the errors in the law in 1836, it was not until about 1898 that Drude, as a result of a long theoretical inquiry, first enunciated the true law of rotatory dispersion in the general form $a=\sum \frac{k_n}{\lambda^2-\lambda_n^2}$; and even then several years elapsed before it was first shown, in 1913, that the general equation (which Drude had applied only in the case of quartz) could be used in its simplest possible form in order to express the rotatory dispersion of a large range of simple organic compounds (Lowry and Dickson, *Journ. Chem. Soc.*, 1913, 103, 1067). If later workers had possessed Biot's peculiar mathematical genius, as well as his experimental skill, this law would surely have been discovered and verified nearly half a century earlier.

THE DISCOVERY OF ANOMALOUS ROTATORY DISPERSION.

The first reference to the optical rotatory power of tartaric acid is contained in a "Mémoire sur la polarisation circulaire et sur ses applications à la chimie organique" (*Mém. Acad.*, 1835, 13, 39-175). At the conclusion of a list of optically-active oils and syrups, it is recorded that a certain solution of tartaric acid gave a rotation of $+8.5^\circ$ for white light, and that the rotation was "plus forte sur les rayons les moins réfrangibles." The memoir itself, which records in a "note additionnelle" the important discovery of the inversion of cane-sugar (pp. 174-175), does not appear to contain any reference to this entry in the table; but three years later, Biot presented to the Academy a long memoir (*Mém. Acad. Sci.*, 1838, 15, 93-279) devoted entirely to the study of the rotatory power of tartaric acid under different conditions. In this memoir, stress was laid on the fact that tartaric acid was almost unique in its failure to obey the law of inverse squares. The existence of a *maximum rotatory power* for green light was indicated in a table (p. 236), which shows the rotation for light of different colours of a solution containing 34.27 per cent. by weight of

tartaric acid. The memoir also contains a clear prediction of the existence of a second form of anomaly, namely, a *reversal of sign*, as indicated by the fact that the limiting values for 0 per cent. of water were negative for low temperatures and for short wave-lengths. This prediction was fulfilled when Biot, in 1850, found a negative rotation in the cold, glassy, anhydrous acid (*Ann. Chim. Phys.*, 1850, 28, 353). The more elaborate work of Bruhat (*Trans. Faraday Soc.*, 1914, 10, 89) has shown that, under these conditions, negative rotations are observed at 15°C . for all wave-lengths less than 5600 Å.U. Negative rotations have also been observed repeatedly in subsequent years, especially in concentrated solutions, and for light of short wave-length (see especially Lowry and Austin, *Phil. Trans.*, 1921, A, 222, p. 280).

SIMPLE AND COMPLEX DISPERSION.

Biot divided optically-active substances into two classes: (i) those which obeyed, at least approximately, the Law of Inverse Squares, (ii) those which made no pretence of obeying it. In the latter class he included tartaric acid, whilst its salts were included in the former class.

These two classes are now generally described as showing *normal* and *anomalous* rotatory dispersion respectively. The distinction between them depends on whether the dispersion-curve remains on the same side of the axis throughout the region of transparency (so that a , $da/d\lambda$, and $d^2a/d\lambda^2$ are of constant sign), in which case the rotatory dispersion is *normal*, or whether it cuts the axis of zero rotation in the region of transparency, in which case the dispersion is *anomalous*. In the latter case the dispersion-curve exhibits all the well-known anomalies, e.g. an *inflexion*, *maximum* and *reversal of sign*; but, as these become less marked, they vanish successively into the infra-red region, where we have no means of following them experimentally. It is therefore impossible in many cases to decide whether a dispersion is really normal, or whether the dispersion-curve may be expected to cut the axis at some wave-length beyond the limit within which visual readings can now be made.

In my own work I have adopted Biot's original classification, with one essential modification, namely, that I have substituted the equation $a=k/(\lambda^2-\lambda_0^2)$ for Biot's Law $a=k/\lambda^2$. Substances of which the rotatory power can be expressed by the equation $a=k/(\lambda^2-\lambda_0^2)$ are said to show *simple rotatory dispersion* (Lowry and Dickson, *Trans. Faraday Soc.*, 1914, 10, 961; Lowry and Richards, *Journ. Chem. Soc.*, 1924, 125, 2511), whilst substances which do not obey the law of simple rotatory dispersion are said to exhibit *complex rotatory dispersion*. The difference between a simple and complex dispersion is seen most clearly in the ultra-violet region, where the course of the dispersion can be followed right up to the limit of transparency of the medium, within which alone the dispersion equations are valid. I therefore prefer to retain, in this modified form, Biot's original method of classifying rotatory dispersions, according as they do or do not obey a certain law, rather than to be guided exclusively by the presence or absence in the visible spectrum of gross anomalies, such as an inflexion, maximum or reversal of sign.

