B R A I N .

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Original Articles.

THE NATURE OF THE OBJECTIVE CAUSE OF SENSATION.—PART II. TASTE.

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HOBBS (subsequently Hartley and many English psychologists) viewed sensation as the result of a pressure or action of an external particle of matter upon the appropriate sense-organ, and a transmission along a nerve to the brain. Those multitudinous feelings of sight and hearing, of taste and smell, of which we are conscious, were all, according to this thinker, the result of transmissions to the brain excited from without; nor is this view without modern scientific support.

It is not one of the newest triumphs of microscopical research to show that the eye, the ear, the nose, and the tongue are all beset with little cellular particles, attached to the sensory nerves of those parts, and extremely sensitive to the "pressures" or "actions" of external particles of matter. Let us call these the sensitive cells or end-organs of the body, understanding by this term that they are formed on the external ends of the nerves. These end-organs are all very much alike in shape and general appearance, it matters not from which sense-organ you take them for examination. In all cases the part attached to the nerve is thick, granular like ground glass, and with a kernel or nucleus; the outer and more projecting part is drawn out into a rod or hair. It is the

style or hair which, directly stimulated from without the body, excites the nerve through the inner segment, sending an impulse to the brain, and giving rise to a sensation.

No doubt an anatomist could, by careful inspection, tell at once the end-organs, taken from the retina of the eye, from those of the ear, or the nose, yet they are all formed, as it were, on the same plan.

No one has insisted more emphatically than Mr. Herbert Spencer that these end-organs have all come from common parentage, hence, in part, their similarity. We are to look, in fact, if we wish to understand their nature aright, upon these different end-organs as arising, by slow development, during the evolution of the animal world, from a layer of simple cells—ectodermic—found covering the bodies of our more primitive ancestors. Most of these ectodermic cells remain as the cells of the skin, but some are changed into the end-organs of the special senses we are discussing.

Now this development, Mr. Herbert Spencer would say, is in part the result of the action of the surrounding forces or the environment upon the organism itself. These acting for many generations have produced changes which depend upon the nature of the organism and of its environment.

That motion of the ether which travels with such velocity and which, striking the eye, sets up an impulse in the optic nerve, and on reaching the brain produces a sensation we call light, is a vibratory motion.

That motion of the air—not of the same velocity as light—which, striking the ear, produces a sensation we call sound, when the impulse it sets up reaches the brain along the auditory nerve, is also a *vibration*.

No one doubts at the present time that all material particles are in constant motion of a vibratory nature. The molecules of a gas are vibrating; so are those of a liquid and a solid. The particles of salt in the sea, or the sugar in a cup of tea, are in constant motion; so are the molecules of quinine and quassia, the odorous particles of musk and of the rose.

We see then that the body is surrounded and acted upon by various forms of matter in vibratory motion. The environments which have developed the special organs out of

the more simple ectodermic cells are moving particles of matter, and they have in all the sense-organs produced the end-organs before alluded to—armed with little rods or styles, the identical structures capable of being to an extraordinary degree affected by motion.

With these general qualities common to the environments of all the special senses, which senses are built up so essentially on the same type, we shall expect to find very striking analogies between the modes of production of the different senses. Thanks to the labours of Young, Maxwell and Helmholtz, we know a good deal about the way in which the organism is stimulated by light and sound, but we know almost nothing about the production of taste and smell. Indeed this matter has as yet received so little attention that scarcely anything is known to the specialist which is not the intellectual property of every one.

The following paper is an investigation into the nature of the production of taste sensations; the question of the production of smell sensations I shall discuss in a subsequent paper.

Let us take for our guide this unity of plan so evident from a study of the microscopical anatomy of the sense-organs; let us study, first the production of sight and hearing, and then endeavour to find analogous ways in which it may be possible to account for the production of taste.

