Researches on the molecular dissymmetry of natural organic products : presented to the Chemical Society of Paris, January 20 and February 3, 1860 / by L. Pasteur ; translated from "Leçons de chimie professées en 1860" by W.S.W. Ruschenberger.

Contributors

Pasteur, Louis, 1822-1895.
Ruschenberger, W. S. W. 1807-1895
Holmes, Oliver Wendell, 1809-1894
Société chimique de Paris.
National Library of Medicine (U.S.)

Publication/Creation

[Philadelphia] : [publisher not identified], [1862]

Persistent URL

https://wellcomecollection.org/works/gb255t9e

PASTEUR (L.)

Researches on the Molecular dissymmetry × × × × ×

Dr Oliver Wendell Holmes
with respects of
W.S.W. Ruschenberger.

[From the American Journal of Pharmacy, January, 1862.]

RESEARCHES ON THE MOLECULAR DISSYMMETRY OF NATURAL ORGANIC PRODUCTS. By L. PASTEUR, Member of the Chemical Society of Paris. Presented to the Chemical Society of Paris, January 20 and February 3, 1860. Translated from "Leçons de Chimie professées en 1860." By W. S. W. RUSCHENBERGER, M. D., U. S. Navy.

INTRODUCTION.

These lectures were prepared on the invitation of the Council of the Chemical Society of Paris. The researches of which they present a rapid summary have occupied me during ten consecutive years. I had often thought of collecting them, of minutely reviewing the details, and adding to them all the developments necessary to the co-ordination of the different memoirs in which they appeared for the first time. But there is in the life of every man devoted to the experimental sciences an age when the value of time is inestimable: this rapid age, in which the spirit of invention flourishes, in which every year ought to be marked by an advance. To stop, then, voluntarily at things acquired, is a restraint and a danger, which the pleasure and even utility of seeing our ideas expand in accordance with our desires too well compensate.

As much as I have recoiled before the laborious task of collecting, of perfecting my researches on the molecular dissymmetry of natural organic products, in the same degree I have yielded eagerly to the prayer of many members of the Chemical Society, to publish the two lectures in which I was charged to set forth the principal results at which I had arrived. Few studies have been better received at the time of their successive appearance, and, nevertheless, I have many proofs that they were scarcely known.

I hope, then, that this publication may be of some use. But should there be nothing beyond the interest which these lectures have excited in the distinguished assembly before which they were delivered, I shall be sufficiently recompensed for my labors.

The Chemical Society has been gratified by the eagerness with which many young men of learning have taken seats among the audience. It has especially marked the sympathetic encouragement given to its labors by the presence of Messrs. Balard, Claude Bernard, Delafosse, Frémy, Serret, members of the Academy of Sciences.

May I be permitted, moreover, to especially thank, in my name and in the name of the Society, our illustrious President, M. Dumas, whose lofty and benevolent patronage has always served science almost as much as his immortal works.
L. PASTEUR.

Paris, 1860.

FIRST LECTURE.

At the close of the year 1808, Malus announced that light reflected from all bodies, whether opaque or diaphanous, acquired very extraordinary new properties, which essentially distinguished it from light transmitted directly from luminous bodies.

The modification which light undergoes in the act of reflection Malus denominated *polarization*. Later, this was designated under the name of *plane of polarization* of the ray, the plane of reflexion itself, that is to say, the plane passing by the incident ray and the normal to the reflecting surface.

Malus did not limit his discoveries on polarized light to this. It had long been known that a ray of direct light always separated into two white fasciculi, of the same intensity, in its passage through a rhomboid of carbonate of lime. The flame of a candle, observed by the aid of such rhomboid, is always double, and the two images have the same brightness.

Huygens and Newton had observed that light, which has passed through a crystal of Iceland spar, no longer comports itself like.direct light. So, looking through a new rhomboid at one or the other of the two images of the candle we have just mentioned: 1. There will not always be bifurcation of the ray: 2. When there is bifurcation, the two new images will not have the same intensity. Light, which has traversed a bi-refrangent crystal, is different, then, from natural or direct light. This admitted, Malus proved that the modification impressed upon light by double refraction was identical with that which reflexion produces from the surface of opaque or diaphanous bodies; in other words, that the two rays, ordinary and extraordinary, given by a bi-refrangent crystal, are polarized rays.

Malus established so clearly from the beginning, these fruitful discoveries, with so much care and so much precision in his facts and in his language, that one might believe, in reading his memoirs, that they were prepared yesterday. But he could not pursue his work: premature death carried him off in 1812, at the age of thirty-seven years. Happily for science, two celebrated physicists, at that time young and full of activity, MM. Biot and Arago, received his legacy, and were not slow to distinguish themselves by brilliant discoveries in the new route which Malus had just opened to science.

In 1811, Arago observed, that when a polarized ray traversed normally a plate of rock crystal cut perpendicularly to its axis, the ray, on issuing from the plate, if analyzed by aid of a rhomboid of Iceland spar, gives *constantly two images* in every position of the rhomboid; and further, these two images are colored with the complementary tints. When the thickness of the spar does not permit an entire separation of the two fasciculi, the image is white where they are in part superposed.

This experiment presents a double anomaly to the ordinary laws of bi-refrangent crystals. Every other crystal, with an axis cut normally to this axis, would have furnished two white images, in place of being colored, and, in two rectangular positions of the rhomboid analyzer, the images would be reduced to a single one.

The conclusion of Arago was, that the results of the preceding experiment are precisely those which should follow, if we suppose that the differently colored rays of the incident white fasciculus are, on issuing from the plate of the quartz, polarized indifferent planes.

Arago does not recur to these brilliant phenomena, the laws of which M. Biot presented since 1813, carefully isolating them from those among which Arago appeared to confound them.

M. Biot formed the polarized ray successively with each of the simple rays of the spectrum, and found that the plane of primitive polarization was deviated at an angle proportional to the thickness of the plate; that this angle is different for each simple color, and goes on increasing with the refrangibility, according to a determined law. M. Biot also made the very curious observation that, of the plates obtained from different spieces of quartz, there were some which deviated the planes of polarization to the right and some to the left, following the same laws.

But the most remarkable discovery of M. Biot, in this kind of phenomena, is, without contradiction, that of the deviation imparted to planes of polarization by a great number of natural organic products, essence of turpentine, solutions of sugar, of camphor, of tartaric acid, &c. The first announcement of this fact is found in the bulletin of the Philomathic Society for December, 1815.

For the understanding of this lecture, we should especially notice the existence of the rotary property in tartaric acid, and its absence in paratartaric or racemic acid, an acid which is isomeric with tartaric acid.

There exists then liquid organic products or solutions in water which possess the rotary property, and in this respect remind us of the solid, crystallized quartz. But it is essential to note here that this analogy to quartz is entirely apparent. There was in both cases deviation of the plane of polarization, but the characters of the phenomenon were very different.

