laquelle j'avais recours est à peu près identique à la sienne. . . . Je m' empresse de satisfaire à cette demande légitime, et je laisse entièrement la priorité sur moi, à M. Pettigrew relativement à la question ainsi restreinte." (*Comptes Rendus* for May 16, 1870, p. 1093.)

The next point which Mr. Garrod takes up is the "induced currents" of the wing. I state that "the efficiency of the wing is greatly increased by the fact that when it ascends it draws a current of air up after it, which current, being met by the wing during its descent, greatly augments the power of the down-stroke. In like manner, when the wing descends, it draws a current of air down after it, which, being met by the wing during its ascent, greatly augments the power of the up-stroke." This is simply a statement of fact, and if Mr. Garrod causes a natural or artificial wing to vibrate he will find that the wing takes a greater catch of the air when a down- and up-stroke or an up- and down-stroke are made in rapid succession, than when a single stroke is made either in the one direction or in the other. This point becomes especially clear if a large artificial wing be constructed on the insect type and made to vibrate in a horizontal direction. If such a wing have its anterior margin slightly elevated and made to travel from right to left of the operator it draws after it a current of air which, being met by the wing when it is reversed and made to pass from left to right, acts as an autumn breeze to a kite. The wing literally flies on the current which it creates. It ascends at each thrust and carries the hand of the operator with it. Similar remarks are to be made of the tail of the fish. It is in this way that the *back air* and *back water* are utilised, and herein lies the excellence of the elastic reciprocating screw, as found in Nature, and as contra-distinguished from the rigid rotatory screw employed in navigation.

Mr. Garrod, adducing no proof in refutation of this and similar experiments, states "that these *induced currents* are of no real service in flight, because in their production there is as much force lost as there may be gained from their subsequent employment on the reversal of the action of the wing, if the bird's body has not advanced sufficiently far to be in each stroke beyond the range of their action, which is probably the case." On what authority does Mr. Garrod make this assertion? When a bird flies in still air, the wing of necessity must vibrate. The quicker it vibrates the more marked the reaction obtained from the air, and the greater the elevating and propelling power. The *induced currents* powerfully contribute to this reaction from the fact that the wing and the air are both moving, and moving in opposite directions. This, as explained, is a matter of experiment, and can readily be verified.

Lastly Mr. Garrod attacks my views on muscular movements. Here again he adduces no counter-proof, and, adhering to the old doctrine, contents himself by saying, "We are not ashamed to say that such has always been and still is our idea." This is not saying much. He takes exception to my statement that muscles have a centripetal or shortening power and a centrifugal or elongating power. Can he inform me how the left ventricle of the heart opens after a vigorous contraction, in which all the blood contained in the ventricular cavity is ejected and the ventricle converted into a solid muscular mass, if not by a spontaneous *elongation* of all its fibres?

Edinburgh, Jan. 27 J. BELL PETTIGREW

Specific Gravity of Sea-water

IN reference to Mr. Strachan's letter in NATURE, vol. ix. p. 183, calling attention to the discrepancy between Dr. Frankland's results and my own, permit me to state that they were not obtained from the same series of samples, and that the figures given by Dr. Frankland were, I believe, obtained by the use of a balance on shore, and also that from the way in which his specimens were packed, they were not liable to any appreciable loss by evaporation. They were not, however, taken from that part of the North Atlantic which was examined during the time that I was on board the *Porcupine* in 1869, to which alone my observations refer. My own results were obtained, as stated on p. 503 of "The Depths of the Sea," by delicate glass hydrometers, so graduated that the sp. gr. could easily be read to the fourth decimal place. Two instruments only were employed for the 105 observations made, and though they gave identical results, I had no opportunity of comparing their indications with the results obtained by a balance from the same specimen of water. I may remark here, however, that though the *absolute* results may not be quite correct, the relations between the sp. gr. of surface, intermediate, and bottom waters, pointed out on p. 505 of "The Depths of the Sea," as well as the range of variation, are probably very near the truth, since the same instruments were employed in all the determinations, and at the end of the series they indicated the same as at the commencement, when placed in a test solution, which was preserved for the purpose of detecting possible variations in the instruments themselves.

