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Symbiosis and Evolution. By H. Reinheimer.

"Throughout the animal and vegetable kingdoms we find incessant conflict of two forces, one endeavouring to preserve health, the other attempting to undermine it. In many plants the dispute is settled by the establishment of symbiosis, in which both forces combine to work for the common good. It is possible that even in man this happy compromise is sometimes achieved. By reflecting on this conflict as it manifests itself throughout the natural world, we shall escape from too narrow an outlook on the question of health and disease."—British Medical Journal, November 18, 1922.

Symbiosis is systematic biological co-operation, and, whether we view it in a narrow, morphological, or in a wider yet more definite socio-physiological sense, it is a phenomenon of first-rate importance, deserving widest attention. Botany, zoology, physiology, pathology, agriculture, sociology are all vitally concerned in symbiosis.

In an article on the "Social Life Among the Insects"(1), Prof. W. M. Wheeler, of Harvard, states: "Even to the great Victorian naturalists the fact was familiar—though they failed to dwell on its great social significance—that all living things are genetically related as members of one great family, one vast, living symplasm, which, though fragmented into individuals in space, is nevertheless absolutely continuous in time, that in the great majority of organic forms each generation arises from the co-operation of two individuals, that most animals and plants live in associations, herds, colonies or societies of the same species and that even the so-called 'solitary' species are obligatory, more or less co-operative members of groups or associations of individuals of different species, the biocœnoses. Living beings not only struggle and compete with one another for food, mates and safety, but they also work together to insure to one another these same indispensable conditions for development and survival. The phenomena of mutualism and co-operation are, indeed, so prevalent among plants and animals and affect their structure and behaviour so profoundly that there has arisen within very recent years a new school of biologists, who might be called 'symbiotists,' because they devote themselves to the investigation of a whole

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world of micro-organisms which live in the most intimate symbiosis within the very cells of many if not most of the higher animals and plants."

Despite this fine appreciation of the solidarity of organic life, Prof. Wheeler evidently adheres to the orthodox view, according to which the concept of symbiosis is confined to physical attachment of partners. From this view I dissent, since to me the spirit matters more than the form, and I attach greater importance to the fact of due reciprocity than to that of intimacy of physical contact. The distance or proximity of symbiotic partners, I contend, matter comparatively little. What matters is the kind of relation that obtains between them. I would stress chiefly the socio-physiological fact of partnership together with its avail towards ampler life. What orthodox biology stresses is the narrow, morphological fact of attachment, irrespective of socio-physiological results.

Unfortunately, biology has not yet freed itself sufficiently from old morphological views. Some fifty years ago, as Prof. Bateson tells us, morphology was studied because it afforded the material believed to be most favourable for the elucidation of the problems of evolution. All this is now to be changed. Morphology by itself is not good enough. "We went on talking about evolution; . . . to-day we feel silence to be a safer course; . . . discussions of evolution came to an end primarily because it is obvious that no progress was being made; . . . how easy it all used to look! What glorious assumptions went without rebuke. Regardless of the obvious consideration that 'modification by descent' must be a chemical process, and that of the principles governing that chemistry science had neither hint, nor surmise, nor even an empirical observation of its working, professed men of science offered very confidently positive opinions on these nebulous topics which would now scarcely pass muster in a newspaper or a sermon. It is a wholesome sign of return to sense that these debates have been suspended."

A very pregnant warning, this, against the self-sufficiency of merely morphological views.

Many cases of attached symbiosis are on the verge of, or merge themselves into, parasitism; and this is enough for orthodox biologists to declare that no hard and fast line can ever be drawn between symbiosis and parasitism, while many go so far as to state that symbiosis invariably and inevitably results in parasitism. From such views I differ *toto cœlo*. *Ex abusu non arguitur ad usum*. Although symbiosis and parasitism have this in common, that sometimes they exhibit physical attachment, yet, in principle, the two are at opposite poles—as opposite as are health and disease. In symbiosis we have a relation of mutual helpfulness; in parasitism, on the

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contrary, one of unilateral exploitation of organism by organism. The respective results are altogether different; and the respective distinction is all important to make. It is *au fond* the vital distinction between that which unconsciously promotes association of a desirable kind and that which promotes association of an undesirable kind, and, in fact, disintegration. The orthodox view, as a result of its shortcomings, recognises only dubious cases of partnership, as symbiosis, of little significance, whilst neglecting the important ones. It overlooks the fact that there has been an evolution in symbiosis, too, *i.e.*, a progressive development from primordial, primitive, and little stable partnerships to more advanced, reliable and significant ones.