The end-organs of the retina are stimulated by the vibrations of that rarefied matter called ether, in a way as yet not clearly understood. These vibrations differ very much from one another in rapidity or pitch, some are so slow—the ultra-red rays of the spectrum—that they produce no sensation at all. Some again—the ultra-violet—produce no sensation, because they are too rapid. Between these two extremes we find a large number of rays of the visible spectrum—which when they fall upon the eye cause a sensation of light and colour. Now it is found that the kind of colour, or, as we may call it, the quality of the sensation, depends directly upon the pitch of the vibration and nothing else. A somewhat slow vibration causes a sensation of red, a more rapid one a sensation of orange, and so on. It is seldom in nature that the eye is stimulated by vibrations of

only one pitch; thus I have in front of me a book that has a cover of a crimson colour, and I know by experiment that this crimson sensation is only produced when the eye receives at the same time from the same object at least two sets of vibrations. The vibrations that produce the sensations of crimson, scarlet, purple, lilac, &c., are all complex; that is, they are combinations of two or more sets of simple vibrations.

We see then that it is the *kind of vibration* which determines the quality of the sensation in the sense of sight, and that there are differences in the vibratory ether outside the body to correspond with the almost limitless colour variations of which we are sensible.

Let us turn to hearing. If we place a long piece of steel in a vice, and alter its length at will, we shall find that on striking it with a rod it will vary in the rapidity of its vibrations, and various sound sensations will be produced.

If it vibrate slowly, some ten times a second, we shall hear nothing, and if it vibrate very rapidly indeed we shall hear nothing; but, as in the case of sight, we shall find varying sound sensations produced within these extreme limits. The quicker the vibration, the shriller the sound.

In nature, observe the analogy with the ether vibration; sonorous vibrations are seldom simple. From a flute, or a violin, we have a bundle of vibrations striking the ear when a note is sounded. The vibration is complex—generally consisting of a slow vibration called a fundamental tone, and a series of overtones harmonically related to it. The sound of a flute is quite different from that of a violin, even when the same note in the musical scale is sounded in both cases. The reason is that the bundles of vibrations are different, the overtones differing in intensity and arrangement. We see therefore that the *kind of vibration* falling on the ear determines the quality of the sound produced. Both in sight and hearing the sensations will depend upon the pitch or rapidity of the vibration if it is a simple one; or if it is complex, upon the pitch and arrangement of the component simple vibrations. We may say then that the kind or character of the vibratory motion determines the quality of the sensation in both cases. A knowledge of these facts, together with the known similarity

in structure of the end-organs of all the senses, will naturally lead an investigator who wishes to study taste or smell production to search for analogous conditions in these senses also.

In sound and light we have motions varying to an almost limitless degree in their kind or character. Have we motions of the same or similar nature in rapid solution?

As we have seen, matter in the liquid state is in motion, the molecules of sugar in water are in motion, and what is more, the motion is characteristic of the substance. The motion of salt is different from the motion of sugar, and the motion of sugar from the motion of quinine. We have then a field for inquiry open to us, for if we can connect definite taste sensations with definite motions we shall have the analogy we seek. Let us proceed to this inquiry. We know that by increasing the weight of a tuning-fork, and also by increasing its bulk, we can cause it to vibrate more slowly, and the same law has been found to hold good for ultimate atoms and molecules, the proof of which will be given later. Is there then any relation between taste sensations and the molecular height of sapid substances?

If we take the molecular weights of acid substances, we shall find in the case of hydrochloric acid a weight of 36.5, in the case of sulphuric acid 98. Lithium chloride, molecular weight 42.5, and potassium sulphate, molecular weight 174, are saline. Many other examples might be adduced from bitter and sweet compounds, to demonstrate that we cannot tell by the molecular weight alone anything about the taste of a substance. In the above example, an acid may have a lower or a higher molecular weight than a salt.