Clifton, Bristol, Jan. 17 WM. LANT CARPENTER

THE LINNEAN SOCIETY

WE regret to hear of an unpleasant event which took place at the meeting of the Linnean Society on Thursday last (5th inst.). So far as we have been able to gather the particulars they are as follows.

When the usual minutes had been read at the commencement of the meeting, a Fellow of the Society rose in his place and endeavoured to propose a motion reflecting upon the conduct of the President at the preceding meeting. The President (Mr. George Bentham, F.R.S.) ruled that the Fellow was out of order and that his motion could not be put, and requested the would-be mover of it to sit down in his place. In spite of frequent calls to order, however, this gentleman persisted in his endeavours to bring forward his grievances, and to address the meeting. At last Mr. Bentham, finding that his efforts to preserve order were vain, and that the mover of the motion (who had given no sort of notice of his intentions) was backed up by a body of clamorous friends assembled specially for the purpose, quitted the chair and left the meeting-room, followed by the Secretary and all the other members of the Council present.

As the chair of the Linnean Society can only be taken by a member of Council, the meeting thus came to a premature end, much to the disappointment of those who had assembled to hear Mr. W. K. Parker read his paper on the osteology of the woodpeckers.

We regret to have to add that, in consequence of this untoward event, Mr. Bentham has tendered his resignation as President of the Society. But we trust that the Fellows who caused the disturbance will, upon reflection, feel that however much they might have considered themselves aggrieved by the President's decision at the previous meeting, they were not justified in the course they pursued. In all meetings the decision of a chairman upon a point of order is held to be final, at all events for the occasion. More especially should this be the case in a learned society assembled for the discussion of scientific problems, and not for vulgar wranglings and disputes upon immaterial subjects.

We trust therefore that an ample apology will be offered to the President by these gentlemen, and that he will be induced to retain his chair until the approaching anniversary meeting of the Society, when he had already given notice of his intention not to accept re-nomination. The great services which Mr. Bentham has rendered to Science generally and to the Linnean Society in particular, are too well known to the readers of NATURE to render it necessary for us to descant upon them in these columns. The Linnean Society has just acquired a new and most convenient abode in the apartments at Burlington House, recently provided for it by the liberality of the country, and it would be a great misfortune if disunion should succeed in marring the work of those who are now endeavouring to make the Society still more useful and more prosperous than it has been in past times.

POLARISATION OF LIGHT*

IV.

THE phenomena exhibited by selenite are also produced by other crystals, but the facility with which plates of the former substance can be obtained, causes them to be generally used in preference to others. There is, however, a peculiar class of crystals, of which quartz, or rock crystal, is the most notable, which gives rise to effects different from those hitherto described.

* Continued from p. 205.

If a ray of light pass through a plate of quartz which has been cut perpendicularly to the axis, or line parallel to the main planes bounding the crystal, it is as usual divided into two; but the vibrations in each ray, instead of being rectilinear and at right angles to one another, are circular and in opposite directions. That is to say, if the motion of vibration in one ray is directed like the hands of a clock, that in the other is directed in the opposite sense; and the light in each ray is then said to be circularly polarised. The motion of a series of particles of ether, which when at rest lie in a straight line, is circular, and, as in plane polarisation, successive; and consequently, at any instant during the motion such a series of particles will be arranged in a helix or corkscrew curve. The sweep of the helix will follow the same direction as that of the circular motion; and, on that account, a circularly polarised ray is spoken of as right-handed or left-handed, according to the direction of motion. A right-handed ray is one in which, to a person looking in the direction in which the light is moving, the plane of vibration appears turned in the same sense as the hands of a watch. Or, what is the same thing, to a person meeting the ray, it appears turned in the opposite sense, viz., that in which angles when measured geometrically are usually reckoned as positive.

