CHAPTER IX

COLLOIDAL BEHAVIOUR

> In fact, to-day colloids may be regarded as an important, perhaps the most important connecting link between the organic and the inorganic world. (7)
>
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In our researches, let us follow the natural order and give a brief structural account of what we know, empirically, about the medium in which life is found; namely, about the colloids. The following few elementary particulars show the empirical importance of structure, and so are fundamental in the present work.

At present, physicians are usually too innocent of psychiatry, and psychiatrists, although they often complain about this innocence of their colleagues, seldom, if ever, themselves pay any attention to the colloidal structure of life; and their arguments about the 'body-mind' problem are still scientifically incomplete and unconvincing, though the 'body-mind' problem has been present with us for thousands of years. It is a very important semantic problem, and, as yet, not solved scientifically, although there is a simple solution of it to be found in the *colloidal* structure of life.

The reader should not ascribe any uniqueness of the 'cause-effect' character to the statements which follow, as they may not be true when generalized. Colloidal science is young and little known. Science has accumulated a maze of facts, but we do not have, as yet, a general theory of colloidal behaviour. Statements, therefore, should not be unduly generalized.

We shall only indicate a few structural and relational connections important for our purpose.

When we take a piece of some material and subdivide it into smaller pieces, we cannot carry on this process indefinitely. At some stage of this process the bits become so small that they cannot be seen with the most powerful microscope. At a further stage, we should reach a limit of the subdivision that the particles can undergo without losing their chemical character. Such a limit is called the molecule.* The smallest particle visible in the microscope is still about one thousand times larger than the largest molecule. So we see that between the molecule and the smallest visible particle there is a wide range of sizes.

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* This statement is only approximate, because there is evidence that chemical characteristics change as the molecule is approached.

Findlay calls these the ‘twilight zone of matter’; and it was Ostwald, I believe, who called it the ‘world of neglected dimensions’.

This ‘world of neglected dimensions’ is of particular interest to us, because in this range of subdivision or smallness we find very peculiar forms of behaviour—life included—which are called ‘colloidal behaviour’.

The term ‘colloid’ was proposed in 1861 by Thomas Graham to describe the distinction between the behaviour of those materials which readily crystallize and diffuse through animal membranes and those which form ‘amorphous’ or gelatinous masses and do not diffuse readily or at all through animal membranes. Graham called the first class ‘crystalloids’ and the second ‘colloids’, from the Greek word for glue.

In the beginning colloids were regarded as special ‘substances’, but it was found that this point of view was not correct. For instance, NaCl may behave in solution either as a crystalloid or as a colloid; so we began to speak about the *colloidal state.* Of late, even this term became unsatisfactory and is often supplanted by the term *‘colloidal behavior’.*

In general, a colloid may be described as a ‘system’ consisting of two or more ‘phases’. The commonest represent emulsions or suspensions of fine particles in a gaseous, liquid, or other medium, the size of the particles grading from those barely visible microscopically to those of molecular dimensions. These particles may be either homogeneous solids, or liquids, or solutions themselves of a small percentage of the medium in an otherwise homogeneous complex. Such solutions have one characteristic in common; namely, that the suspended materials may remain almost indefinitely in suspension, because the tendency to settle, due to gravity, is counteracted by some other factor tending to keep the particles suspended. In the main, colloidal behaviour is not dependent upon the physical state or chemistry of the finely subdivided materials or of the medium. We find colloidal behaviour exhibited not only by colloidal suspensions and emulsions where solid particles or liquid droplets are in a liquid medium, but also when solid particles are dispersed in gaseous medium (smokes), or liquid droplets in gaseous media (mists), .

Materials which exhibit this special colloidal behaviour are always in a very fine state of subdivision, so that the ratio of *surface exposed* to *volume of material* is very large. A sphere containing only 10 cubic centimetres, if composed of fine particles 0.00000025 cm. in diameter, would have a total area of all the surfaces of the particles nearly equal to half an acre.[1] It is easy to understand that under such *structural* conditions the *surface forces* become important and play a prominent role in colloidal behaviour.