Although only a small correction is needed in order thus to convert Biot's law into the Law of Simple Rotatory Dispersion, this correction is of great importance, since if all optically-active substances obeyed the Law of Inverse Squares, all rotatory dispersions would be normal, and all would be identical with one another, e.g. $\alpha_{4358}/\alpha_{5461} = (5461)^2/(4358)^2 = 1.52$. The superposition of two normal dispersions, even if of opposite signs, would then always give rise to a normal dispersion of the same magnitude, and no form of anomalous rotatory dispersion could be developed by this process.

THE ORIGIN OF ANOMALOUS ROTATORY DISPERSION.

(a) *Anomalous Rotatory Dispersion produced by Optical Superposition.*—The secret of the origin of an anomalous rotatory dispersion was disclosed by Biot in 1836, when he showed that *anomalous rotatory dispersion can be produced in transparent media by the superposition of two normal rotations of opposite sign and of unequal dispersion.* This superposition may be entirely optical, i.e. two independent columns of liquid may be balanced against one another by inserting them end to end in the same polarimeter; or the liquids may be mixed in the same tube. Both methods were used by Biot in compensating lævorotatory turpentine against dextrorotatory oil of lemon, in the experiments already described (*Compt. rend.*, 1836, 2, 543).

These two cases are easily understood, since the existence of two independent partial rotations of opposite sign can be demonstrated quite conclusively. Much more complicated are those cases in which a single optically-active compound, such as tartaric acid or α' -bromocamphor, gives rise to anomalous dispersion, since in these cases it is impossible to isolate from the medium a dextrorotatory and a lævorotatory component. Here again, however, a correct lead was given by Biot when he described his researches on the rotatory power of tartaric acid, under the title "Mémoire sur plusieurs points fondamentaux de mécanique chimique," since he evidently regarded the problem as fundamentally chemical and not merely physical in character.

(b) *Origin of Anomalous Rotatory Dispersion in Tartaric Acid.*—Biot's view that the changes of rotatory power which tartaric acid undergoes under the influence of bases, of boric acid, of water and of alcohol, are chemical in origin, was developed in a more concrete form by Arndtsen, who spent the summer of 1858 in working on rotatory polarisation in the laboratory of M. Verdet at the École Normale Supérieure.

To Arndtsen's view, that the anomalous rotatory dispersion of tartaric acid is due to the superposition of the opposite rotations of two interconvertible forms of the acid, I have given consistent support. In addition to making a careful study, during a period of more than twenty-five years, of the conditions under which a reversible isomeric change can take place in solution, I have proved (Lowry and Cutter, *Journ. Chem. Soc.*, 1925, 121, 532) that the anomalous rotatory dispersion at 20° C. of pure recrystallised ethyl tartrate can be expressed with perfect accuracy as the sum of two simple partial rotations, by means of the equation

$$[\alpha] = 20.005/(\lambda^2 - 0.03) - 20.678/(\lambda^2 - 0.056).$$

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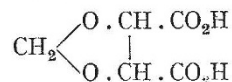
This dispersion is anomalous, and a simple calculation serves to locate the *inflection* at 6950 Å.U., the *maximum* at 5630 Å.U., and the *reversal of sign* at 4245 Å.U. In the same way the rotatory power of a 50 per cent. solution of tartaric acid in water at 20° C. can be expressed (Lowry and Austin, *Phil. Trans.*, 1922, A, 222, p. 293) by the equation

$$[\alpha] = 17.485/(\lambda^2 - 0.03) - 12.080/(\lambda^2 - 0.074).$$

This dispersion is anomalous, like that of the ester, and calculation shows (in agreement with direct experiment) that the *inflection* occurs at 6376 Å.U., the *maximum* at 5373 Å.U., and the *reversal of sign* at 4140 Å.U.