Quartz deviates, but it must be crystallized. Dissolved or solid, and not crystallized, it has no action. Not only must it be crystallized, but it must be cut in plates perpendicular to the axis. From the moment the plate is a little inclined in the direction of the ray, the action abates and then ceases.

Sugar deviates, (and what I say of sugar is true of all other organic products), but the sugar must be either dissolved, or solid and amorphous like barley sugar. In the crystallized state it is impossible to discover any action.

The tube containing the solution of sugar may be inclined. The deviation does not change for the same thickness. Further, by violently agitating the liquid by the assistance of a clockwork movement, the phenomenon remains the same.

Thus M. Biot concluded from the beginning, strictly that the action exerted by organic bodies was a molecular action, peculiar to their ultimate particles, dependent upon their individual constitution. In quartz the phenomenon results from the mode of aggregation of the crystalline particles.

These are the physical precedents, if I may so express myself, of the researches with which I propose to entertain you. Here are their mineralogical precedents.

II.

Hemihedrity* is assuredly, among the peculiarities of crystallization, the one which is the easiest to seize in its external manifestation : consider, for example, a species of mineral crystallizing in the cubic form. This form, as all know, may surround different kinds of determinate forms by the law of symmetry, a law so natural that it is, so to speak, a physical axiom. The expression of this law is, that a form being given, all others compatible with it may be obtained by a contrivance which would consist in modifying, truncating, as Romé de Lisle said, at the same time and in the same manner the identical parts. The identical edges are those which are at the intersection of faces respectively identical, mutually cutting at the same angle ; and solid identical angles, those which are formed by dihedral angles respectively equal and similarly placed. For example, in the cube there is but one kind of solid angles and one kind of edges. Let one of the solid angles be truncated by a face equally inclined to the three faces of the solid angle, and the seven other angles should be, at the same time, by a face of the same nature. This is observed in alum, in galena, and generally in all cubic species.

Let us consider a right prism with a rhomb base. The eight edges of the bases are identical. If one is truncated, the seven others should be, and in the same manner. The four vertical edges are of another kind. Generally they will not be truncated at the same time as those of the bases, and if they are, it will be differently.

These examples alone will suffice to explain the law of symmetry and its application.

Nothing is more simple than to have a clear idea of hemihedrity. Experiment has long since shown, Haüy was acquainted with the most celebrated instances, that, in a crystal,

---

* *Emisus*, half ; *edron* side.

the half only of the identical parts are sometimes modified at the same time and in the same manner. It is said in such case that there is hemihedrity. Thus, the cube ought to be truncated at the same time on its eight solid angles. But, in certain cases it is so only on four. Boracite affords an instance of this kind. Under these circumstances the modification occurs in such wise that in prolonging the four truncations in a way to make the faces of the cube disappear, we obtain a regular tetrahedron. If the modification were applied to the four remaining angles it would produce another regular tetrahedron, identical with and superposable on the first, and differing from it only by its position on the cube.

In the same way let us take our right prism truncated on the eight edges of its bases. In certain species the truncation occurs upon half of the edges only, and it also happens here that the truncations, bearing upon edges opposite at each base and crossing at the two extremities, when prolonged, lead to a tetrahedron. There are two tetrahedrons possible, as for the cube, differently placed in relation to the prism, accordingly as it preserves such or such group of four truncations; but here the two tetrahedrons are not absolutely identical. These are symmetrical tetrahedrons. We cannot superpose them.

These notions suffice to show what is meant by hemihedrity, and what is understood by hemihedric faces or forms.

Now, quartz of which we just spoke, is one of the rare mineral substances in which Haüy found hemihedric faces. The habitual form of this mineral, a regular hexagonal prism, terminated by two pyramids of six faces, is well known. It is clear that the trihedral angles situated at the base of the faces of the pyramid are identical, and, consequently, if one of them bears a face, it ought to be reproduced on all the others. This is true of the face termed *rhombiferous* by mineralogists.

But Haüy first remarked, in certain specimens, a face very different from this, which he designated by the letter x, which falls more on one side than on the other, without being double, as the law of symmetry would in this case require. Another very curious peculiarity of these crystals has not escaped crystallographers. It is that the face x is inclined sometimes in one direction and sometimes in another. Haüy, who was fond of bestowing epithets appropriate to each variety of a species, applied the term *plagihedral* to the variety of quartz having the face x. Crystals in which the face x inclined to the right, are designated under the name right plagihedrals, the crystal being adjusted in a suitable manner; and those crystals in which the face x inclined in an opposite direction are termed left plagihedrals.

Nothing is more variable than this character. Here it exists; there it is absent. Upon the same crystal there are angles which bear the face x; others which should have it, have it not. Sometimes we find plagihedral faces to the right and to the left. Nevertheless, all persons versed in a knowledge of crystals, admit that there is in quartz a true hemihedrity in two opposite directions.

Here is placed a very ingenious approximation due to Sir John Herschell, communicated to the Royal Society of London, in 1820.

M. Biot, as I previously said, made the remarkable observation, that among the specimens of quartz, some deviated in the direction of the plane of polarized light, and others in an opposite direction, to the right and to the left. This stated, John Herschell associated the crystallographic observation of Haüy with the physical remark due to M. Biot. Experiment confirmed the idea of a relation, in fact, between the right and left plagihedrals and the right and left optical deviations. Specimens of quartz which bear in one direction the face x, deviate the plane of polarized light in the same direction.

Such is an exposition of the principal facts which have preceded the researches, an abridged history of which I have to relate.

III.

When I began to devote myself to particular pursuits I sought to fortify myself in the study of crystals, anticipating that I would derive assistance from it in my chemical researches. The most simple means, it seemed to me, was to take a somewhat extensive work upon crystalline forms, to repeat all the measurements and to compare my determinations with those of the author. In 1841, M. de la Provostaye, whose exactness is well known, published a handsome work on the crystalline forms of tartaric acid, paratartaric acid, and their saline combinations. I took hold of this memoir. I crystallized tartaric acid and its salts, and I studied the forms of their crystals. But, in my progress, I perceived that a very interesting fact had escaped the learned physicist. All the tartrates I studied afforded decided indications of hemihedric faces.

This particularity of form in the tartrates was not very evident. This may be readily conceived, since it had not yet been observed. But when, in one species, it appeared in doubtful characters, I always succeeded in rendering it more manifest, by recommencing the crystallization and slightly modifying the conditions. Sometimes the crystals bore all the faces required by the law of symmetry, but hemihedrity had credit for an unequal development of one half the faces. This was seen for example in the ordinary tartar emetic. It may be said that what adds to the difficulty in recognising hemihedrity, are the frequent irregularities of crystals which are never easily developed. Hence their results, deformities, arrests of development in this or that direction, faces accidentally suppressed, &c. Except under circumstances almost exceptional, the ascertaining of hemihedrity, especially in crystals of the laboratory, requires a very attentive study. Besides that, although hemihedrity may be possible in a form, although it may be a function of the internal structure of the body, it may not be externally manifest, any more than is found upon every crystal of the cubic species all the forms compatible with the cube.