The question, however, which mainly concerns us is the condition of the vibrations after emerging from the plate of quartz and before entering the analyser. In the passage of the ray through the plate the ether is subjected to a double circular motion, one right-handed, the other left-handed; but, as one of these motions is transmitted with greater velocity than the other, it follows that at any given point and at the same instant of time one of the revolutions will, in general, be more nearly completed than the other, or, to use an expression adopted in plane polarisation, there will be a difference of phase. The motions may be represented by two clock hands moving at the same rate in opposite directions, and the difference of phase by the angle between them when one of them is in the position from which angles are reckoned. As both are supposed to move at the same rate, they will have met in a position midway between their actual positions; and if we consider a particle of the ether (say) at the extremity of the clock-hands, it will be solicited when the hands are coincident by forces producing two opposite circular motions. Now, whatever may have been the forces or structural character within the crystal whereby this double circular motion is perpetuated, it is clear that when the ray emerges into air the particle of ether immediately contiguous to the surface of the crystal will be acted on by two sets of forces, one whereby it would be caused to follow the right-handed and the other the left-handed rotation. Each of these may, as is well known, be represented by a pair of forces, one directed towards the centre of the circle, the other in the direction of the motion and at right angles to the first, or, to use geometrical language, one along the radius and towards the centre, the other along the tangent and in the direction of the motion. The two forces acting along the tangent being in opposite directions will neutralise one another, and the resultant of the whole will, therefore, be a force in the direction of the centre. The particle in question, and consequently all those which following in succession serve to compose the entire ray until it enters the analyser, will vibrate in the direction of the diameter drawn through the point under consideration; or, to express it otherwise, the ray will be plane-polarised, and the plane of vibration will be inclined to the plane from which angles are measured by an angle equal to half the difference of phase on emergence due to the thickness of the crystal. The retardation being the same absolute quantity for all rays, will, as in the case of plane polarisation, be a different fraction of the wave-length for rays of different colours, and will be greater for the shorter waves than for the longer. Hence the planes of vibration of the different coloured rays, after emerging from the quartz, will be differently inclined. Each ray will therefore enter the analyser in a condition of plane polarisation; and if the analyser be turned round, it will cross the vibrations of the various coloured rays in succession, and extinguish each of them in turn. Each of the images will consequently exhibit a gradual change of colour while the analyser is being turned; and the tints will be, as explained before, complementary to those which are successively extinguished. For a given plate of quartz the order of the tints will be reversed when the direction of rotation of the analyser is reversed. But it should be here explained that there are two kinds of quartz, one called right-handed and the other left; and that, for a given direction of rotation of the analyser, these cause the colours to follow one another in opposite orders. A similar effect is produced by turning the polariser round in the opposite direction.

The angle of rotation of the plane of vibration for any particular colour varies, as stated above, with the thickness of the plate; while for a given thickness it increases nearly as the square (product of the quantity into itself) of the wave-length decreases. In mathematical language it varies approximately inversely as the square of the wave-length. If this law were accurately true, the product of the angles of rotation into the square of the corresponding wave-lengths (λ) would be the same for all rays. The following are some measurements made by Brock, with a quartz plate one millimetre thick, which show that the law may be considered as true for a first approximation.

Rays	Rotations	Rotations $\times\ \lambda^2$.
B	15° 18′	7,238
C	17° 15′	7,429
D	21° 40′	7,511
E	27° 28′	7,596
F	32° 30′	7,622
G	42° 12′	7,842

If the colours exhibited by a plate of quartz when submitted to polarised light be examined by a spectroscope, in the way described when we were speaking of selenite, the spectrum will be found to be traversed by one or more dark bands, whose position and number depend upon the thickness of the plate. But there will be this difference between plane and circular polarised light, that if the analyser be turned round, the bands will never disappear, but will be seen to move along the spectrum in one direction or the other, according as the plate of quartz be right-handed or left-handed, and according to the direction in which the analyser is turned. This is, in fact, identical with the statement made before, that the analyser in its different positions successively crosses the plane of vibration of each ray in turn, and extinguishes it.