We shall see hereafter that molecular weight is not without its importance, and even at this stage of our inquiry it may be well to allude to a series of facts in this relationship. Bodies which have the greatest molecular weight of any, such as albumens, albuminoids, starches, gums, &c., are totally without taste; nor need it be urged that a ready explanation of this is at hand. No doubt many of these substances are not readily soluble in water, and in consequence they will not readily permeate the viscous layer of saliva covering the tongue and the surface of the gustatory end-organs. Some

albumens, such as serum and egg albumen, are fairly soluble, and they may all be converted by appropriate ferments into allied products called peptones, which are soluble and readily diffusible, and nevertheless devoid of taste. In like manner, starch may be converted into dextrin, a substance readily diffusible in water, and tasteless.

We find also among the list of tasteless bodies all those of very small molecular weight. Water, molecular weight 18, is an example. The simple gases dissolved in water are tasteless, but when we examine substance with a molecular weight over 30, we find that when dissolved in water it is capable of producing some taste or other. Sulphurated hydrogen, molecular weight 34, is very slightly acid to the taste; hydrochloric acid, molecular weight 36.5, is very acid; and nitrogen monoxide, molecular weight 46, is sweet. It is true that the monatomic alcohols, such as ordinary commercial alcohol, have molecular weights over 34, and are tasteless, so that the same rule does not apply to all the carbon compounds; but even here we are struck with the fact, that these alcohols are the lowest of a series, all the polyatomic and more complex alcohols being sapid and sweet in character.

There seems then to be some analogy between taste on the one hand, and sight on the other. The substances of lowest molecular weight, and therefore of most rapid vibration, like the ultra-violet rays of the spectrum, are incapable of producing sensation. In like manner, there are substances of very great molecular weight, and of the most sluggish molecular vibration like the vibrations of the ultra-red, also incapable of affecting the sensorium.

Let us turn again to our study of sapid substances, restricting ourselves in the first case to the investigation of inorganic compounds. A large number, perhaps the greater number, of inorganic compounds are insoluble in water, and are therefore tasteless; we are therefore confined to those which are soluble, and which are chiefly the salts of certain metals. I have endeavoured to obtain information as to the tastes of different substances, by consulting standard works on chemistry, especially the dictionary edited by Watts. In many cases I was unable to obtain any information at all, and in nearly

every case it was insufficient for my purpose. One knows pretty exactly what is meant by a peacock blue, or a salmon colour, but the general descriptions of tastes are absolutely unreliable. Common salt and nitre are both described as saline, sulphate of magnesia and quinine both as bitter. I have been obliged on this account to taste the different substances for myself, and all the observations recorded in this paper are the result of at least two careful experiments with each substance. By the term *salt* I shall indicate a taste like that of common table salt; by *saline*, a taste like that of nitre.

In recent times a remarkable discovery of Newlands has formed a fresh point of departure in connection with the science of chemical physics. His observations led him to formulate a law which he termed the law of octaves. Lothar Meyer, Mendelejeff and Carnelley, in extending his work, have shown that the Periodic Law—as it is now termed—is one of wide application and importance. The nature of the Periodic Law is now so well known, thanks to the many recent publications of Professor Carnelley, that it would be superfluous to do more than merely sketch its main features.

If we arrange the elements in the order of their atomic weights, beginning with that which has the lowest, and passing to that which has the highest, we shall find that there is a periodic recurrence of function or property in the series. The first element is a monad, the second a dyad, the third a tryad, and the fourth a tetrad. Then we find the fifth a triad, the sixth a dyad, and the seventh once more a monad. Then follows a second series of seven elements, showing the same variation in atomicity, and this repeats itself right through the list of elements.

This periodic recurrence is seen not only with atomicity, but with the atomic volume, the fusibility, the electrical and other properties of the elements. There is then a general resemblance in physical properties between the first, eighth, fifteenth, &c.; between the second, ninth, sixteenth, &c., and so on. Mendelejeff has arranged the elements in a very convenient tabular form, see table p. 152, which brings out these and some other important facts.

Those elements which resemble one another, and which we

can pick out, taking every eighth one from that one we start with, form what he calls a *group* (see table). In vertical series are arranged the *groups* of similar elements, and the *series*, each of seven elements, are seen on the horizontal line.

TABLE OF NATURAL CLASSIFICATION OF ELEMENTS. AFTER MENDELEJEFF.