Nor is there clearness even with regard to the vital distinction between health and disease. Who can separate the grain from the chaff? It seems fitting and opportune, therefore, to formulate a new theory of disease concurrently with that of symbiosis. Disease, degeneration, and extinction, I hold, originate with failure of co-operation, be it between organs or species. This truth the slow-consenting academic mind will not readily admit. A few biologists incline to agree with my proposition that Nature abhors parasitism; but few as yet would concede that Nature is consistent enough to penalise predacity in every shape or form. This proposition is too novel, too sweeping, and too upsetting to deep-rooted prejudice to meet with ready acceptance. Some have even declared it to be inconceivable. Yet the proposition will find acceptance in the end. For from a comprehensive view it emerges that Nature is thoroughly consistent, that the struggle for life, as it has been called, is pre-eminently a tug-of-war between two contrasting principles of life—co-operativeness, on the one hand, and predacity on the other—and that evolution is in the main constituted by socio-physiological development. Organisms do not live by themselves, nor for themselves. None can say to the rest, "I have no need for thee." The problem of the mutual accommodation of organic beings, involving, as it necessarily does, a kind of bio-morality, was pivotal from the first. Species evolved in power and in status in proportion as they learnt progressively to tackle and to solve the bio-social and bio-economic problems of existence. Such evolution was in accordance with the Emersonian maxim: "Do the thing, and you shall have the power; but they who do not the thing have not the power." In the aforesaid address Prof. Bateson tells us that we know nothing about the origin of species, that "we cannot see how the differentiation into species came about." This nescience I consider to be mainly due to the neglect of the study of organic sociality—one of the gaping apertures of biology. Darwin stressed this very matter

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with enormous emphasis, pointing out that there could be no complete understanding of the evolutionary process pending fuller elucidation of "mutual relations."

What we have been lacking, more particularly, as a result of such backwardness, is precisely this: definite criteria for the vital distinction between symbiosis and parasitism, between health and disease. Just as there can be no complete understanding of the evolutionary process, so there can be no due comprehension of pathological processes, unless zoology, botany, and particularly physiology, are supplemented by duly apprehended bio-social data. Nature knows no water-tight compartments. A transgression against bio-social law is generally tantamount to one against physiological law too. Sociology and physiology, therefore, must be united. They form, indeed, an indissoluble amalgam. Socio-physiology alone is not at all adequate to deal comprehensively with evolutionary data, and with those phenomena of the seamy side of life which go to form the subject-matter for pathology.

Let us see how this works out. By symbiosis I mean systematic biological partnership, be it in the attached or in the unattached form. The symbiotic relation is characterised by reciprocal differentiations of a progressive order; by due compensation as between the partners; by widely availing usefulness in the web of life. Parasitism, on the other hand, is the denial of such reciprocity, the undoing of its good effects. It is the antithesis of symbiosis, as the facts bear out abundantly when they are stripped of misleading details. Symbiosis is a good relation; parasitism is an evil one. Good and evil, of course, are relative terms. But once we have a standard by which reliably to judge biological activities and their results, we need not shrink from the attempt to discriminate between legitimate and illegitimate developments, and thus to introduce order into biology in the place of the present chaos and indeterminateness of jargon. The claim made by some that biology is not a matter of values is preposterous. It is a species of scientific fatalism no longer warranted to-day. The very term "survival of the fittest" involves a value-judgment. There is no cause for fatalism or pessimism on a due appreciation of symbiosis, no cause to falter and to think that Nature sanctions crime equally with good conduct. True, in the course of evolution, legions of species have strayed from the symbiotic path, and have elected instead that of least resistance—that of predacity or of parasitism. But it can be shown that they have declined accordingly, whilst others, which have persisted in a more honest course, have meanwhile gone forward.