This being so, it is clear that a change of colour exhibited by a quartz plate when submitted to plane-polarised light and examined with an analyser, forms a test of a change in the plane of original polarisation. And if the plate be composed of two parts, one of right-handed, the other of left-handed quartz, placed side by side, any change in the plane of polarisation will affect the two parts in opposite ways. In one part the colours will change from red to violet, in the other from violet to red. At two positions of the polariser, or analyser, the colours must be identical. With plates, as usually cut, one of these identities will be in the yellow, the other at the abrupt passage from violet to red, or *vice versâ*. In this case the field appears of a neutral tint, *teinte sensible* or *teinte de passage*, as the French call it, and the slightest change in the plane of polarisation exhibits a marked distinction of colour, one part verging rapidly to red, the other to violet. This arrangement is called a biquartz, and affords a very delicate test for determining the position, or change of position, of the plane of polarisation, especially in cases where feebleness of light or other circumstance interfere with the employment of prismatic analysis.

If the thickness of the plate be such that the difference of rotation of the planes of vibration of the rays corresponding to the two ends of the visible spectrum (or, as it is sometimes termed, the "arc of dispersion") be less than 180°, there will be one dark band in the spectrum; because there can then be only one plane of vibration at a time at right angles to that of the analyser. If the arc of dispersion is greater than 180° and less than 360°, there will be two bands. And so on for every 180° of dispersion.

This mode of examination by means of prismatic analysis is the most accurate yet devised for measuring the angle of rotation produced by circular polarisation; especially if solar light be employed, and the fixed lines used to form a scale of measurement.

The property of circular polarisation is, however, not confined to quartz. Among solids, chloride of sodium is the only other known instance, but among fluids and fluid solutions there are not a few.

The following list is given by Verdet. The angles have reference to the red rays given by a plate of glass coloured with oxide of copper, and are affected with the sign + in the case of right-handed, and with − in the case of left-handed rotation. The length of the column of the solution is in every case one decimetre.

Essence of	turpentine	−29°·6
,,	lemon	+55°·3
,,	bergamot	+19°·08
,,	bigarade	+78°·94
,,	aniseed	− 0°·70
,,	fennel	+13°·16
,,	carroway	+65°·79
,,	lavender	+ 2°·02
,,	peppermint	+16°·14
,,	rosemary	+ 2°·29
,,	marjorum	+11°·84
,,	sassafras	+ 3°·29
Solution of	sugar 50 per cent.	+33°·64
,,	quinine 6 per cent. in alcohol	−30°.

It will be noticed that the rotary power of all these substances is much less than that of quartz.

A mixture of liquids, one or both of which is active, generally exhibits a rotatory action represented by the sum or difference of their separate powers (a neutral liquid being considered to have a power represented by 0); but this law is true only when no chemical action takes place between the elements of the mixture. Saccharine solutions vary not only in the amount but also in the character of their power of rotation; thus cane sugar is right-handed, but grape sugar left-handed.

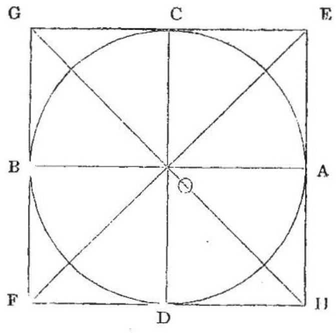
The property in question has been turned to practical use by employing the rotatory power of a saccharine solution as a measure of the strength of the solution. For this purpose a tube containing the solution to be examined is placed between two Nicol's prisms. The simple fact of circular polarisation is proved by a feeble exhibition of the phenomena shown by a plate of quartz cut perpendicularly to the axis. But for accurate measurement various expedients have been adopted. If a biquartz be inserted behind the analyser (the end of the apparatus next the eye being considered the front), then for a certain position of the analyser the two halves will appear of the same colour. When the tube for examination is inserted the similarity of colour will be disturbed; and the angle through which, right or left, the analyser must be turned in order to restore it will be a measure of the rotary power of the fluid.