Group	I.	II.	III.	IV.	V.	VI.	VII.	Group VIII.
Series.	Monads.	Dyads.	Triads.	Tetrads.	Triads or Pentads.	Dyads or Hexads.	Monads or Heptads.	
1	H=1	..	..	..	..	..	..	..
2	Li=7	Be=9	B=11	C=12	N=14	O=16	F=19	..
3	Na=23	Mg=24	Al=27	Si=28	P=30	S=32	Cl=35.5	..
4	K=39	Ca=40	Sc=44	Ti=48	V=51	Cr=53	Mn=55	{ Fe=56 Co=57 Ni=59
5	Cu=63	Zn=65	Ga=69	..	As=75	Se=79	Br=80	..
6	Rb=85	Sr=87	Y=89	2n=90	Nb=94	Mo=96	..	{ Ru=104 Rh=104 Pd=106
7	Ag=108	CD=112	IN=113	SN=118	SB=120	TE=125	I=127	..
8	Cs=133	Ba=137	La=139	Ce=142	Di=147	..	..	..
9	..	..	..	..	ER=166	..	..	..
10	..	..	Yb=173	..	Ta=182	W=184	..	{ Os=193 Ir=193 Pt=195
11	AU=197	HG=200	TI=204	PB=207	BI=210	..	..	..
12	..	..	..	Th=234	..	U=240	..	..

There is one other point of importance, namely, that the elements of a *group* which are in an *even* series are especially related one to another in their properties. In the table they are represented in small type. So, in like manner, elements belonging to the same group of *odd* series are especially related.

Thus Li, Na, K, Cu, Rb, Ag, Cs, Au have all of them properties in common; but in this group Na, Cu, Ag, Au are most alike, and Li, K, Rb, Cs, also in like manner, are especially related.

Scientific men have long been taught to expect that material substances similar in their ordinary physical properties, will exert a similar influence on organic life. No one has more completely demonstrated this than Drs. Lauder Brunton, Fraser, and Crum Brown, who have shown that not only elementary protoplasm, but even highly differentiated muscular and nervous tissues are affected in a similar way by substances having allied chemical and physical properties.

Every one is aware, too, of the important part played by the component atoms of a molecule, how by replacing an atom of

hydrogen by an atom of potassium one can convert ordinary water into a caustic alkaline substance. Inasmuch as we have a number of salts formed, say, by the union of chlorine with another element, it is a question well worth the discussion, whether salts formed by the union of chlorine with elements of the *same group* have similar tastes. Speaking more generally: do elements belonging to the same group when combined with the same element or group of elements to form salts, similar as they are in physical properties, produce similar tastes?

It was this question which occurred to me, when, baffled in the hope of connecting taste directly with the gross atomic weight of the sapid substance, I had to reconsider the question afresh. This question, I shall hope to show, may be answered in the affirmative.

By far the greater number of sapid substances contain elements found in Groups I., II. and VII., and these I accordingly studied. The salts of Groups I. and II. most easily obtained are the chlorides and sulphates, and of Group VII. I selected the combinations these elements form with sodium and potassium. As it was very necessary to use salts as pure as possible, many were prepared for me with great care by Mr. Harris the chemist, but for the greater number I have to thank my colleague Dr. Nicol, who placed at my disposal a large collection of very pure salts prepared by himself for his own well-known investigation on solubilities.

In the subjoined tables are the results of an investigation of Groups I., II. and VII. We have then to see whether the same taste sensations are produced by the chlorides, &c., of elements having similar physical properties.

GROUP I.

	Metal.	Chloride.	Sulphate.
	L	Salt	Sal. Bit.
	Na	Salt	Sal. Bit.
	K	Salt Sal. <i>Bit.</i> ¹	Sal. Bit.
	Cu	Insoluble	Sal. Bit.
	Rb	Salt <i>Bit.</i> Sal.	..
	Ag	Insoluble	Sal. Bit.
	Cs	Salt <i>Bit.</i> Sal.	..
	Au	Sal. Ast.	..