The pathway of progress consisted in the main of what I have termed "norm-symbiosis," namely, the symbiosis between plant and animal,

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which, on the grand scale of Nature, constitutes the essence of the evolutionary process—so much so that often it would be a gain to speak of "co-evolution" instead of "evolution." It is to this stable, successful and all-essential form of symbiosis—contemned by official biology—that I chiefly call attention. On "norm-symbiosis" I base my biological relativity with regard to good and evil, normal and abnormal. Do the activities of the species further norm-symbiosis, and, hence, co-evolution? If so, they are legitimate and good. Do they, on the whole, frustrate this, the main scheme of evolution? If so, they are illegitimate, evil and abnormal. There is no go-as-you-please in the universe. The good life is not an easy life. Restraint and ordered freedom are as much the rule in the web of life as they are in the physiological economy of the individual body. The legitimacy of the metabolism is determined by the behaviour of the organism. The general difference of metabolism as between plant and animal is clearly determined with reference to the difference of vocation in norm-symbiosis. It is not for nothing that plant and animal are physiological and bio-economic complements. Their respective physiology and anatomy are determined accordingly. Which is also saying that they are fundamentally determined with reference to the maximum good of organic life.

It merely remains to be seen to what an extent an organism can by anti-symbiotic behaviour, at the risk of health and status, flout the fundamental dispensation of organic life. Here are a few examples in illustration of the way in which the new pathology looks at these things. A plant of abnormal metabolism is one which is faulty also with regard to the (symbiotic) provision of oxygen, carbon, and calcium (all of which are essential to the animal in the form which the plant best knows how to supply). An animal of abnormal metabolism is one that fails to render (symbiotic) counter-services to the plant (which must rely upon same). Let a plant turn parasite, and it will lose, not only its woody fibre, but also eventually its chlorophyll—the chief glory of the vegetable. Chlorophyll has justly been called the most precious single substance in the world. Such a loss means *inter alia* a diminution of the power of directing animal evolution into legitimate channels. Mushrooms, which by their mode of life approach the parasitic goal of existence, are almost completely deficient in vitamin A. It seems that the presence of chlorophyll is essential for the synthesis of vitamin A. Hence degenerate plants are for the most part excluded in this important particular. (The plant alone knows how to manufacture vitamins, by means of which it directs growth and development amongst animals.)

Again, let us take an example of illegitimacy from the physiological

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sphere. The cancer-cell is a predaceous and parasitic entity. It thwarts the co-operation between the parts. It opposes internal symbiosis, and thereby militates against the usefulness of the organism in biological symbiosis. It seizes that which does not rightfully belong to it. It renders no counter-services to other cells. On the contrary, it utterly fails to co-operate. It represents a complete divorce from symbiosis. That it is penalised in its turn is seen from the fact that it loses its nobler parts one by one. It typifies in its life the path of suicidal evolution. Its reproduction proceeds morbidly and destructively of its own source of sustenance. It exhibits a reversion to an embryonic type as though returning to nullity. Tumours, which are largely composed of cancer-cells, are, contrary to what is the rule with normal structures, imperfectly provided with blood-vessels. It is thus true, in Emersonian parlance, that the thief steals from himself. There may be more complexity in the web of life, but the socio-physiological sequence is the same as in the individual body. True, organisms enjoy a larger measure of autonomy than organs (which may be viewed as semi-independent organisms); but this does not dispense them from duty. "Freedom with virtue takes her seat." For a fuller comprehension of socio-physiological sequence it is necessary to understand the biology of food, regarding which I cannot here say much, but must refer the reader to my various writings on the subject. The study of this subject shows conclusively that everywhere predacity and parasitism are stages on the road to failure, that in Nature, as amongst men, the inexorable law of moral consequences holds good.

I am convinced that the official view, mixing up symbiosis with parasitism, is due, not to any profound probing of the respective facts, but rather to a facile tradition and to the bias against co-operation created by the now obsolete doctrine of "natural selection," which has acted hitherto as a shield of ignorance. Natural selection had enthroned competition—which, of course, has an important, though secondary, function to fulfil—as the exclusive power in evolution; and this has caused biologists to be almost morbidly afraid of taking a generous view of Nature. The German professor dearly loved his "Zuchtwahl."

How little warrant there is for the view that symbiosis inevitably degenerates into parasitism may be demonstrated by the case of the lichen, which is generally adduced as the stock-example of symbiosis. The lichen, a dual plant, composed of an alga and a fungus in (attached) partnership, is a classical example of healthiness. It is a pioneer of organic civilisation. It is widely useful. Lichens, as is well known, will thrive on bare rocks and in arctic regions—in localities where singly the partners could not get on at all. They are characterised

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by resistance to adverse circumstances, by longevity, and, frequently, by progressiveness, none of which good qualities are ever exhibited by parasites. In the tropics lichens may be found simulating the structure and form of the leafy shoots of the higher plants. That sometimes lichens may be met with, growing parasitically upon others, merely proves that there are traitors everywhere, that the "bad uses" of Nature are sometimes "good uses" gone to the bad.