The smaller the colloidal particles, the closer we come to molecular and atomic sizes. Since we know atoms represent electrical structures, we should not be surprised to find that, in colloids, surface energies and electrical charges become of fundamental importance as by necessity all surfaces are made up of electrical charges. The surface energies operating in finely grained and dispersed systems are large, and in their tendency for a minimum, every two particles or drops tend to become one; because, while the mass is not altered by this change, the surface of one larger particle or drop is less than the surface of two smaller ones—an elementary geometrical fact. Electrical charges have the well-known characteristic that like repels like and attracts the unlike. In colloids, the effect of these factors is of a fundamental yet opposite character. The surface energies tend to unite the particles, to coagulate, flocculate or precipitate them. In the meanwhile the electrical charges tend to preserve the state of suspension by repelling the particles from each other. On the predominance or intensity of one or other of these factors, the instability or the stability of a suspension depends.

In general, if 'time' limits are not taken into consideration, colloids are unstable complexes, in which continuous transformation takes place, which is induced by heat, electric fields, electronic discharges, and other forms of energy. These transformations result in a great variation of the characteristics of the system. The dispersed phase alters its characteristics and the system begins to coagulate, reaching a stable state when the coagulation is complete. This process of transformation of the characteristics of the system which define the colloid, and which ends in coagulation, is called the 'ageing' of the colloid. With the coagulation complete, the system loses its colloidal behaviour—it is 'dead'. Both of these terms apply to inorganic as well as to organic system.

Some of the coagulating processes are partial and reversible, and take the form of change in viscosity; some are not. Some are slow; some extremely rapid, particularly when produced by external agencies which alter the colloidal equilibrium.

From what has been said already, it is obvious that colloids, particularly in organisms, are extremely sensitive and complex structures with enormous possibilities as to degree of stability, reversibility. , and allow wide range of variation of behaviour. When we speak of 'chemistry', we are concerned with a science which deals with certain materials which preserve or alter certain of their characteristics. In 'physics', we go beyond the obvious characteristics and try to discover the *structure* underlying these characteristics. Modern researches show clearly that atoms have a very complex structure and that the macroscopic characteristics are directly connected with sub-microscopic structure. If we can alter this structure, we usually can alter also the chemical or other characteristics. As the processes in colloids are largely structural and physical, anything which tends to have a structural effect usually also disturbs the colloidal equilibrium, and then different macroscopic effects appear. As these changes occur as series of interrelated events, the best way is to consider colloidal behaviour as a physico-electro-chemical occurrence. But once the word ‘physical’ enters, structural implications are involved. This explains also why all known forms of radiant energy, being structures, can affect or alter colloidal structures, and so have marked effect on colloids.

As all life is found in the colloidal form and has many characteristics found also in inorganic colloids, it appears that colloids supply us with the most important known link between the inorganic and the organic. This fact also suggests entirely new fields for the study of the living cells and of the *optimum conditions for their development, sanity included.*

Many writers are not agreed as to the use of the terms ‘film’, ‘membrane’, and the like. Empirically discovered structure shows clearly, however, that we deal with surfaces and *surface energies* and that a ‘surface tension film’ behaves as a membrane. In the present work, we accept the obvious fact that organized systems are film-partitioned systems.

One of the most baffling problems has been the peculiar periodicity or rhythmicity which we find in life. Lately, Lillie and others have shown that this rhythmicity could not be explained by purely physical nor purely chemical means, but that it is satisfactorily explained when treated as a *physico-electro-chemical structural occurrence.* The famous experiments of Lillie, who used an iron wire immersed in nitric acid and reproduced, experimentally, a beautiful periodicity resembling closely some of the activities of protoplasm and the nervous system, show conclusively that both the living and the non-living systems depend for their rhythmic behaviour on the chemically alterable film, which divides the electrically conducting phases. In the iron wire and nitric acid experiment, the metal and the acid represent the two phases, and between the two there is found a thin film of oxide. In protoplasmic structures, such as a nerve fibre, the internal protoplasm and the surrounding medium are the two phases, separated by a surface film of modified plasm membrane. In both systems, the electromotive characteristics of the surfaces are determined by the character of the film.[2]

That living organisms are film-bounded and partitioned systems accounts also for irritability. It appears that irritability manifests itself as sensitiveness to electrical currents. These currents seem to depend on polarizability or resistance to the passage of ions, owing to the presence of semi-permeable boundary films or surfaces enclosing or partitioning the system. It is obvious that we are here dealing with complex *structures* which are intimately connected with the characteristics of life. Living protoplasm is electrically sensitive only as long as its structure is intact. With death, semi-permeability and polarizability are lost, together with electrical sensitivity.

