

## THE ANT-COLONY AS AN ORGANISM<sup>1</sup>

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As a zoologist, reared among what are now rapidly coming to be regarded as antiquated ideals, I confess to a feeling of great diffidence in addressing an audience so thoroughly versed in the very latest as well as the very oldest biological facts, methods and hypotheses. I feel, indeed, like some village potter who is bringing to the market of the metropolis a pitiable sample of his craft, a pot of some old-fashioned design, possibly with a concealed crack which may prevent it from ringing true. Although in what I have to say, I shall strenuously endeavor to be modern, I can only beg you, if I fail to come within hailing distance of the advance guard of present day zoologists, to remember that the range of adaptability in all organisms, even in zoologists, is very limited.

Under the circumstances, my only hope lies in appealing to our permanent common biological interests and these, I take it, must always center in the organism. But the point of view from which we study this most extraordinary of nature's manifestations, is continually shifting. Twenty years ago we were captivated by the morphology of the organism, now its behavior occupies the foreground of our attention. Once we thought we were seriously studying biology when we were scrutinizing paraffine sections of animals and plants or dried specimens mounted on pins or pressed between layers of blotting paper; now we are sure that we were studying merely the exuviae of organisms, the effete residua of the life-process. If the neovitalistic school has done nothing else, it has jolted us out of this delusion which was gradually taking possession of our faculties. It is certain that whatever changes may overtake biology in the future, we must henceforth grapple

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with the organism as a dynamic agency acting in a very complex and unstable environment. In using the term organism, therefore, I shall drop the adjective 'living,' since I do not regard pickled animals or dried plants as organisms.

As I wish to describe a peculiar type of organism, I may be asked, before proceeding, to state more concisely what I mean by an organism. It is obvious that no adequate definition can be given, because the organism is neither a thing nor a concept, but a continual flux or process, and hence forever changing and never completed. As good a formal definition as I can frame is the following: An organism is a complex, definitely coördinated and therefore individualized system of activities, which are primarily directed to obtaining and assimilating substances from an environment, to producing other similar systems, known as offspring, and to protecting the system itself and usually also its offspring from disturbances emanating from the environment. The three fundamental activities enumerated in this definition, namely nutrition, reproduction and protection seem to have their inception in what we know, from exclusively subjective experience, as feelings of hunger, affection and fear respectively.

Biologists long ago constructed an elaborate hierarchy of organisms. Those of a speculative turn of mind, like Spencer and Weismann, postulated the existence of very simple organisms, the physiological units, or biophores, which, though invisible, were nevertheless conceived as combining the fundamental activities above enumerated. These biophores were supposed to form by aggregation the cells, which may exist as independent organisms in the Protozoa and Protophyta or unite with other cells to form more complex aggregates, for which Haeckel's term 'persons' may be adopted. The person may be merely a cell-aggregate or consist of complexes of such aggregates as the metameres of the higher animals, for the separate metameres, according to a very generally accepted theory, are supposed to be more or less modified or highly specialized persons. Somewhat similar conditions are supposed to obtain in the composition of the vascular plants. The integration both of the metameric and non-metameric Metazoa may proceed still further, the simple persons combining to

form colonies in which the persons are primarily nutritive and acquire fixed and definite spatial relations to one another, whereas the more specialized animals, like the social insects, may constitute families of mobile persons with reproduction as the 'Leitmotiv' of their consociation. In man we have families associating to form still more complex aggregates, the true societies. Other comprehensive organisms are the cœnobioses, or more or less definite consociations of animals and plants of different species, which the ecologists are endeavoring to analyze. Finally we have philosophers, like Fechner, stepping in with the assertion, that the earth as a whole is merely a great organism, that the planetary systems in turn are colonies of earths and suns and that the universe itself is to be regarded as one stupendous organism. Thus starting with the biophore as the smallest and ending with the universe as the most comprehensive we have a sufficiently magnificent hierarchy of organisms to satisfy even the most zealous panpsychist. As biologists we may, for present purposes, lop off and discard the ends of this series of organisms, the biophores as being purely hypothetical and the cosmos as involving too many ultrabiological assumptions. We then have left the following series: first, the Protozoon or Protophyte, second the simple or non-metameric person, third the metameric person, fourth the colony of the nutritive type, fifth the family, or colony of the reproductive type, sixth the cœnobiöse, and seventh the true, or human society. Closer inspection shows that these are sufficiently heterogeneous when compared with one another and with the personal organism, which is the prototype of the series, but I believe, nevertheless that all of them are real organisms and not merely conceptual constructions or analogies. One of them, the insect colony, has interested me exceedingly, and as I have repeatedly found its treatment as an organism to yield fruitful results in my studies, I have acquired the conviction that our biological theories must remain inadequate so long as we confine ourselves to the study of the cells and persons and leave the psychologists, sociologists and metaphysicians to deal with the more complex organisms. Indeed our failure to coöperate with these investigators in the study of animal and plant societies has blinded us to many aspects of the

cellular and personal activities with which we are constantly dealing. This failure, moreover, is largely responsible for our fear of the psychological and the metaphysical, a fear which becomes the more ludicrous from the fact that even our so-called 'exact' sciences smell to heaven with the rankest kind of materialistic metaphysics.