Normally, in the lichen, the alga is protected by the threads (hyphæ) of the fungus, and is supplied by the fungus with water and salts and, possibly, organic nitrogenous substances. In turn, the alga manufactures photosynthetically carbohydrates, the surplus of which it yields to the fungus. Such and similar forms of partnership between plant and plant, and plant and animal, are very wide-spread, more being discovered almost every day.

Entailed in the symbiotic relation is the fullest physiological and sociological "give and take." The more A can rely on B, the more A can give and in turn stimulate B to increasing outputs. Further, the more A and B progress in correlated efficiency, the better will they be able to help C and D, as fellow-members in evolution, causing them, in turn, to increase in efficiency and usefulness. The whole level is thus gradually and almost insensibly advanced by every symbiotic increase of power. I have spoken of this "urge" or "momentum" producing power of symbiosis as "symbiogenesis," by which I mean the direction given to evolution by the long-continued operation of symbiosis in the production of higher forms of life, and in the more complete development of beneficial relations between them. Stahl, a German botanist, succeeded in making new species of lichens artificially by bringing the spores of a lichen-forming fungus into contact with algal cells, with which they had never been associated in Nature. The fungus, which is thus ready for co-operation, is thereby apt to assist in a general way the advancement of life on our globe; for it becomes a partner in the bio-chemically, bio-physically, and bio-socially important business of converting in a most suitable way inorganic into organic substances. This, surely, is a major task, a catholic end, for organic life. In symbiosis, then, are to be found the primordia of integrity. It also contains, as the above example shows, the secret of evolution, *i.e.*, of the origin of species. When Prof. Bateson declares "that particular and essential bit of the theory of evolution which is concerned with the origin and nature of species remains utterly mysterious," we can point him to Stahl's experiment and to that morphogenesis generally, which is due to long-protracted symbiotic processes. According to Bateson, we should search diligently for variations in which something has been added instead of variations by loss, with which kind we have hitherto

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generally dealt. In my opinion the good variations are in the line of symbiosis, and the retrograde ones in that of selection (inasmuch as this means unilateral exploitation and, consequently, an abnormal metabolism). Symbiosis alone, I hold, is capable of producing positive, *i.e.*, physiological results, attended by an enrichment of the protoplasm.

A generation which has suffered itself to be lured into the belief of "the origin of the fit by the fortuitous," which has overlooked the fact that bio-chemistry rests upon behaviour, which has ignored the study of organic sociality and that of food, is not one likely to discover the truth that progressive variation, like freedom, is dependent upon perseverance of the organism in a path of legitimacy and of "virtue."

In view of all of which it may now be opportune to consider a brief recital of the evolutionary accomplishments of symbiosis—at least on my interpretation of the facts.

The fixation of atmospheric nitrogen was one of the earliest problems of organic life, and the successful solution of the problem one of life's greatest triumphs. It was the plant which here, as in many other important ways, anticipated by long ages the inventions of man. The importance to the organic world of plants which force nitrogen to combine in a form useful to living beings is almost inconceivable. But for such supplies of nitrogenous food life itself would become impossible in the world. Bacteria and fungi are prominent as vegetable "chemists," active in the fixation of nitrogen. A bacteria-less ocean and a bacteria-less earth would soon be inhospitable either for plants or animals. Not only did these lowly organisms fix atmospheric nitrogen, but in due course they carried the process to the nitrate terminus. The secret of their power lay, at least in great part, in combination, in division of labour, in co-operation.

Nitrates represent an end-product. They are produced in stages and with contributions by different organisms. That is to say, their manufacture requires systematic mutual industry, or symbiosis, on the part of many organisms.