Another method is as follows:—Use a single quartz instead of a biquartz; in front of it place a pair of quartz wedges, with the thin end of one opposite the thick end of the other; the outer surfaces having been cut perpendicularly to the axis. If the plate be right-handed, the wedges must be left-handed, and *vice versâ*. The wedges must be made to slide one over another so as together to form a plate of any required thickness, and a scale connected with the sliding gear registers the thickness of the plate produced. When the tube is removed the wedges are adjusted so as to compensate the quartz plate, and their position is considered as the zero point of the scale. When the tube is replaced, the wedges are again adjusted so as to compensate the action of the fluid in the tube, and the difference of the readings gives the thickness of quartz necessary for the compensation. The rotatory effect of a given thickness of quartz being supposed known we know at once the effect of a thickness of the fluid under examination equal to the length of the tube.

Another method has been based upon the principle of Savarts bands; but sufficient has perhaps here been said to illustrate the principle of the saccharometer.

Circular polarisation may, however, be also produced by other means, namely, by total reflexion, and by transmission through doubly-refracting plates of suitable thickness.

It will perhaps be best to begin with the last. And in order the better to understand the process we must consider briefly the result of compounding two rectilinear vibrations under different circumstances.



Suppose a particle of ether to be disturbed from its point of rest O in a direction O A. The attraction of the particles in its neighbourhood would tend to draw it back to O; and let O A be the extreme distance to which under these attractions it would move. Having reached A it would return to O, and passing through O with a velocity equal to that with which it started under the disturbing force, it would move to a point B equidistant from O with A, but in the opposite direction. And if, as is generally supposed, the ether is perfectly elastic, or that there are no internal frictions or other conditions whereby the energy of motion is converted into other forms of energy, the oscillations or vibrations of the particle between the points A and B will continue indefinitely. Now suppose that while these vibrations are going on, a second disturbing impulse, equal in intensity, but in a direction at right angles to the first, be communicated to the particle, it is clear that the effect on the motion of the particle will be different according as it takes place at the point of greatest velocity O, or at that of no velocity A or B, or at some intermediate point. Our object is to consider the effects under these various circumstances.

A complete vibration consists in the motion from O to A, thence to B, and finally back to O; so that if O be the starting point the passage through A will be removed one-fourth, the passage through O from A towards B will be one-half, the passage through B will be three-fourths, and the passage through O from B to A a complete vibration from the commencement. This being so, suppose that the second impulse be communicated while the particle is at O on its way towards A, then the impulses may be considered as simultaneous and the vibrations to which they give rise will commence together, and the waves of which they form part will be coincident. If the second impulse take place when the particle is at A, the two sets of vibrations or waves to which they belong will have a difference of phase (*i.e.* the first will be in advance of the second) equal to one-fourth of a vibration or one-fourth of a wave-length. If the second impulse take place when the particle is at O on its way to B, the difference of phase will be half; if when it is at B the difference will be three-fourths of a wave-length.

The particle being at O, and subject to two simultaneous impulses of equal strength, one in the direction of A, the other in that of C, must move as much in the direction of C as in that of A, that is, it must move in a straight line equally inclined to both, namely O E in the same figure. And inasmuch as the two impulses in no way impede one another, the particle will move in each direction as far as it would have done if the other had not taken place. In other words, if we draw a square about O with its sides at distance equal to O A or O B, the extent of the vibration will be represented by O E where E is a corner of the square. The complete vibration will then be represented by the diagonal E F in the same way as it was by the line A B in the first instance. If the impulse had been communicated at the instant of passage through O on the way to B, it is clear that a similar train of reasoning would have shown that the vibration would have been in the other diagonal G H. We conclude, therefore, that if two sets of rectilinear vibrations, or plane waves, at right angles to one another combine, then when they are coincident they will produce a rectilinear vibration, or wave, whose plane is equally inclined to the two, and lying in the direction towards which the motions are simultaneously directed. In the figure this is represented by the dexter diagonal. When the two sets of waves have a difference of phase equal to half a wave length, their combination gives rise to a wave represented in the figure by the sinister diagonal.