The latter equation is of interest because Longchambon (*Compt. rend.*, 1924, 178, 951; *Bull. Soc. fr. Min.*, 1922, 45, 161) has proved that solid tartaric acid is lævorotatory and has a "normal" dispersion. Moreover, it gives a dispersion-ratio $\alpha_{4358}/\alpha_{5780} = 2.14$, which agrees closely with the ratio 2.2 deduced for the negative partial rotation in the above equation (Lowry and Austin, *NATURE*, Sept. 20, 1924, 114, 430). There can, therefore, be little doubt that this negative partial rotation is due to the persistence in the solutions, as Biot postulated, of unchanged molecules of the solid acid, which Longchambon describes as α -tartaric acid. Conversely, the positive partial rotation in our equation can be attributed to the presence of the β -tartaric acid, which Longchambon supposes to be formed by a reversible chemical change from the α -acid, just as Biot postulated ninety years ago.

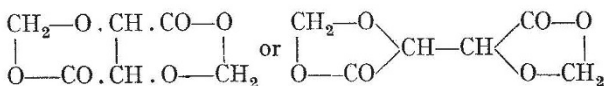
This view of the origin of the anomalous rotatory dispersion of tartaric acid is confirmed by the fact that it is possible to prepare dextrorotatory and lævorotatory derivatives of tartaric acid, the rotatory dispersions of which are not merely normal but simple, like the two partial rotations of the above equations. Thus the rotatory power of *methylene-tartaric acid*,



(Austin and Carpenter, *Journ. Chem. Soc.*, 1924, 125, 1939), can be expressed by the equation

$$[\alpha] = -24.627/(\lambda^2 - 0.0446),$$

whilst the rotatory power of *dimethylene tartrate*,



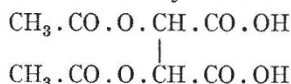
can be expressed (*ibid.* p. 1945) by the equation

$$[\alpha] = +34.168/(\lambda^2 - 0.03132).$$

There can be little doubt that the lævorotatory compound is a derivative of pure α -tartaric acid, whilst the dextrorotatory compound is a derivative of pure β -tartaric acid. This conclusion is confirmed by the fact that, although the dispersion constants are not identical with those of the two partial rotations in the above equations (which are themselves variable from compound to compound), the dextrorotatory compound has a smaller dispersion constant than the lævorotatory compound.

Exceptional interest attaches to the acetyl-derivatives. In this case, Austin and Park have shown

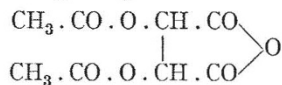
(*Journ. Chem. Soc.*, 1925, 127, 1926) that the rotatory power in dry acetone of *diacetyl-tartaric acid*,



can be expressed by the equation

$$[\alpha] = -6.508/(\lambda^2 - 0.0833).$$

In the same way the rotatory power in dry acetone of *diacetyl-tartaric anhydride*,



can be expressed by the equation

$$[\alpha] = +18.354/(\lambda^2 - 0.0507).$$

In this case again, therefore, the rotatory dispersion of the two derivatives is simple, and the dextrorotatory compound has the smaller dispersion constant. In

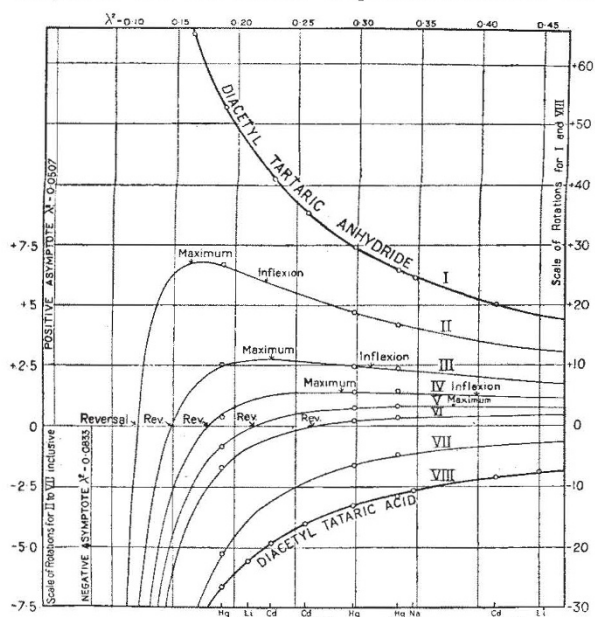


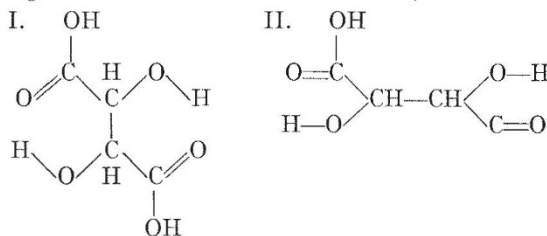
FIG. 2.—Mutarotation and rotatory dispersion of diacetyl-tartaric anhydride in wet acetone at 20°C.