Now the coming of the higher plants and of the animals was dependent upon the presence in sufficient quantities of suitable nitrates in the soil, and the number of plants which at the present day live in active symbiosis with bacteria and fungi is legion. The higher plant is able to spare some of its carbohydrate surplus in exchange for nitrogen, and it has been found that a continuous supply of carbohydrates from the green plants is a prime condition of the nitrogen synthesis. It is my thesis that the great steps in the evolution of the higher forms were without exception based upon a succession of ever higher forms of life-partnerships. Darwin held that all plants and

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animals are descended from a common ancestor. The symbiotic division of the descendants into plants and animals was probably the greatest single step in advance made by life. The two "kingdoms" remained essentially complemental, and, fundamentally, they still stand to each other in a relation of symbiosis. In the same sense, symbiosis was the secret of the general diversification of life on our globe, of the successful conquest of the sea and, subsequently, of the land by organic life, as the following example is well calculated to show.

In some cases of alga-cum-sponge symbiosis in the sea, the alga branches profusely and ramifies through the canal system of the sponge, the alga using for food the carbon dioxide given off by the living sponge tissues, obtaining its salts from the water passing through the canals, and, on the other hand, supplying the sponge with the oxygen given off in photosynthesis. What emerges is this: the sponge needs a particular substance, which the alga knows how to manufacture, and which the latter can well afford to surrender in exchange for a spare product of the sponge. Given a situation such as this, given, in other words, a pair of opposites to be adequately accommodated, given also sufficient disposition on the part of the opposite parties, the opportunity is provided for a continuous process of mutual stimulation purporting increasing mutual benefits, and conducing in the result to increased specialisation, increased capacity and efficiency, and increased yields, not only to the partners, but also to life generally, which is thus the richer for the adoption of the symbiotic mode of life wherever met with.

That the plants have succeeded in constraining the animals to numerous counter services, on the principle of *do ut des*, is a well-known fact. Fruit-eating animals, including birds and mammals, have in many ways been made instrumental in the dispersal of plants over our globe, and this very reliably so. If the respective plants were thus favourably circumstanced, this was due to their having (unconsciously) understood and mastered the secret of symbiosis.

Again, the constant "crossing" of plants, effected by animal agency, in pollination, is an important factor in ensuring the viability and evolution of the plant. The plant can well afford to succour the pollen- or nectar-seeking animal in return for vital symbiotic services.

Further, by means of symbiosis, plants and animals have rendered both the sea and the land progressively hospitable to each other. On the land, as in the water, the plants have led the way. Without the plant the animal could not have made a home upon the land. Food, moisture and shelter, all had to be supplied by the plant if terrestrial life was to be permanently successful. Here, as in the

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waters, the plant has known how to drill the animal into habits of symbiosis. In the important transition from maritime to shore life —a preliminary step in many cases to a more terrestrial life—many animals, such as the tiny flat-worm, *Convoluta roscoffensis*, have found it essential to take their plant partners with them. These animals harbour green algæ within themselves, with which they live in a relation of (seasonal) symbiosis, and this gives them a wonderful independence so far as outside food supplies are concerned; and it is thus a great aid in the accomplishment of a big step in evolution.

(1) *The Scientific Monthly*, June, 1922.

Clinical Notes and Cases.

A Preliminary Note on the Use of Collosol Bromine in the Treatment of Insane Epileptics. By GEOFFREY F. COBB, M.R.C.S.Eng., L.R.C.P., D.P.M.Lond., Senior Assistant Physician, Rubery Hill and Hollymoor Mental Hospital, Birmingham.

THE use of collosol bromine apparently affords a convenient method of studying the action of the bromine ion apart from other inorganic elements. The bromides of potassium, sodium and ammonium have generally been regarded as the most useful preparations in the treatment of epilepsy. It would appear that a colloidal preparation of bromine (a product of the bromination of protein) presents itself as being a possible, if not probable, therapeutic agent which deserves a trial. Further, in the case of the potassium salt the depressant action of the potassium ion would be eliminated. Epilepsy, being a syndrome rather than a disease *per se*, increases the difficulty of making accurate observations and deductions as to whether or not such and such a drug has benefited the malady as a whole; or whether it has merely alleviated the more obvious of its signs and symptoms. In the case of the insane the fits themselves or their equivalents form the most outstanding dramatic manifestations of the disease. These have certainly been modified in a very striking manner in the cases that have been under this treatment. On the other hand, as is well known, it is a matter of opinion and controversy as to whether or not it is desirable to arrest the fits in the case of every epileptic, especially in the case of the insane. Allowing that the fit itself is only one of the significant characteristics of the disease, yet it is undoubtedly one of the most important. At present it would seem that no conclusion can be arrived at regarding this disputed and important point, *e.g.*, whether to attempt the arrest of

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