¹ *Italics* indicate that the sensation is but slightly perceived.

It will be seen that all the soluble chlorides are salt like table salt, although with the higher members we have the taste becoming more saline, a very slight bitter taste also develops. Some salts are astringent, as will be seen in a study of this and of other groups. I do not think this astringency is generally looked upon as a taste at all; depending, as it does, upon the formation of insoluble albuminates, it is purely a local action on the mucous membrane of the tongue, and will not be again discussed.

The sulphates are saline, not salt at all, and in addition they are distinctly bitter. I have not been able to obtain the sulphates of cæsium and rubidium.

GROUP II.

Metal.	Chloride.	Sulphate.
Be	..	Acid. Sweet. Ast.
Mg	Bit. Sal. Wrm. Pung.	Bit. Sal.
Ca	Bit. Sal. Wrm. Pung.	Insoluble
Zn	Bit. Sal. Wrm. Pung.	Bit. Sal. Ast.
Sr	Bit. Sal. Wrm. Pung.	Insoluble
Cd	Bit. Sal. Wrm. Ast.	Bit. Wrm. Ast.
Ba	Bit. Sal. Pung.	Insoluble
Hg	..	..

In Group II. the chlorides are all bitter salines with, in nearly every case, a warm pungent flavour. They are very disagreeable to taste, and it is long before the flavour leaves the mouth. Beryllium chloride with the sulphate is described as sweet. I have not tasted the chloride; the sulphate is distinctly acid and astringent as well. Beryllium salts then are a well-marked exception to the other salts, giving, as they do, such constant taste sensations. The atomic weight of beryllium was long an open question. I am informed on competent authority that there is now no doubt on this head, and I am at a loss therefore to explain its action as a sapid substance. The soluble sulphates are saline and bitter.

In Group VII. we have tastes produced which are in the main salt. In the case of both the sodium and potassium compounds there is a tendency to the production of the saline and bitter among the higher members of the group, and this is sooner seen in the case of potassium—itself a higher

GROUP VII.

	Element.	Sodium Comp.	Potassium Comp.
	F	Salt	Salt. <i>Sal.</i>
	Cl	Salt	Salt. <i>Sal. Bit.</i>
	Mn	..	..
	Br	Salt. <i>Sal.</i>	Salt. <i>Sal. Bit.</i>
	I	Sal. <i>Bit.</i>	Sal. <i>Bit.</i>

member—than in the case of sodium, a lower member of Group I.

From a study of these groups we may learn many important facts. It will be seen that much depends upon the electro-negative group with which the element is combined. Thus sodium combined as a chloride has a different taste from the sulphate of the same element: with the same electro-negative group similar elements give similar tastes, but with a curious and very uniform change as we pass from an element of low to one of high atomic weight. As we shall soon see, a change in physical property may, in like manner, be seen as we pass from a lower to a higher member of a group.

So far then we have reduced taste to a *function* of elements and their compounds, and we see that it obeys laws which are the same for so-called physical properties of these elements. Just as from a knowledge of the components of a compound we can account for its physical properties, so we have to take to pieces the sapid substance, before we get the clue to relationship between its nature as indicated by its chemical and physical properties, and the sensation it produces.

This is much already to learn; but can we go a step further and ask “in what *essential* are elements alike that produce similar tastes?” We turn naturally to the question with which we started, and ask, “do these elements vibrate in any way that is similar?” Rapid advances are being made in the more exact and extended inquiring, how do the ultimate particles of matter move? In a few years, no doubt, the investigations into the ultra-red and ultra-violet spectrum will shed a flood of light on this question, and will enable us to come to some more definite conclusion than at present. Still much is known, and it may not be premature even now to make use of this incomplete knowledge.