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|------------------------|---|
| I. Initial rotations. | Simple (dextro). |
| II. After 3½ hours. | Complex and anomalous
(with reversal of sign). |
| III. After 45 hours. | |
| IV. After 49 hours. | |
| V. After 51 hours. | |
| VI. After 53 hours. | |
| VII. After 61½ hours. | Complex but normal (lævo). |
| VIII. Final rotations. | Simple (lævo). |

wet acetone, however, the anhydride is not stable, and is gradually hydrolysed to *diacetyl-tartaric acid*. Since the rotations of the two compounds are opposite in sign, and their dispersion constants are of unequal magnitude, all the conditions necessary to produce anomalous dispersion are present in the solution. Thus, a freshly prepared solution of the anhydride, which gave a *simple dextrorotation*, soon showed a *complex and anomalous dispersion*, owing to the development in the free acid of a negative partial rotation with a high dispersion coefficient. This complex and anomalous dispersion was transformed in turn into a *complex and normal dispersion*, when the negative term had become predominant over the

whole range of wave-lengths; and finally, when hydrolysis was complete, the solution showed only the *simple levorotation* of the free acid (Austin and Park, *loc. cit.*). This case is of special importance, since it provides a working model of the mechanism postulated by Biot, by Arndtsen, and more recently by Longchambon, in order to account for the development of anomalous rotatory dispersion in solutions of the free acid.

The ease of transformation of α into $\alpha \rightleftharpoons \beta$ tartaric acid suggests that the difference between the two compounds involves a rearrangement of structure which is even less drastic than a keto-enolic change. I therefore formed the opinion some years ago that the difference between the two forms of the acid might depend merely on an arrest, in two favoured positions, of the free rotation of the molecule about the single bond between the two central carbon atoms. The clear recognition of the bivalency of hydrogen (Lewis, "Valence," 1923, p. 109; Lowry and Burgess, *Journ. Chem. Soc.*, 1923, 123, p. 2111; Lowry, "Nouveaux aspects de la théorie de la valence," *Bull. Soc. Chim.*, 1924, p. 9) has, however, made it possible to assign to tartaric acid alternative formulæ I. and II. (Lowry and Austin, *NATURE*, 1924, 114, p. 431) which appear to fulfil all the essential conditions required for a graphical representation of the α - and β -tartaric acid of Longchambon. There is, however, not enough evidence available to show which of these formulæ should be assigned to α -tartaric acid and which to β -tartaric acid.



(c) *Origin of the Quasi-anomalous Rotatory Dispersion of Camphor.*—Although the rotatory dispersion of camphor is *normal*, it depends on the superposition of two partial rotations of opposite sign, and is therefore *quasi-anomalous* (Lowry and Cutter, *Journ. Chem. Soc.*, 1925, 127, p. 608). What, then, is the origin of these two opposite partial rotations? Tschugaeff has shown that anomalous rotatory dispersion can be produced by superposing the opposite partial rotations of two radicals in the same molecule, as in *l*-menthyl *d*-camphorsulphonate (*Trans. Faraday Soc.*, 1910, 10, 73). I have adopted this view in the case of camphor, with a novel assumption as to the nature of the asymmetric radicals. Thus I suppose that the high-frequency negative partial rotation of camphor is associated with the two saturated quadrivalent asymmetric carbon atoms. On the other hand, it is clear that the positive partial rotation, which is controlled by a dispersion constant corresponding approximately with the wave-length of the ketonic absorption-band (Lowry and Cutter, *Journ. Chem. Soc.*, 1925, 127, 611), is in some way linked up with the double bond of the $>\text{C}=\text{O}$ group. I have therefore suggested (Lowry and Walker, *NATURE*, April 19, 1924, 113, 565) that although a carbonyl radical in a symmetrical molecule possesses a plane of symmetry, this is no longer true in an unsymmetrical molecule. As

evidence of this absence of symmetry, I have adduced the fact that camphor gives unequal yields of borneol and isborneol on reduction, proving that the two links of the double bond are of unequal strength. It is, therefore, a mere unjustified analogy which has led to the assumption that the carbonyl-group of camphor is a symmetrical radical, and no further evidence is required to justify the view that the carbon atom of the ketonic group is in fact an asymmetric carbon atom, *i.e.* that it possesses an *induced asymmetry*, in view of the influence upon it of the *fixed asymmetry* of two of the saturated quadrivalent carbon atoms. This property of induced asymmetry appears to be

very frequent in unsaturated optically-active compounds, and can be used in order to account for the presence of low-frequency partial rotations in many compounds in which the unsaturated group is not too far removed from the fixed asymmetric centres.