One of the baffling peculiarities of organisms is the rapidity with which the chemical and metabolic processes spread. Indeed, it is impossible to explain this by the transportation-of material. All evidence shows that electrical and, perhaps, other energy factors play an important role; and that this activity again depends on the presence of surfaces of protoplasmic structures with electrode-like characteristics which form circuits.

The great importance of the electrical charges of the colloidal particles arises out of the fact that they prevent particles from coalescing; and when these charges are neutralized, the particles tend to form larger aggregates and settle out of the solution. Because of these charges, when an electrical current is sent through a colloidal solution, the differently charged particles wander to one or the other electrode. This process is called cataphoresis. There is an important difference in behaviour in inorganic and organic colloids under the influence of electrical currents, and this is due to the difference in structure. In inorganic colloids, an electrical current does not coagulate the whole, but only that portion of it in the immediate vicinity of the electrodes. Not so in living protoplasm. Even a weak current usually coagulates the entire protoplasm, because the inter-cellular films probably play the role of electrodes and so the entire protoplasm structurally represents the ‘immediate vicinity’ of the electrodes. Similarly, structure also accounts for the extremely rapid spread of some effects upon the whole of the organism.

Electrical phenomena in living tissue are mainly of two more or less distinct characters. The first include electromotive energy which produces electrical currents in nerve tissue, the membrane potentials, . The second are called, by Freundlich, electrokinetic, and include cataphoresis, agglutination, . There is much evidence that the mechanical work of the muscles, the secretory action of the glands, and the electrical work of the nerve cells are closely connected with the colloidal structure of these tissues. This would explain why *any factor* (semantic reactions included) capable of altering the colloidal structure of the living protoplasm must have a marked effect on the behaviour and welfare of the organism.

Experiments show that there are four main factors which are able to disturb the colloidal equilibrium: (1) Physical, as, for instance, X-rays, radium, light, ultra-violet rays, cathode rays. ; (2) Mechanical, such as friction, puncture. ; (3) Chemical, such as tar, paraffin, arsenic. ; and, finally, (4) Biological, such as microbes, parasites, spermatozoa, . *In man, another (fifth) potent factor; namely, the semantic reactions,* enters, but about this factor, I shall speak later.

For our purpose, the effects produced by the physical factors, because obviously structural, are of main interest, and we shall, therefore, summarize some of the experimental structural results. Electrical currents of different strength and duration, as well as acids of different concentration, or addition of metallic salts, which produce marked acidity, usually coagulate the protoplasm, these effects being structurally interrelated. Slow coagulation involves changes in viscosity, all of which, under certain conditions, may be reversible.[3] When cells are active, their fluidity often changes in a sharp and rapid manner.[4]

Fat solvents are called surface-active materials; when diluted, they decrease protoplasmic viscosity; but more concentrated solutions produce increased viscosity or coagulation.[5] The anaesthetics, which always are fat solvents and surface-active materials, are very instructive in their action for our purpose, as they affect very diversified types of protoplasm similarly, this similarity of action being due to the similarity of colloidal structure. Thus, ether of equal concentration will make a man unconscious, will prevent the movement of a fish and the wriggling of a worm, or stop the activity of a plant cell, without permanently injuring the cells.[6] In fact, the action of all drugs is based on their effect upon the colloidal equilibrium, without which action a drug would not be effective. It is well known that various acids or alkalis always change the electrical resistance of the protoplasm.[7]

The working of the organism involves mostly a structural and very important ‘vicious circle’, which makes the character of colloidal changes *non-additive.* If, for instance, the heart, for any reason, slows down the circulation, this produces an accumulation of carbonic acid in the blood, which again increases the viscosity of the blood and so throws more work on the already weakened heart.[8] Under such structural conditions, the results may accumulate very rapidly, even at a rate which can be expressed as an exponential function of higher degree.