No one would expect to find very closely allied spectra when comparing elements even of the same groups, and for this reason. Suppose potassium and lithium to have such a fundamental tone and a series of upper partials each in an exactly similar inharmonic ascending scale, the tones of the heavier—potassium—would all be of lower pitch than the lighter—lithium. An absorption line of potassium in the visible spectrum will correspond in this case to one of lithium in the ultra-violet. Thus all attempts to establish exact mathematical relationships between the wave lengths of similar metals are for the present out of the question. We can but hope to find rough points of similarity, and these are forthcoming. The chlorides of the alkaline earths are nearly related. The lithium and sodium spectra have some points of similarity, especially in their extreme simplicity; also potassium and rubidium, each with their five groups of lines. Then again, chlorides, bromides, and iodides of calcium and barium are nearly related, the lines shifting towards the red end of the spectrum in a way which is nearly proportional with the increase of atomic weight.

Many salts absorb light of different wave lengths, and are in consequence of a definite colour. The colour is an index to this absorption, and to the state of molecular vibration of the salt molecules. In a paper on the colour of chemical compounds, recently published in the philosophical magazine ('Phil. Mag.,' July 1884), Professor Carnelley demonstrated a relationship between salts of metals of the same group in respect to colour. The salts, say, the chlorides, of a group of metals, are much of the same colour, except that, as you pass to the higher members of a group, this changes somewhat, shifting uniformly towards the red end of the spectrum. This is illustrated by the following diagrams taken from his paper, in which only those metals of a group are given, which are in alternate series.

Metal.	Cl.	I.	Metal.	Cr O ₄ .	As O ₄ .
Na	White	White	Mg	Lemon Yellow	White
C	White	Cream	Zn	Yellow	White
Ag	White	Light Yellow	Cd	Orange Yellow	White
Au	Yellow White	Golden Yellow	Hg	Red	Yellow

The striking analogy between the above tables and those of taste already alluded to, needs scarcely to be pointed out, it is obvious.

But what does this shifting towards the red end of the spectrum indicate in the case of these coloured salts?

Probably the colourless ones have vibrations of high pitch in the ultra-violet; with a higher atomic weight and slower vibration they gradually absorb the rays of the visible spectrum. The blue rays are first absorbed, and the salt appears yellow; then the green giving orange, and then the yellow and orange rays are also absorbed giving red.

In the case of tellurium chloride, all are absorbed, and the salt is black. Carnelley has therefore demonstrated that the salts of a group have molecular vibrations which are similar, which absorb light and give rise to *colour sensations* which are similar, changing uniformly, however, with increasing atomic weight.

Here then is the whole analogy between taste and sight, and it is most complete in its nature. If a curve be constructed in which the ordinates represent the atomic weights of the positive elements, and the abscissæ a chromatic scale rising from blue, green, &c., to black, we shall obtain a curve indicating that the colours of the compounds are a periodic function of the elements arranged in atomic series. This is best seen in the case of the normal iodides.

Upon the pitch of the vibration depends the colour sensation, as every one would admit: we find in the case of taste a result in every way is the same.

This has been one induction from the study of the inorganic compounds, but a whole field of inquiry had been untouched. As yet no allusion has been made to the carbon compounds, many of which are sapid. One of the most important and interesting facts in connection with the chemistry of the carbon compounds is, that they have what may be termed a *structure*. Thus the formula for common alcohol is C^2H^6O , but one of the hydrogen atoms is found to be especially related to the oxygen, and it is written $C^2H^5(OH)$. In this case then there is one group (compound radical) C^2H^5 united with another group OH . Now these

groups play the same part that elements do in inorganic compounds, and it is necessary to know this so-called structural formula in order to understand the property of an organic substance. Just as one can replace the hydrogen in water with potassium, and form another substance of different properties, depending upon the nature of the substance added, so, in like manner, one can replace the C^2H^5 , or the OH , by other compound radicals, or even elements, and produce a substance whose properties will depend upon the nature of the radical you add. There are then two points for investigation. In the first case, can we find in sapid substances, having, say a sweet or a sour taste, any compound radicals always present, and from whose presence we may say that the taste sensations result? The chemist associates certain properties with the presence of a certain radical in a substance; can we find similar associations with taste sensation?