But be that as it may, I repeat, I found hemihedric tartrates.

This observation would have been barren, probably, without the following :—

Let a, b, c, be the parameters of the crystalline form of any tartrate ; α, β, γ, be the angles of the crystallographic axes. These are ordinarily right angles or a little oblique. Besides, the relation of the two parameters, such as a and b, is nearly the same in the different tartrates, whatever may be their composition, the quantity of their water of crystallization, the nature of their bases ; γ, alone differs sensibly. There is a kind of semi-isomorphism among all the tartrates. One might say that the tartaric group prevails and impresses a stamp of resemblance between these different forms, in spite of the difference of the other constituent elements.

It follows from this that there is something in common in the forms of all the tartrates, and it is possible to arrange them similarly, in taking for example, as character of similar position, the position of the axes α and β.

Now, if the disposition of the hemihedric faces be compared on all the prisms of the primitive forms of the tartrates, arranged in the same manner, this disposition is found to be the same.

Let us sum up in two words these results, which have been the point of departure in all my ulterior researches: the tartrates are hemihedric, and they are so in the same direction.

Guided on the one hand by the fact of the existence of molecular rotary polarization, discovered by M. Biot in tartaric acid and in all its combinations; on the other, by the ingenious approximation of Herschell; in the third place, by the learned views of M. Delafosse, with whom hemihedrity has always been a law of structure and not an accident of crystallization, I presumed there might be a correlation between the hemihedrity of the tartrates and their property of deviating the plane of polarized light.

It is important to seize here the sequence of ideas:

Haüy and Weiss ascertained that in quartz there exists hemihedric faces, and that these faces fall to the right in certain specimens, and to the left in others. On his side, M. Biot found that crystals of quartz are also divided into two groups, under the relation of their optical properties, some deviating to the right, and the others deviating to the left, the plane of polarized light according to the same laws. Herschell comes in his turn, places between these two facts, until then isolated, a line of connexion, and says: The plagihedrals of one direction deviate in the same direction; the plagihedrals of the other direction deviate in the opposite direction.

For my part I find that all the tartrates are plagihedral, if I may so express myself, and that they are all in the same direction. I should then presume that here, as in quartz, there was a correlation between hemihedrity and circular polarization. At all events, the essential differences which I have just noticed between the circular polarization of quartz and that of tartaric acid, ought not to be neglected.

We are now, thanks to the new facts which precede, and to the approximations which I have just enumerated, in possession of a preconceived idea, (for it is as yet nothing more,) on the possible correlation of hemihedrity and the rotary power of the tartrates.

Very desirous to find in experiment a corroboration of this still speculative proof, my first thought was to ascertain whether the very numerous crystallizable organic products, which possess the molecular rotary property, have hemihedric crystalline forms, which no one suspected, notwithstanding the approximation of Herschell. This investigation had the success which I anticipated for it.

I occupied myself also with the examination of the crystalline forms of paratartaric acid and its salts, substances isomeric with tartaric combinations, but all of which M. Biot found inoperative upon polarized light. None was found hemihedric.

The idea of the correlation of hemihedrity, and the molecular rotary power of natural organic products, gained ground.

I was soon led to develope it clearly by a very unexpected discovery.

IV.

It is necessary to submit here a very remarkable note from M. Mitscherlich, which was communicated to the Academy of Sciences by M. Biot. Here it is :—

"The paratartrate and tartrate (double) of soda and ammonia have the same chemical composition, the same crystalline form with the same angles, the same specific weight, the same double refraction, and consequently the same angle of optical axes. Dissolved in water their refraction is the same. But the dissolved tartrate turns the plane of polarized light and the paratartrate is indifferent, as M. Biot found through the series of these two genera of salts. But, adds M. Mitscherlich, *here the nature and the number of atoms, their arrangement and their distances, are the same in the two compared bodies.*"

This note of M. Mitscherlich deeply interested me at the time of its publication. I was then a pupil at the Normal School, leisurely meditating on the beautiful studies of the molecular constitution of bodies, and attained, as I thought at least, to a clear comprehension of the principles generally admitted by physicians and chemists. The preceding note disturbed all my ideas. What precision in all the details! Are there two bodies whose properties have been better studied, better compared? But in the actual state of science can we conceive two substances so similar without being identical? M. Mitscherlich himself tells us what was, in his mind, the consequence of this similitude:

The nature, the number, the arrangement, and the distance of atoms are the same. If this is true, what then becomes of this definition of chemical species, so rigorous, so remarkable for the time in which it appeared, given in 1823, by M. Chevreul? *In compound bodies, species is a collection of beings identical in the nature, the proportion and the arrangement of their elements.*

In short, the note of M. Mitscherlich rested in my mind as an obstacle of the first order to our manner of considering material bodies.

Every body will understand now, that, being prepossessed, for reasons stated, with a notion of a possible correlation between hemihedrity of the tartrates and their rotary property, the note of M. Mitscherlich, of 1844, would recur to my memory. M. Mitscherlich, I at once supposed, was deceived upon one point. He could not have seen that his double tartrate was hemihedric, that his paratartrate was not, and if these things are so, the results of his note are not extraordinary; and I would have in it besides the best criterion of my preconceived idea about the correlation of hemihedrity and the rotary phenomenon.

I then hastened to resume the study of the crystalline form of the two salts of M. Mitscherlich. I found, in fact, that the tartrates were hemihedric like all the tartrates which I had previously studied, but, strangely enough, the paratartrate was also hemihedric. Only the hemihedric faces which, in the tartrate, had all the same direction, were inclined in the paratartrate sometimes to the right, sometimes to the left. In spite of all that was unexpected in this result, I did not the less pursue my idea. I carefully separated the crystals hemihedric to the right, and the crystals hemihedric to the left, and observed their solutions separately in a polarizing apparatus. I then saw with no less surprise than pleasure, that the crystals hemihedric to the right deviated the plane of polarization to the right; the crystals hemihedric to the left deviated to the left, and when I took an equal weight of the two kinds of crystals, the mixed solution was neutral to light by the neutralization of the two equal and opposite individual deviations.