In this address I have presented an intimate mixture of Biot's researches with those of my colleagues of the present day. The fact that so intimate a blend is possible is in itself a tribute to the genius of Biot, whose work, although carried out with the mechanical equipment of the nineteenth century, was always conceived in the spirit of the twentieth century.

The American Bison: A Questionable Experiment.

By Dr. JAMES RITCHIE.

THIRTY-EIGHT years ago the sum total of American bison had been reduced from the millions of a century earlier to a number estimated by Hornaday at 1091, and there was a prospect that the species might become extinct. The situation was saved by the action of the Governments of the United States and of Canada, each of which placed remnants of the dwindling herds under protection in large reserved areas. The rapidity with which the protected animals recuperated is well illustrated by the history of the Canadian herd. In 1907 the Dominion Government, acting through the Department of the Interior, purchased the 709 members of the herd owned by Michael Pablo of Montana, which can be traced back to 4 wild calves captured by an Indian in 1873. By 1909 the Pablo herd had been set at large in the Buffalo National Park at Wainwright, an area 15 miles long and 13 miles wide, and in 1925 this herd was found to number approximately 12,000 head, the increase in sixteen years being about 11,300. The future of the species in Canada, therefore, seems to be assured. So far, the success of the experiment of protection has been all that could be desired.

A new difficulty now faced the authorities in Canada. The area of close on 200 square miles set aside for the original herd was insufficient to support the new numbers, and some method of reducing the numbers and of disposing of the annual increase had to be devised. Some 2000 have been slaughtered for food and robes, some have been transferred to other parks, including a pair sent to the Scottish Zoological Park in Edinburgh, and more than 1600 have been transported northward for 700 miles to Wood Buffalo Park in the North-West Territories. The Wainwright stock now reduced to about 8000, or about one to 16 acres, must be still near the food limit of the area (10 acres to one sheep is a rough guide to the food capacity of Scottish mountain pastures), but arrangements are being made for the disposal of the annual increase, which in the full herd amounted to 1500 individuals a year. It is, however, to the transference of large numbers to Wood Buffalo Park that attention is here particularly directed.

The Department of the Interior is to be congratulated on the success of the work of transference; for, by means of specially designed cars and barges, 1634 bison were moved by rail and water for 700 miles with only 8 casualties. But the transference

gives rise to some doubt from the scientific point of view.

In Wood Buffalo Park there existed the only herd of wild bison which has survived, and these, the "wood buffalo," have been separated from the "plains buffalo" of the reserves as a distinct race, *Bison bison athabascæ*, characterised by its larger size, darker colour, more dense and silky hair, and larger and more incurved horns. Whether these characters are due to innate variation emphasised by segregation, or are simply the evidences of the effect of a different environment, is not known. At any rate, this race has now little likelihood of survival as a pure strain, for amongst its members, which probably do not exceed 1500 in number, have been deposited 1600 individuals of the contradistinctive race of the plains; and the wardens report that "the plains and the wood buffalo are mingling freely and that there is every prospect of the complete amalgamation of the two herds."

From the scientific point of view the opportunity of making an interesting experiment has been missed. Had the surplus plains buffaloes been deposited in an area similar in latitude, vegetation and climate to Wood Buffalo Park, but isolated from it, instead of in the Park itself, the wood buffalo race would have remained uncontaminated, and time would have shown whether in the new environment the plains buffalo would have assumed the distinctive characters of the wood buffalo. Had it turned out that these characters were wholly environmental, as they may well be, an interesting biological correlation would have been proved, and no objection could then have been taken to fortifying the wood buffalo herd by the addition of plains individuals.

In the meantime two suggestions may be made. First, in view of the possible swamping and disappearance of the distinctive wood buffalo as the result of crossing, it should be assured that several pure-bred typical specimens of that race find a place in one or more of the Dominion or other great museums. Secondly, if it be possible, the next batch of surplus plains buffaloes to be transferred from Wainwright should be placed in a northern area other than Wood Buffalo Park, with the view of establishing a new and independent herd in which the influence of climate might be watched. The result would finally condemn or vindicate the 1925 experiment of commingling the two racial forms.