In the second place, do we find with the spectroscope that the various combinations of a compound radical preserve the character of the vibrations of the radicals, unaltered in any marked degree?

The answer to the first question can be readily given, for it will be sufficient to obtain a list of substances giving a definite taste, and to search for some common or similar radical. If a radical common to all be found, we may safely answer it in the affirmative. There are among the carbon compounds many substances having an acid taste. Here is a list of those most familiar:

					CH (OH) CO . OH
Tartaric acid	..	..	..	..	CH (OH) CO . OH
Benzoic acid	..	..	..	..	C ₆ H ₅ . CO . OH
Malic acid	..	..	..	..	CH (OH) . CO . OH
					CH ₂ . CO . OH
					CHO
Glyoxylic acid	..	..	..	..	CO . OH
					CO . OH

The above ten examples of substances possessing distinct acid tastes are taken from various classes of organic acids, and they will be seen to have in all cases a common group of elements. This group is a compound radical CO . OH, which is combined in all cases with a different molecule. We have then the same right to impute to this radical the capacity of producing a given taste sensation, as the chemist has of looking upon it as related to certain physical properties of the compounds in which it may be found.

Among sweet substances we find the following :

Glycol..	..	..	..	..	CH ₂ . OH
					CH ₂ . OH
Glycerine	..	..	..	..	CH ₂ . OH
					CH . OH
					CH ₂ . OH
Mannite	..	..	..	..	C ₆ H ₈ (OH) ₆
Glucose	..	..	..	..	C ₆ H ₁₂ O ₆
Inosit ..	..	..	..	..	C ₆ H ₁₂ O ₆
Saccharine	..	..	..	..	C ₁₂ H ₂₂ O ₁₁

These are all alcoholic bodies, glycol, glycerine, mannite being, respectively, diatomic, triatomic and hexatomic alcohol. The rational formulæ of the last three and other nearly related substances, such as levulose, maltose, &c., are not at present definitely settled; but it is certain that they contain a radical CH₂OH, found in the first three substances. Thus the formula of glucose, according to Colley, is—

Monatomic ethyl alcohol is tasteless, and has been alluded to already. It is the simplest alcohol, the polyatomic alcohols referred to having a sweet taste.

We see here again that, with a definite molecular structure, with the presence of certain groups of elements, a definite taste sensation is produced. A chemist examining the rational formula of a substance will predict its properties to an extent which will vary with the extent of his knowledge. We too can predict a property, that of producing particular sensation when applied to the tongue.

There is a large number of organic compounds having a bitter taste, such as quinine, quassia, strychnia, &c.; but inasmuch as so little is known as to the chemical nature of these bodies, an investigation, if applied to this class of substances, would be of little use.

We have seen that in inorganic compounds the physical, chemical, and taste properties vary with the nature of the elements in the sapid substance; with similar elements similar properties are associated. So too we have seen among the carbon compounds that the physical, chemical, and taste properties vary with the compound radicals present in the sapid substance. The question now to be determined is, whether or not the compound radicals behave as elements, vibrating in a characteristic and definite way, not materially disturbed by altering the combination? This may be determined by the eye, with or without the aid of the spectroscope.

We know that chromic acid has an orange-red colour; combine it with metallic elements to form chromates, and we find that these are coloured, the colour varying very slightly with the metal.

Picric acid is a coloured solid, and it probably owes its colour, at any rate in part, to the presence of a radical (NO_2). Its salts too are coloured, the absorption shifting towards the red end of the spectrum.

In his interesting researches into the spectra of colourless fluids, observed through a considerable length of tube, Dr. W. S. Russell finds that ammonia gives certain well-marked absorption bands. If an atom of hydrogen in the ammonia be replaced by methyl, forming a substance methylamine, the ammonia bands are still seen, shifted however slightly towards the red end of the spectrum.

Replace the hydrogen by the higher group C_2H_5 , or ethyl, to form ethylamine, and the shifting continues towards the red.