Thus I set out from the paratartaric acid; I obtained in the ordinary way the double paratartrate of soda and ammonia, and after some days the solution deposits crystals, all of which have exactly the same angles, the same aspect to such a degree, that M. Mitscherlich, the celebrated crystallographer, in spite of the most minute and severe study, could not detect any difference between them. The molecular arrangement in the two, however, is entirely different. The rotary power as well as the mode of dissymmetry attest it. The two species of crystals are isomorphous, and isomorphous with the corresponding tartrate; but here the isomorphism is presented with a peculiarity without example up to this time; it is the isomorphism of two dissymmetric crystals which reflect themselves in a mirror. This comparison presents the fact in a very just manner. In fact, if in both species of crystals I suppose the hemihedric facettes prolonged until they mutually meet, I obtained two symmetrical tetrahedrons inverse, and which cannot be superposed in spite of the perfect identity of all their respective parts. Hence I must conclude that I had separated by the crystallization of the double paratartrate of soda and ammonia, two atomic groups symmetrically isomorphous, intimately united in paratartaric acid. Nothing is easier than to prove that these two species of crystals represent two distinct salts, from which may be derived two different acids.

It is sufficient to proceed, as in all similar cases, to precipitate each salt by a salt of lead or barytes, and then to isolate the acids by sulphuric acid.

The study of these acids possesses immense interest; I know none more interesting.

But before submitting it, permit me to present here some notes relative to their discovery.

V.

The announcement of the preceding facts naturally placed me in relation with M. Biot, who was not without doubts about their exactness. Charged with reporting upon it to the Academy, he caused me to go to his place to repeat the decisive experiment under his eyes. He sent to me the paratartaric acid which he had previously studied with particular care, and found to be perfectly neutral to polarized light. I prepared in his presence the double salt of soda and ammonia, which he also desired me to procure. The liquor was left in one of his closets to slowly evaporate, and when it had furnished about 30 or 40 grammes of crystals, he requested me to go to the college of France for the purpose of collecting and isolating, under his eye by examining their crystallographic characters, the right and left crystals, desiring me to declare anew, if I affirmed that the crystals which I should place to his right would deviate to the right and the others to the left. That done, he said he would take charge of the rest. He prepared the solutions in strong proportions, and at the moment of observing them in the polarizing apparatus he again invited me into his cabinet. He first placed in the apparatus the most interesting solution, that which ought to deviate to the left. Even without any measuring, he saw, from the aspect alone of the tints of the two images, ordinary and extraordinary, of the analyser, that there was a strong deviation to the left. Then, with very visible emotion the illustrious sage took my arm and said :—" My dear child, I have loved science so much all my life that this makes my heart beat."

You will excuse, gentlemen, these personal recollections, which will never be effaced from my mind. In our times, with our habits, they should be excluded from a scientific memoir, but they seem to me proper in an oral exposition; and perhaps the biographic interest of similar recollections will constitute one of the advantages of the kind of teaching which the Chemical Society now inaugurates.

Besides, there is more here than personal recollections. The emotion of the sage in M. Biot was mingled with the internal pleasure of beholding his own anticipations realized. For more than thirty years M. Biot had vainly endeavored to induce chemists to participate in his conviction, that the study of rotary polarization afforded one of the surest means of obtaining knowledge of the molecular constitution of bodies.

VI.

Let us return to the two acids which furnish the two kinds of crystals so unexpectedly deposited by the crystallization of the double paratartrate of soda and ammonia. Nothing, I repeat, is more interesting than the study of these acids.

In fact, one of the two, that which is derived from crystals of the double salt hemihedric to the right, deviates to the right, and is identical with the ordinary tartaric acid. The other deviates to the left like the salt which furnishes it. The deviation impressed by these two acids upon the planes of polarization is rigorously the same in absolute value. The right acid follows in its deviation particular laws which no active body had yet presented. The left acid offers them in the most faithful manner in inverse sense, without a suspicion of the smallest difference.

And the proof that paratartaric acid is the combination, equivalent to equivalent of these two acids, is, that if we mix, as I am about to do before your eyes, solutions somewhat concentrated of equal weights of each of them, their combination is accompanied by a disengagement of caloric, and the liquid solidifies at once by an abundant crystallization of paratartaric acid, identical with the natural paratartaric acid.*

Relatively to their chemical and crystallographic properties, whatever may be done with one of these acids, can be repeated with the other under the same conditions, and in all cases we obtain identical products, but not superposable, products which are as like as is the right hand to the left. The same forms, the same faces, the same angles, hemihedric in both cases. The only dissimilarity is in the right or left inclination of the hemihedric facettes, and in the direction of the rotary power.

VII.

It is manifest, from all these results, that we have to deal with two isomeric bodies, whose general relations of similitude and molecular dissimilitude are known.

---

*This beautiful experiment called forth applause from the audience.

Bear in mind the definition of chemical species just now mentioned, namely, the collection of all individuals identical by the nature, the proportion and arrangement of elements. All the properties of bodies are the functions of these three terms, and the object of all our efforts consists in recurring by experiment on properties to the knowledge of these three things.

In isomeric bodies, the nature and proportion [of constituents] are the same. The arrangement alone differs. The great interest of isomerism has been to introduce into science this principle—that bodies may be and are essentially different by that alone, that the arrangement of atoms is not the same in their chemical molecules.

But no isomeric bodies existed whose relations of molecular arrangements were known. This gap is filled for the first time by the discovery of the constitution of paratartaric acid and the relations of constitution of the right and left tartaric acids. We know, in fact, on the one hand, that the molecular arrangements of the tartaric acids are dissymmetric, and on the other, that they are rigorously the same, with the sole difference of presenting dissymmetries in opposite directions. Are the atoms of the right acid grouped according to the spire of a dextrorse helix, or placed at the summits of an irregular tetrahedron, or disposed according to such or such determined dissymmetric assemblage? We are unable to reply to these questions. But what cannot be doubted is, that there is a grouping of atoms according to an order dissymmetric to a non-superposable image. What is not less certain is, that the atoms of the left acid precisely realize the inverse dissymmetric grouping of this one. We also know, that paratartaric acid results from the juxtaposition of these two groupings of inversely dissymmetric atoms.

From this moment the ascertaining the resemblances and the chemical and physical differences which correspond to these arrangements whose relations are known, affords particular interest, and gives to the molecular mechanism assured bases. It permits us to establish the connexion of physical and chemical properties with the molecular arrangement which determines their proper existence, or inversely it permits us to recur from properties to their first cause.

These general relations of properties and corresponding atomic arrangements may be summarily stated as follows:—

1st. When the elementary atoms of organic products are dissymmetrically grouped, the crystalline form of the body manifests this molecular dissymmetry by non-superposable hemihedrity.

The cause of hemihedrity is then recognized.

2d. The existence of this same molecular dissymmetry is translated beyond by the rotary optical property.

The cause of rotary polarization is also determined.*

3d. When non-superposable molecular dissymmetry is found realized in opposite directions, as happens in the two, right and left, tartaric acids and all their derivatives, the chemical properties of these identical and inverse bodies are rigorously the same; whence it follows that this mode of opposition and of similitude does not alter the ordinary play of chemical affinities.

I am mistaken: upon this latter point there is a restriction to be placed, an important restriction, eminently instructive. Time would fail me to-day to develope it at leisure and properly. It will find a place in the next lecture.