Different regions of the organism have different charges; but, in the main, an injured, or excited, or cooler part is electro-negative (which is connected with acid formation), and the electro-positive particles rush to those parts and supply the material for whatever physiological need there may be.[9]

The effects of different forms of radiant energy on colloids and protoplasm are being extensively studied, and the results are very startling. The different forms of radiant energy differ in wave-length, frequency. ,—that is to say, generally in *structure*,—and, as such, may produce structural effects on colloids and organisms, which effects may appear on the gross macroscopic level in many different forms.

Electrical currents, for instance, retard reversibly the growth of roots, may activate some eggs into larval stages without fertilization, which makes it possible to understand why, in some cases, a mere puncturing of the egg may disturb the equilibrium and produce the effects of fertilization.[10]

The X-, or Röntgen-rays have been shown to accelerate 150 times the process of mutation. Muller, in his experiments with several thousand cultures of the fruit fly, has established the above ratio of induced mutations, which become hereditary.[11] 'Cosmic rays' in the form of radiation from the earth, in tunnels, for instance, show similar results, except that mutation occurs only twice as often as under the usual laboratory conditions. Under the influence of X-rays, mice change their colour of hair; gray mice become white, and white ones darker. Sometimes further additional bodily changes appear; as, for instance, one or no kidneys, abnormal eyes or legs, occur more often than under ordinary conditions. Some animals lose their power of reproduction, although the body is not obviously changed. Plants respond also to the X-ray treatment. They grow faster, flower more, and produce new forms more readily. In humans the effect of X-ray irradiation has often proven disastrous to the health of experimenters. There are even data that the irradiation of pregnant mothers may result in deformation of the head and limbs of the unborn child and, in one-third of the cases, feeble-mindedness of the children has resulted.[l2]

Ultra-violet rays also show a marked effect. In some instances, they slow down or stop the streaming of protoplasm, because of increased viscosity or coagulation; plants grow slowly or rapidly; certain valuable ingredients in plants are increased; certain animals, as, for instance, small crustacea or bacteria are killed; eggs of Nereis (a kind of sea worm), which usually have 28 chromosomes, after irradiation have 70; certain bone malformations in children are cured; the toxin in the blood serum of pernicious anaemia patients is destroyed, .[13] In this respect, we should notice again that ultra-violet irradiation produces curative effects like those of cod-liver oil, which shows that the effect of both factors is ultimately colloidal and structural.

Extensive experimentation with cathode rays is very recent, but already we have a most astonishing array of structural facts. Moist air is converted into nitric acid, synthetic rubber is produced rapidly, the milk from rubber trees is made solid and insoluble without the use of sulphur, liquid forms of bakelite are solidified without heating, linseed oil becomes dry to the touch in three hours and hard in six hours, certain materials, like cholesterol, yeast, starch, cottonseed oil, after exposure for thirty seconds, heal rickets, and similar unexpected results. What are usually called ‘vitamins’ do not only represent ‘special substances’, but become structurally active factors; and this is why ultra-violet rays may produce results like those of some ‘substance’. It seems that in ‘vitamins’ the surface activities are important; the parallelism shown by von Hahn between the surface activities of different materials and the Funk table of vitamin content is quite suggestive. Some data seem to show that, in some instances, surface-active materials, such as coffee or alcohol, produce beneficial surface activities similar to the ‘vitamins’.[14]

The above short list gives only an approximate picture of the overwhelming importance of the roles which structure in general, and colloids in particular, play in our lives. We see about us many human types. Some are delicate, some are heavy-set, some flabby, some puffy, all of which indicates a difference in their colloidal structure. Paired with these physical colloidal states are also nervous, ‘mental’, and other characteristics, which vary from weak and nervous to the extreme limitation of nervous activities, as in idiocy, which is a negation of activity.