With a series of alcohols, such as methylic, ethylic, propylic alcohol, we find, as we pass to the more complex, heavier, but similarly constituted molecules, a shifting of equally characteristic bands towards the red end of the spectrum. It is very much (and here we may recall the colour experiments of Professor Carnelley) as if we took an instrument, say a violin, and kept loading its strings. The notes would be heard deeper and deeper in tone, but it would be still recognised as being the tone or quality of the violin.

I have mentioned the above instances, though many others might have been adduced to demonstrate the same fact. We have every reason then to believe that the radical $\begin{array}{c} -\text{C}-\text{O}-\text{H} \\ || \\ \text{O} \end{array}$

and the radical $\begin{array}{c} \text{H} \\ | \\ -\text{C}-\text{O}-\text{H} \\ | \\ \text{H} \end{array}$ of the acid and sweet substances

are both in constant and characteristic vibration, although this vibration does not effect the rays of the visible spectrum. Not only so, but we know that this vibration will not be altered in character (from the analogy with the ammonia radical in methylamine), being merely shifted to a small extent in pitch, when its combinations are changed. This is, however, the analogy which we have sought.

Both in the case of sight, hearing, taste, and, as I hope afterwards to prove, in the case of smell we have these analogous phenomena. On the side of sensation we have variations in what we may call quality; on the objective side we have matter in vibration—these vibrations vary in character; and it is possible to connect the quality of the sensation with the character of the vibration.

It may be urged that inasmuch as an acid like hydrochloric acid produces much the same taste as oxalic acid, there

is no such definite connection between vibration and sensation. There are, too, some sweet substances having no relationship to an alcohol. We know that one can get the same colour sensation from a solution of either a picrate or a chromate, two substances absolutely dissimilar in chemical properties. The reason is that they both give a group of vibrations in the same part of the solar spectrum. It would be reasonable to expect that instances would be forthcoming of substances of dissimilar nature and chemical composition, with similar tastes. It would seem probable then that there is a scale of vibrations, which may stimulate the taste organs analogous to the visible spectrum. If a substance vibrates in a definite part of this scale, a definite taste will be produced.

One must always remember that the tongue has, like the eye and unlike the ear, no power of analysis. It may be that just as a colour, say orange, may be produced by either a simple vibration, or a combination of vibrations, some higher and some lower in pitch than that of the simple one, so the same taste may, in like manner, be produced by a simple vibration or a compound one made up of simple vibrations of higher or lower pitch.

In conclusion, it will be necessary to state very emphatically that it is *analogy* that this paper proves—analogy in the production of the senses. It would be premature to say definitely how the vibrations of common salt produce irritation of the gustatory nerve. Is it by setting up a sympathetic vibration, when, as in the ear, the sonorous waves set in motion the end-organs of the labyrinth? Upon such a question I have no wish to hazard what could only be an opinion? In the eye, vibrations stimulate the cones. How is this done? It is quite conceivable that this is by setting up sympathetic vibrations, but many suppose it to be a chemical action.

If we ask what is a chemical action, no adequate reply will be forthcoming, though many would hesitatingly affirm that even so-called chemical actions may have a vibratory and mechanical interpretation. When we say that we *understand* the manner in which the end-organs of the ear are stimulated, we mean that we can prove an analogy between the sympathetic vibration of a tuning-fork and of the organ of Corti,

when affected by the same wave motion. It is nothing but an analogy after all.

The production, on the other hand, of end-organ irritation, by light or molecular vibration, has no sufficient definite analogue in the laboratory of the experimenter.

All that I claim to have proved is, that the body is surrounded by vibrating of matter, stimulating its sensitive surface; that in all cases the process of stimulation with the production of a consequent sensation is the same to this extent; that the quality of sensation is dependent upon the character (pitch and complexity) of the vibratory matter.

Just as a certain class of salts of allied chemical and physical properties vibrate in a similar way, and stimulating the eye, produce the same colour sensations; just as certain strings of definite length and consistency vibrate in a similar way, and produce the same sound sensation—so, in like manner, similar sapid compounds (containing similar elements, or the same compound radicals) vibrate in a similar way, and produce the same taste.