Fresnel, by one of those views of genius of which he has had so many has in a manner presented this cause of rotary polarization.

He expresses himself thus, in one of his memoirs, in volume xxviii. of the "Annales de Chimie et de Physique," year 1825:—"Rock crystal presents optical phenomena, which cannot be reconciled with the complete parallelism of the molecular lines, and which would seem to indicate a progressive and regular deviation from these lines in the passage, from one slice of the medium to the next."

(To be continued.)

[From the American Journal of Pharmacy, March, 1862.]

SECOND LECTURE.

If we consider material objects, whatever they may be, in the relation of their forms and of the repetition of their identical parts, we shall not be slow to perceive that they are distributed in two great classes, thus characterized: Some placed before a mirror give an image which to them is superposable; the image of others would not cover them although it faithfully reproduces all their details. A straight stair, a stem of distich leaves, a cube, the human body, are bodies in the first category. A winding stair, a stem of leaves spirally inserted, a screw, a hand, an irregular tetrahedron, are so many forms of the second group. These latter have no plane of symmetry.

We know on the other hand that compound bodies are aggregates of identical molecules, themselves formed of assemblages of elementary atoms distributed according to laws which regulate the nature, the proportion, the arrangement of them. The individual, for every compound body, is its chemical molecule, and this is a group of atoms, not a group pell-mell; there is, on the contrary, a very determinate arrangement. Such is the manner in which all physicists represent the constitution of bodies.

This stated, it would have been very astonishing had not nature, so varied in her effects, and whose laws permit the existence of so many species of bodies, offered in the atomic groups of compound molecules both of these two categories in which all material objects are distributed. In other words, it would have been very extraordinary, if among all chemical substances, natural or artificial, there had not been individuals with a superposable image and others with an image non-superposable.

Things happen in fact as might be naturally anticipated ; all chemical combinations, without exception, are equally distributed in two classes ; those having an image superposable, and those having an image not superposable.

II.

It is easy to show that this is a legitimate consequence, necessary from our first comparison. To place it in clear light I will briefly recall the principal conditions of the decisive experiment which closed the preceding lecture.

I prepare by the aid of natural paratartaric acid, the paratartrate of soda and ammonia. It is deposited in beautiful crystals.

Observed in a polarizing apparatus, a solution of any portion of this double salt offers no indication of optical deviation ; and in separating from the crystals the acid which they contain, paratartaric acid, identical with that which served to form them, is reproduced. So far all is simple and natural, and it seems as if we had to deal with the crystallization of an ordinary salt. There is nothing of the kind, however.

Take another portion of the same crystals and examine them one by one. You will find that one half has the form, a model of which I here present, characterized by a non-superposable hemihedrity; that the other half has the inverse form identical with the first in all its respective parts, and yet cannot be superposed on it. Then let the two kinds of crystals be isolated to be dissolved separately, and we observe that one of the two solutions deviates the polarized light to the left and the other to the right, and both equally.

If we extract by the ordinary chemical processes the acids from these two kinds of crystals, we perceive that one of them is identical with common tartaric acid, and that the other is in all points similar, except that it cannot be superposed on it. They bear to each other the relations of the two salts from which they were separated. They resemble each other as much as the right hand resembles the left, or as two irregular symmetric tetrahedrons resemble each other, and these analogies and these differences are found in all their derivatives. What can be done with one may be repeated with the other under the same conditions, and the resulting products constantly manifest the same properties, with this single difference, that in some the deviation of the plane of polarization is to the right, and in others to the left, and that the forms of corresponding species, although identical in all their details, cannot be superposed.

All these facts, so clear, so demonstrative, oblige us to refer the general exterior characters of these acids and their combinations, to their individual chemical molecules. Not to do it would be to ignore the rules of the most common logic. It is thus we arrive at the following conclusions :

1st. The molecule of tartaric acid, whatever it may be otherwise, is dissymmetric, and of a dissymmetry with an image non-superposable. 2d. The molecule of the left tartaric acid is formed precisely by the group of inverse atoms. And by what characters shall we recognize the existence of molecular dissymmetry? In the one case by non-superposable hemihedrity; in the other, and especially by the rotary optical property when the body is in solution.

These principles being stated, let us examine all bodies, whether from nature or the laboratory, and we shall find easily that among them a great number possess both this kind of hemihedrity and the molecular rotary property, and that all others possess neither the one nor the other of these characters.

I was right, then, in saying: The legitimate and forced consequence of our first lecture may be thus expressed :—

All bodies (I use this expression chemically) are divided into two great classes; bodies with a superposable image, and bodies with a non-superposable image; bodies constructed of dissymmetric atoms, and those formed of homohedric atoms.

III.

Here we encounter a fact worthy of fixing the attention, even though we should regard it alone and isolated from the whole of the considerations about to follow. It is this:

All artificial products of the laboratory and all mineral species have a superposable image. On the contrary, most of the natural organic products, (I might say all, if I had to name only those which play an essential part in the phenomena of animal and vegetable life,) all products essential to life are dissymmetric and of the dissymmetry which causes their image to be non-superposable.

Before proceeding further, I desire to set aside some objections which cannot fail to present themselves to your minds.

IV.

Quartz, you will say at once? We have seen in the last lecture that quartz possesses the two characters of dissymmetry, the hemihedrity in form observed by Haüy, and the rotary phenomenon discovered by Arago. Nevertheless, all molecular dissymmetry is absent in quartz. To understand it, let us advance a little further in the knowledge of the phenomena we are considering. We shall find, moreover, the explanation of the analogies and differences already previously indicated between quartz and natural organic products.

Permit me to describe roughly, though in the main accurately, the structure of quartz and that of natural organic products. Imagine a winding stair, the steps of which shall be cubes, or any other object with a superposable image. Destroy the stair, and the dissymmetry will have disappeared. The dissymmetry of the stair was the result only of the mode of putting together its elementary steps. Such is quartz. The crystal of quartz is the stair all built. It is hemihedric. For this reason it acts on polarized light. But let the crystal be dissolved, melted, its physical structure destroyed in any manner, and its dissymmetry is suppressed, and with it all action on polarized light, as would happen, for example, in a solution of alum, a liquid formed of molecules of a cubic structure distributed without order.

Imagine, on the contrary, the same winding stair formed of irregular tetrahedrons for steps. Destroy the stair, and the dissymmetry will still exist, because you have to deal with an assemblage of tetrahedrons. They may be in any position, but each one of them will have its proper dissymmetry, nevertheless. Such are organic bodies in which all the molecules have a proper dissymmetry, which is translated in the form of the crystal. When the crystal is destroyed by solution, there results from it a liquid active for polarized light, because it is formed of molecules pell-mell, it is true, but each having a dissymmetry in the same direction, if not of the same intensity in all directions.

V.