It is curious that in all illnesses, whether ‘physical’ or ‘mental’, the symptoms are very few, and fundamentally of a standard type. In ‘physical’ illness we find the following common characteristics: fever, chills, headaches, convulsions, vomiting, diarrhoea, . In ‘mental’ ills, identifications, illusions, delusions, and hallucinations—in general, the reversed pathological order—are found. It is not difficult to understand the reason. Because of the general colloidal background of life, different disturbances of colloidal equilibrium *should* produce similar symptoms. In fact, many of these symptoms have been reproduced experimentally by injecting inert precipitates incapable of chemical reactions, which have induced artificial colloidal disturbances. Thus, if the serum from an epileptic patient is injected into a guinea pig, it results in an attack of convulsions, often ending in death. But, if the guinea pig is previously made immune by an injection of some colloid which accustoms the nerve-endings to the colloidal flocculation, then, for a few hours following, we can, with impunity, introduce into the circulation otherwise fatal doses of epileptic serum. Epileptic serum can also be made immune by filtration, or by strong centrifugation, or by long standing, which frees it from colloidal precipitates.[15]

Death through blood transfusion or the injection of *any* colloid into the circulation has also, in the main, similar symptoms, regardless of the chemical character of the colloid, indicating once more the importance and fundamental character of structure.[16]

That illnesses are *somehow* connected with colloidal disturbances (note the wording of this statement) becomes quite obvious when we consider catarrhal diseases, inflammations, swellings, tumours, cancer, blood thrombi. , which involve colloidal injuries, resulting in extreme cases in complete coagulation or fluidification, the variation between 'gel' and 'sol' appearing in a most diversified manner.[17] Other illnesses are connected with precipitation or deposits of various materials. Gout, for instance, results from a morbid deposit of uric acid, and different concretions, such as the 'stones', are very often found in different fluids of the organism. We have, thus, concretions in the intestines, the bile, the urine, the pancreas, the salivary glands; lime deposits in old softened tissues, 'rice bodies' in the joints, 'brain sand', .[18]

In bacterial diseases, the micro-organisms rapidly produce acids and bases which tend to destroy the colloidal equilibrium. Lately, it has been found that even tuberculosis is more than a mere chapter in bacteriology. All the main tubercular symptoms can be reproduced, experimentally, by means of colloidal disturbances without the intervention of a single bacterium.[19] This would explain also why, in some instances, psychotherapy is effective in diseases with tubercular symptoms.[20]

By structural necessity, every expression of cellular activity involves some sort of colloidal behaviour; and any factor disturbing the colloidal structure must be disturbing to the welfare of the organism Vice versa, a factor which is beneficial to the organism must reach and affect the colloids.

After this brief account of the structural peculiarities of the domain in which life is found, we can understand the baffling 'body-mind' problem. We do not yet know as many details as we could wish, but these will accumulate the moment a general solution is clearly formulated. It is a well-established *experimental* fact that all nervous and 'mental' activities are connected with, or actually generate, electrical currents, which of late are scrupulously studied by the aid of an instrument called the psychogalvanometer.[21] It is not suggested that electrical currents are the only ones which are involved. There may be many different forms of radiant energy produced or effective, which we have not yet the instruments to record. Experiments suggest such a possibility. Thus, for instance, the apex of a certain rapidly growing vegetable or animal tissue emits some sort of invisible radiation which stimulates the growth of living tissue with which it is not in contact. The tip of a turnip or onion root, if placed at right angles to another root, at a distance of a quarter of an inch, so stimulates the growth of the latter that the increase of the number of cells, on its side nearest the point of stimulation, is as high as seventy per cent. These radiations accelerate the growth of some bacteria. Other examples could be given.[22]

A classical example of the effect left on protoplasm by energetic factors is given by Bovie.[23]

As yet, we have not assumed that the protoplasm of plants also shows lasting structural and functional results of stimulation, some sort of 'learning' or 'habit-formation' characteristics. But such is the case; and further experimentation along these lines will help greatly to understand the mechanism of 'mental' processes in ourselves.