Suppose now that the second impulse is communicated at the instant when the particle is at A; in other words, that the two sets of waves have a difference of phase equal to one-fourth of a wave-length. At that instant the particle will have no velocity in the direction of A B (for convenience, say eastwards), and will consequently begin to move in the direction of the second impulse, say northwards. But as time goes on the particle will have an increasing velocity westwards and a diminishing velocity northwards, it will therefore move in a curve which gradually and uniformly bends, until when it has reached its greatest distance northwards it will be moving wholly westwards. And as the motion not only will be the same in each quadrant, but would be the same even if the directions of the impulses were reversed, it is clear that the curvature of the path will be the same throughout, that is to say, if two sets of waves of the same magnitude in planes perpendicular to one another, and with a difference of phase equal to one-fourth of a wave-length combine, they will produce a wave with circular vibrations.

If the second impulse be given when the particle arrives at B, that is, if the waves have a difference of phase equal to three-fourths of a wave-length, similar considerations will show that the motion will be circular, but in the opposite direction.

Suppose, therefore, that we allow plane-polarised light to fall upon a plate of doubly refracting crystal cut perpendicularly to the axis in the case of a uniaxal crystal, or in the case of a biaxal to the plane containing the two axes, say a plate of mica which splits easily in that direction; then the vibrations will, as before explained, be resolved in two directions, at right angles to one another. And further, if the original directions of vibration be equally inclined to the new directions, *i.e.*, if it be inclined at 45° to them, the amount or extent of vibration resolved in each direction will be equal. Further, if the thickness of the plate be such as to produce retardation or difference of phase equal to a quarter of a wave, or an odd number of quarter wave-lengths, for the particular ray under consideration; then the two sets of vibrations on emerging from the mica plate will recombine, and, in accordance with the reasoning given above, they will form a circular vibration, left-handed or right-handed according as the retardation amounts to an integral number of three-quarter wave-lengths or not.

It thus appears that a plate of mica which retards one of the sets of waves into which it divides an incident set by an odd multiple of quarter-wave lengths, affords a means of producing circular from plane polarisation. It remains to be shown that, with the same plate in different positions, right or left handed circular polarisation may be produced at pleasure. Suppose that the original vibrations are in the direction E F in the foregoing figure; the mica plate will resolve them into the two directions A B, C D, one of the rays, say the first, will be transmitted with greater velocity than the other, and the vibrations along C D will be one-fourth of a wave-length behind those along A B. This will correspond to the case discussed above, and will give rise to a circular vibration in a direction opposite to that of the hands of a clock. Suppose, however, that the plate be turned round through a right angle, so that the vibrations which are transmitted with greater velocity are placed parallel to C D, and those which are transmitted with lesser along A B. The ray whose vibrations are along A B will then be a quarter wave-length in advance, or, what comes to the same thing, they are three-quarters of a wave-length in rear of the others; and this condition of things produces, as explained before, a circular vibration in a direction the reverse of the former. It thus appears that the plate placed in one direction will convert plane into right-handed circular polarisation; and if turned round through a right angle from that position will convert plane into left-handed circular polarisation. A like change from right-handed to left-handed circular polarisation, or *vice-versâ*, may obviously be effected by turning the orginal plane of polarisation through a right angle; so that it shall lie between lines of concurrent instead of between lines of discordant motion.

W. SPOTTISWOODE

(*To be continued.*)

A COMPLETE SPECIMEN OF A PALÆOTHERIUM

FROM *La Nature* we learn that the palæontological collection of the Museum of Natural History of Paris has just been enriched by the addition of a new specimen of very great scientific interest, which is the entire skeleton of *Palæotherium magnum*, imbedded in a large block of gypsum and marl, the whole being exhibited in the anatomical department of the museum.

The *Palæotherium magnum*, whose name alone indicates its ancient existence, was first recorded by the great French naturalist Cuvier, in his celebrated "Recherches sur les Ossemens Fossiles." It is an animal which is entirely extinct, without any present representative. Individuals of the species must have been extremely abundant during the period that it existed. Modern zoologists place it among the Perissodactylates, that is to say, with the at present existing rhinoceros, tapir, and horse. It forms part of the fauna which is found abundantly embedded in the deposits of gypsum. All palæontological collections, even the most humble, have for a long time been provided with the remains, or more or less complete portions of this fossil form, but none have yet had the good fortune to obtain a complete skeleton.

The principal result of the examination of the new specimen which we are describing has been to show that until now very inexact notions have been entertained as