Quartz, then, is not molecularly dissymmetric, and up to the present time we do not know any example of a mineral which possesses molecular dissymmetry. I have said that we must extend this proposition to the artificial compounds of laboratories. Here still we may have some scruples. We may object, for example, that native camphor, which is dissymmetric, yields artificially camphoric acid, also dissymmetric; that aspartic acid derived from asparagine by a reaction in the laboratory is dissymmetric like asparagine, and I might cite many other like examples. But no one doubts that camphoric and aspartic acids owe to camphor and to asparagine their proper dissymmetry. This exists in the mother products, and it is transferred, modified more or less by substitution, from the mother products to their derivatives. We are unable to produce better evidence, in general, of the preservation of the primitive type in a series of products connected by a common origin, than the permanence of the optic property.

When I affirm that no artificial substance has yet presented molecular dissymmetry, I mean to speak of artificial substances, properly so called, formed entirely of mineral elements or derived from non-dissymmetric bodies. For example: Alcohol is not dissymmetric. Its molecule, if we could isolate and study it, placed before a mirror, would present an image superposable to it. Now, there is no derivative from alcohol which is not dissymmetric. I could multiply examples of this kind without end. Further, take any dissymmetric body, and if you subject it to somewhat energetic chemical reactions, you will assuredly see the dissymmetry of the primitive group disappear. Thus, tartaric acid is dissymmetric. Pyrotartaric acid is no longer so. Malic acid is dissymmetric. Maleïc and paramaleïc acids of M. Pelouze are not. Gum is dissymmetric, mucic acid is not.

Artificial products, then, have no molecular dissymmetry; I do not know how to indicate the existence of a more perfect separation between the products originating under the influence of life and all others. We insist a little, because you will see in the sequel of this lecture the physiological aspect of these studies disengages itself more and more. Let us pass in review the principal classes of natural organic products:

Cellulose, feculæ, gums, sugars; tartaric, malic, quinic, tannic acids; morphia, codeia, quinia, strychnia, brucia; essences of turpentine, of lemon; albumen, fibrin, gelatin. All these immediate principles are molecularly dissymmetric. All these substances have the rotary power when in solution; a character necessary and sufficient to establish their dissymmetry, even when, in the absence of possible crystallization, hemihedrity would be wanting for the recognition of this property.

All the substances most essential to the vegetable and animal organism figure in this enumeration.

There are many natural substances which are not dissymmetric. But are they natural in the same sense as the others? Do we not necessarily see in such bodies as oxalic acid, hydruret of salicyle, fumaric acid, the derivatives of natural substances properly so called, formed by actions analogous to those of the laboratory? These products seem to me to be in the vegetable organism what urea, uric acid, creatin, glycocol, are in the animal organism, rather excretions than secretions, if I may so speak. It will be very interesting to follow this point of view experimentally.

We may add to this, that many bodies, non-dissymmetric in appearance, may be *paratartarics*. A word is wanting in chemical language to express the fact of a double molecular dissymmetry concealed by the neutralization of two inverse dissymmetrics, the physical and geometric effects of which rigorously compensate each other.

The double proposition, to which we have just been led, upon the habitual dissymmetry of immediate organic principles, and upon the absence of this character in all the products of inorganic nature, enables us to enlarge and render more and more precise our manner of viewing the subject of this remarkable molecular property.

VI.

In 1850, M. Dessaignes, whose ingenious skill is known to chemists, announced to the Academy that he had succeeded in transforming the bimalate of ammonia into aspartic acid. It was a step which tended to confirm the important results that M. Piria had obtained some years previously. M. Piria had succeeded in transforming asparagine and aspartic acid into malic acid. M. Dessaignes, in his turn, showed inversely that malic acid could be re-formed into aspartic acid.

Thus far there was nothing but what was very natural in the observation of M. Dessaignes, even in the optical point of view. For my part, I had recognised that asparagine, aspartic acid, and malic acid, were active on polarized light. The chemical passage of one of these bodies to the others was not surprising.

Some months later M. Dessaignes made another step forward. He announced that not only the bimalate of ammonia, but also the fumarate and maleate of ammonia had equally the property of being transformed by heat into aspartic acid.

Here I perceived an impossibility; or, if the thing was as M. Dessaignes asserted, this skilful chemist had made a discovery which he did not suspect. Indeed, I observed that fumaric and malic acids, and all their salts, were without action on polarized light. If, then, M. Dessaignes had succeeded in transforming their salts of ammonia into aspartic acid, he must have realized, for the first time, the production of a dissymmetric body by the aid of compounds which are not.

But it appeared to me more reasonable to believe that the aspartic acid of M. Dessaignes differed from natural aspartic acid decidedly in the absence of the molecular rotary property. M. Dessaignes, it is true, had carefully compared the properties of the artificial acid with those of the natural acid, and, as he said, found them identical. Better than any one, from the example of M. Mitscherlich, of whom I spoke at our last meeting, I knew how delicate is the determination of the identity of chemical species, in studies in which the greatest similitude of properties often conceal profound differences. I did not hesitate to believe, therefore, that the new fact announced by M. Dessaignes had need of confirmation.

I attached so much importance to the elucidation of this question, and in the anticipation even of the results which I am about to have the honor to lay before you, that I immediately made a journey to Vendome, where I submitted my doubts to M. Dessaignes, who at once presented me with a specimen of his aspartic acid. On my return to Paris, I found immediately, in fact, that the acid of M. Dessaignes was only an isomeric of the natural aspartic acid, that is, the acid derived from asparagine, and that it differed from it, as I had foreseen, by the rotary property, entirely absent in the artificial acid, not at all doubtful in the natural acid. But all the other physical and chemical properties possessed the greatest analogies, so great that M. Dessaignes, who was not put on his guard by any pre-conceived idea, had concluded that the two substances are really identical.

What attracted me most in the examination of the new compound, (which by itself offers no very remarkable crystallizable combinations,) was its transformation into malic acid. It is indeed known that M. Piria, just mentioned, long ago gave the means of obtaining malic acid from asparagine and aspartic acid; and I was assured by the most exact proofs that this malic acid was identical with that of the service, [*sorbus,*] the apple, the grape, and tobacco.

I then treated the new acid in the manner discovered by M. Piria, and transformed it into a new malic acid very similar to the natural acid, so close to the latter, that a chemist would have great difficulty in distinguishing them, even if warned of their real dissimilarity; only this malic acid had no action on polarized light, and it was the same with all its saline combinations.

There are certain derivations of these two malic acids, the comparison of which does not very clearly manifest the true mutual dependence of the molecular arrangements of these curious isomerics, but there are others in which it is plainly seen. Let us consider, for example, the ordinary active bimalate of lime, and the corresponding inactive bimalate. Their chemical composition is exactly the same, and their crystalline forms are alike, with this difference that the form of the active bears four small hemihedric faces, always absent in the form of the inactive. Whence it results that placed before a glass, the image of the active cannot be superposed on it, while the image of the inactive is absolutely identical and superposable to the reality which gives it. Excepting the hemihedric faces, there is a perfect resemblance between the two forms.