If we take the seed of a plant, for instance, of a squash, and keep it in a moist tropism chamber in the dark, it will grow a root. When the root is about one inch long, we begin our experiment. Originally, under the influence of gravitation, the root grows vertically downwards (A). If we rotate the tropism chamber 90° so that the root is horizontal (B), the root will soon bend downwards under the influence of positive geotropism. But the bending does not occur at once. There is a latent period—in the case of the squash seed, about ten minutes—after which pause the root is bent downwards. When we have determined this latent period for a given seedling, we then rotate the chamber to the positions (B), (C), (A), (B), (C), just within the 'time' limit before the bending would occur. We repeat such procedure several times. When we set the root again in its vertical downward position (A), we notice that the root, without any more changes of position, will wag backwards and forward with the period as was used in the experiment. This unexpected behaviour will last for several days. It shows that the alternating stimulus of gravitation, as applied to the root, has produced some structural changes in the protoplasm which persist for a comparatively long period after the stimulus has ceased to act. It be-

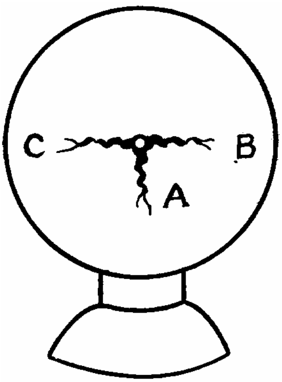

FIG. 1

comes obvious that teachability and the structural tendency for forming engrams is a general characteristic of protoplasm.

All the examples given above show clearly that *structure* in general and of colloids in particular, gives us a satisfactory basis for the understanding of the *equivalence* between occurrences which belonged formerly to ‘chemistry’ and those classified as ‘physical’, and ultimately between these and those we call ‘mental’. Structure, and structure alone, gives not only the *unique* content of what we call ‘knowledge’, but also the bridge between the different classes of occurrences—a fact which, as yet, has not been fully understood.

To sum up: It is known that colloidal behaviour is exhibited by materials of very fine subdivision, the ‘world of neglected dimensions’, which involves surface activities and electrical characters of manifold and complex structure, and therefore the flexibility of gross macroscopic characteristics. It is well known that all life-processes, ‘feelings’, ‘emotions’, ‘thought’, semantic reactions, and so forth, involve *at least* electrical currents. As electrical currents and other forms of energy are able to affect the colloidal structure on which our physical characteristics depend, obviously ‘feelings’, ‘emotions’, ‘thought’. ; in general, *s.r*, which are connected with manifestations of energy, will also have some effect on our bodies, and vice versa. Colloidal structure supplies us with an extremely flexible mechanism with endless possibilities.

When we analyse the known empirical facts from a structural point of view, we find not only the equivalence which was mentioned before, but we must, also, legitimately consider the so-called ‘mental’, ‘emotional’, and other semantic and nervous occurrences in connection with manifestations of energy which have a powerful influence on the colloidal behaviour, and so ultimately on the behaviour of our organisms as-a-whole. Under such environmental conditions, we must take into account all energies which have been discovered, *semantic reactions not excluded*, as all such energies have structural effect. As language is one of the expressions of one of these energies, we ought to find it quite natural that the structure of language finds its reflection in the structure of the environmental conditions which are dependent on it.

Until lately, the disregard of colloidal science and of structure in general has greatly retarded advance in biology, psychiatry, and other sciences. Biology, for instance, has mostly studied ‘life’ where none existed; namely, in death. If we study corpses, we study death, not life, and life is a function of living cells. The living cell is semi-fluid, and all the forces which act in colloidal solutions and constitute colloidal behaviour are acting because they *can act*, while a dead cell is *coagulated* and so a different set of energies is operating there.[24]

Should we wonder that life, being a form of colloidal behaviour on microscopic and sub-microscopic levels, conditioned by little colloidal 'wholes', and structures separated from their environment by surfaces, preserves a similar character on macroscopic levels ? We should, instead, be surprised if this did not turn out to be the case.