Who could doubt after that, the relations of molecular arrangements of these two salts? Is it not evident that we have here to deal with a malic acid identical to the natural, except the simple suppression of its molecular dissymmetry?

This is the natural malic acid untwisted, if I may so express it. The natural acid, in the arrangement of its atoms, is a winding stair; this one is the same stair, formed of the same steps, but straight, instead of being spiral.

It might now be asked if the new malic acid is not the paratartaric of the series, that is, the combination of the right malic acid with the left malic acid. That is scarcely probable; for then not only with an inactive body we would have made an active body, but would have made two, one right and one left.

Besides, I have ascertained that just as there exists a non-dissymmetric inactive malic acid, so there is also a non-dissymmetric inactive tartaric acid, very different from paratartaric acid, and which cannot be resolved into right tartaric and into left tartaric acids. Here it cannot be doubted that we have to deal with right or left tartaric acid rendered non-dissymmetric.

I have also discovered inactive amylic alcohol, which yields a whole series of inactive products corresponding to the series of active amylic alcohol.

Thanks to the discovery of inactive bodies, we are in possession of a fruitful idea: a substance is dissymmetric, right or left, by certain modes of isomeric transformations, which must be sought and discovered in each particular case; it may lose its molecular dissymmetry, untwist itself, to use a coarse illustration, and effect in the arrangement of its atoms a disposition with a superposable image. So that every dissymmetric substance offers four varieties, or rather four distinct subspecies: the right body, the left body, the combination of the right and the left, and the body which is neither right nor left, nor formed by the combination of the right and left.

VII.

This general conclusion from the preceding studies, throws new light upon our ideas of molecular mechanism. We see that if natural products, organized under the influence of vegetable life, are ordinarily dissymmetric, contrarily to what mineral and artificial products offer us, this disposition of elementary particles is not a condition of existence of the molecule, that the twisted organic group can untwist itself, and then take the general character of artificial or mineral substances. On the other hand, it seems to me logical to regard the latter as susceptible of presenting a dissymmetric arrangement of their atoms in the manner of natural products. The conditions of their production are to be discovered.

As final analysis and summing up of what precedes, the groups of elementary atoms which constitute compound matter may cover two distinct states, corresponding to two general types to which every material object may be referred. The form of the group is with a superposable image, or with a non-superposable image; but this latter type is double, because its inverse can exist on the same ground as itself. We must add the case of the association of these two inverse types, which recalls the union by pairs of the identical and non-superposable members of the superior animals. So that there is in reality four remarkable dispositions for the groups of atoms which constitute matter. All our efforts should tend towards producing them for each particular species.

There is in almost all these considerations such exactitude, that it seems impossible to call them in question.

How refuse to admit that a right body has its possible left, knowing as we know the signification of the right or left character? This would be to doubt that an irregular tetrahedron has its inverse, that a dextrorse helix has its sinistrorse inverse, that a right hand has its possible left.

And hence, if the mysterious influence to which the dissymmetry of natural products is due should come to change in sense or direction, the constituting elements of all living beings would take an inverse dissymmetry. Perhaps a new world would be presented to us. Who could foresee the organization of living beings, if the cellulose, which is right, should become left, if the left albumen of the blood should become right? There are here mysteries which prepare immense labors for the future, and from this hour invite the most serious meditations of science.

VIII.

Only because chemistry has been up to the present time powerless in the preparation of dissymmetric bodies, might we fear that we may be always ignorant of the mode of production of the inverse bodies of natural organic substances. Happily this fear is exaggerated. I have ascertained indeed that, by ordinary chemical processes, such as the action of heat, a right body can be changed to its left, and inversely. Thus in warming right tartaric acid under certain determinate conditions, which it would be too long to specify here, it is transformed into left tartaric acid, or rather into paratartaric acid; and inversely, under the same conditions exactly, left tartaric acid becomes right.

Here are ten or twelve grammes* of entirely pure, left tartaric acid, which were thus procured. Their preparation cost me much trouble. But M. Biot desired to study in a very particular manner the characters of dispersion of this left tartaric acid, so remarkable on account of its origin. He desired himself to be at the cost of the operation; very expensive, because the transformation depends upon the employment of the tartrate of cinchonine or of quinine, and the base is lost because the tartrate must be heated to a temperature which destroys it.

I have prepared by this process sufficient paratartaric acid to take from it twelve grammes of left tartaric acid, which presents rigorously, in an inverse sense, the same optical characters as tartaric acid.

Every analogous transformation of a natural dissymmetric body into its inverse, should be regarded as a great advance in organic chemistry.

IX.

At the conclusion of our first lecture, I alluded to observations to which it is time we should give all the attention they merit. These observations are relative to the comparison of the physical and chemical properties of right and corresponding left isomerics. I have already insisted upon the perfect identity of all their properties, excepting, however, the inversion of their crystalline forms, and the opposition of direction of their optical deviations.

---

* A gramme is equal to about 15½ grs.—Tr.

Physical aspect, lustre of the crystals, solubility, specific gravity, single or double refraction, all is not only alike, similar, very near, but identical in the most rigorous acceptation of the word.

This identity is the more remarkable as we shall see it replaced by a general and considerable opposition of the properties of these same substances, when they are found in particular conditions which I am about to point out.

We have seen that we must distribute all chemical compounds, artificial or natural, mineral or organic, in two great classes; compounds non-dissymmetric with superposable image, and compounds dissymmetric with non-superposable image.

This stated, the identity of properties, of which I have just spoken in the two tartaric acids and their similar derivatives, constantly exists with the absolute characters I have named, whenever these substances are placed in presence of any compound of the class of bodies with superposable image, such as potassa, soda, ammonia, lime, barytes, aniline, alcohol, the ethers—in a word, of all compounds, whatever they may be, not dissymmetric, not hemihedric in form, without action on polarized light.

Submit them, on the contrary, to products of the second class with non-superposable image, asparagine, quinine, strychnine, brucine, albumen, sugar, &c., &c., bodies dissymmetric like them, all changes in an instant. Solubility is no longer the same. If there is combination, the crystalline form, specific gravity, the quantity of water of crystallization, the more or less ready destruction by heat, all differ as much as the most distant isomeric bodies differ.

Here then we have the molecular dissymmetry of bodies introducing itself in chemistry as a powerful modifier of chemical affinities. In presence of the two tartaric acids, quiñia does not behave like potassa only because it is dissymmetric, and potassa is not. Molecular dissymmetry is hence offered as a property capable by itself, as far as dissymmetry, of modifying chemical affinities. I do not believe any discovery has yet entered so far into the mechanical part of the problem of combinations.

Let us endeavor to present the cause of these identities and of these dissemblances. Let us suppose a dextrorse helix and a sinistrorse helix separately penetrating two blocks of identical wood, and in right lines. All the mechanical conditions of the two systems will be the same. It will be no longer so from the moment these same helices shall be associated with blocks, themselves shaped in helices of the same direction, or of opposite directions.

X.

Here is a very interesting application of the facts which I have just submitted.

Seeing right and left tartaric acids become thus dissimilar solely in virtue of the rotary power of the base, there was room to hope that from this very dissemblance would result chemical forces capable of balancing the mutual affinity of these two acids, and consequently a chemical means of separating the two elements of paratartaric acid. I long sought without success; but I succeeded in it by the aid of two new bases, isomerics of quinine and cinchonine, and I obtain very easily without the smallest loss, by the aid of these latter, quinicine and cinchonicine.

I prepare the paratartrate of cinchonicine by neutralizing the base, then adding as much acid as was required for its neutralization, I crystallized, and the first crystallizations are formed of left tartrate of cinchonicine perfectly pure. All the right tartrate remains in the liquid because it is more soluble. Then itself is crystallized, and under a different aspect, because it has not the same crystalline form as the right [qu. left?] One would suppose that he had to deal with the crystallization of two very distinct salts, of unequal solubility.

XI.

But the dissemblance of the properties of corresponding right and left bodies when submitted to dissymmetric forces, appears to me to be of the highest interest, in connection with the ideas it suggests on the mysterious cause, which presides over the dissymmetric disposition of atoms in natural organic substances. Why this dissymmetry? why such a dissymmetry in preference to its inverse?

Recur with me in thought to the epoch when, having recognised the absolute identity of the physical and chemical properties of corresponding right and left bodies, I had no idea, not even a suspicion, of possible differences between these bodies. It is, indeed, many years since I recognised these identities and these differences.

It was then impossible for me to understand how nature could make a right body, without making at the same time a left body. For the same forces which are in play at the moment of the elaboration of the molecule of right tartaric acid, ought, it seems, to give a left molecule, and there should be only *paratartarics*.

Why even rights or lefts? Why not, only non-dissymmetrics, substances of the order of those of inorganic nature?

There are evidently causes for these curious manifestations of the play of molecular forces. To indicate them in a precise manner, would be certainly very difficult. But I do not believe I am mistaken in saying that we know one of their essential characters. Is it not necessary and sufficient to admit that, at the moment of the elaboration in the vegetable organism of immediate principles, a dissymmetric force is present? For we have just seen there was but a single case in which the right molecules differed from their left, the case in which they are submitted to actions of a dissymmetric order.

May these dissymmetric actions, placed perhaps under cosmic influences, reside in light, in electricity, in magnetism, in heat? Are they in relation with the motion of the earth, with the electric currents by which physicists explain the terrestrial magnetic poles? It is not even possible, at the present time, to emit the smallest conjectures in this respect.

But I regard as necessary the conclusion, that dissymmetric forces exist at the moment of elaboration of natural organic products, forces which would be absent or without effect in the re-actions of our laboratories, either on account of the sudden action of these phenomena, or on account of some other unknown circumstance.

XII.

We come to the last experiment, the interest of which does not yield to any of those which precede, in the proof which it will manifestly afford us of the influence of dissymmetry on the phenomena of life. We have just seen dissymmetry intervene as a modifier of chemical affinities; but it dealt with re-actions purely mineral, artificial, and we all know how prudent we should be in the application of results in our laboratories to the phenomena of life. Therefore I have reserved almost all the views presented in this lecture until I recognised in the most certain manner, that molecular dissymmetry offers itself as a modifier of chemical affinities, not only in the re-actions of inorganic nature, but in those of a physiological order, in fermentations.

This is the remarkable phenomenon to which I allude.

It has long been known, through the observation of a manufacturer of chemical products in Germany, that the impure tartrate of lime of the factories, soiled by organic matters, and abandoned under water in the spring, may ferment and yield different products.

That stated, I place in fermentation the common right tartrate of ammonia in the following manner:—I take the very pure crystallized salt, dissolve it, adding to the liquid a very limpid solution of albumenoid matters. One gramme of dry albumenoid matters is enough for 100 grammes of tartrate. Very often the liquid, placed in a stove, spontaneously ferments: I say very often; I might add, that it always takes place, if care is taken to mix with the liquid a very small quantity of one of those liquids in which spontaneous fermentation has been obtained.

Thus far there is nothing remarkable; it is a tartrate which ferments. The fact is known.

But apply this mode of fermentation to the paratartrate of ammonia; and, in the preceding conditions, it ferments. The same yeast, or leaven, is deposited. All indicates that things go on absolutely, as in the case of the right tartrate. If, however, we follow the steps of the operation with the aid of the polarizing apparatus, we very soon perceive marked differences between the two operations. The liquid, at first inactive, possesses a rotary power sensibly to the left, which augments little by little, and attains a maximum. Then the fermentation is suspended. There is no longer a trace of right acid in the liquid, which, evaporated and mixed with its volume of alcohol, immediately furnishes a fine crystallization of left tartrate of ammonia.

We remark at first in this phenomenon two distinct things; as in every fermentation, properly so called, there is a substance which is chemically transformed, and correlatively, there is a development of a body possessing the manners of a mycodermic vegetable. Elsewhere, and it is this which it is important to note at this time, the yeast which causes the right salt to ferment, respects the left salt, in spite of the absolute identity of the physical and chemical properties of the two right and left tartrates of ammonia, whenever they are not subjected to dissymmetric actions.

Observe then molecular dissymmetry proper to organic matters intervening in a phenomenon of the physiological order, and it intervenes here in its character of modifier of chemical affinities. There is not the least doubt in the world about what may be the kind of dissymmetry proper to the molecular arrangement of left tartaric acid, which is the sole, exclusive cause of the difference that it presents with the right acid, under the relation of its fermentation.

And thus is found introduced into physiological considerations and studies the idea of the influence of the molecular dissymmetry of natural organic products, of the great character which establishes, perhaps, the only well-marked line of demarcation, which can be placed at the present time between the chemistry of organic nature and the chemistry of inorganic nature.

XIII.

Such are, gentlemen, in their totality, the labors with which I have been charged to entertain you.

You have learned, as we advanced, why I have entitled my exposition, On the Molecular Dissymmetry of Natural Organic products. It is, in fact, the theory of molecular dissymmetry that we have just established; one of the highest chapters of science, entirely unforeseen, and which offers to physiology entirely new, distant, but certain horizons.

I entertain this opinion of the results of my own researches, without mingling in the expression of my thought any of the self-satisfaction of the author. May it please God that personalities shall never be possible in this chair! These are as pages of the history of chemistry, which we shall successively write, with the sentiment of dignity which a true love of science always inspires.