Leaving these generalities for the present, permit me to present the evidence for the contention that the animal colony is a true organism and not merely the analogue of the person. To make this evidence as concrete as possible I shall take the ant-colony as a paradigm and ask you to accept my statement that the colonies of the termites, social bees and wasps, which the limited time at my disposal does not permit to consider, will be found to offer the same and in some cases even more satisfactory data. I select the ant-colony not only because I am more familiar with its activities, but because it is much more interesting than that of the polyps, more typical and less specialized than that of the honey bee, less generalized than that of the wasps and bumble-bees, and has been much more thoroughly investigated than the colonies of the stingless bees and the termites.

The most general organismal character of the ant-colony is its individuality. Like the cell or the person, it behaves as a unitary whole, maintaining its identity in space, resisting dissolution and, as a general rule, any fusion with other colonies of the same or alien species. This resistance is very strongly manifested in the fierce defensive and offensive coöperation of the colonial personnel. Moreover, every ant-colony has its own peculiar idiosyncrasies of composition and behavior. This is most clearly seen in the character of the nest, which bears about the same relation to the colony that the shell bears to the individual Foraminifer or mollusc. The nest is a unitary structure, built on a definite but plastic design and through the coöperation of a number of persons. It not only reflects the idiosyncrasies of these persons individually and as a whole, but it often has a most interesting adaptive growth and orientation which may be regarded as a kind of tropism. In many species the nest mounds, which are used as incubators of the brood and as sun-parlors for the adult ants, are constructed in

such a manner as to utilize the solar radiation to the utmost. In the Alps and Rocky Mountains we find the nests oriented in such a manner that the portions in which the brood is reared face south or east, and as time goes on the nests often grow slowly in these directions, like plants turning to the light, so that they become greatly elongated. This orientation is, in fact, so constant in some species that the Swiss mountaineers, when lost in a fog, can use it as a compass.

Every complete ant-colony, moreover, has a definite stature which depends, of course, on the number of its component persons. And this stature, like that of personal organisms, varies greatly with the species and is not determined exclusively by the amount of food, but also by the queen mother's fertility, which is constitutional. Certain ants live in affluence but are nevertheless unable to form colonies of more than fifty or a hundred individuals, while others, under the same conditions, have a personnel of thousands or tens of thousands.

One of the most general structural peculiarities of the person is the duality of its composition as expressed in the germ-plasm on the one hand and the soma on the other, and the same is true of the ant-colony, in which the mother queen and the virgin males and females represent the germ-plasm, or, more accurately speaking, the 'Keimbahn,' while the normally sterile females, or workers and soldiers, in all their developmental stages, represent the soma. In discussing the question of the inheritance or non-inheritance of acquired characters the Neodarwinians trace all the congenital modifications of the worker and soldier phases to the queen, just as in the personal organism all the congenital somatic characters are traced to the germ-plasm of the egg. Since the homologue of the reproductive organ of the ant-colony consists of the virgin males and females, and since the males mature earlier than the females, the colony may be regarded as a protandric hermaphrodite. Some colonies, however—and this is probably characteristic of certain species—produce only males or females and are therefore in a sense gonochoristic, or dioecious. And this protandric hermaphroditism and gonochorism, like the corresponding conditions in persons, may be interpreted as a device for, or, at

any rate, as an aid, in insuring cross-fertilization. The fecundated queen of the ant-colony represents the first link in the 'Keimbahn' and therefore corresponds to the fertilized egg of the personal organism. She produces both the worker personnel and the virgin males and females, just as the fertilized egg produces both the soma and the germ-cells. The colonial soma, moreover, may be differentiated as the result of a physiological division of labor into two distinct castes, comprising the workers in which the nutritive and nidificational activities predominate, and the soldiers, which are primarily protective. Here, too, the resemblance to the differentiation of the personal soma into entodermal and ectodermal tissues can hardly be overlooked.

The structure of the ant-colony thus appears to be very simple as compared with that of its component persons. The question naturally arises as to the particular type of unicellular or personal organism which it most resembles. Undoubtedly, if we could see it acting in its entirety, the ant-colony would resemble a gigantic foraminiferous Rhizopod, in which the nest would represent the shell, the queen the nucleus, the mass of ants the plasmodium and the files of workers, which are continually going in and out of the nest, the pseudopodia.

The ant-colony, of course, like the person, has both an ontogenetic and a phylogenetic development; the former open to observation, the latter inferred from the ontogeny, a comparison of the various species of ants with one another and with allied Hymenopterous insects, and from the paleontological record. The fecundated queen, as I have stated, represents the fertilized egg which produces the colonial organism, but she is a winged and possibly conscious egg, capable not only of actively disseminating the species, like the minute eggs of many marine animals, but of selecting the site for the future colony. After finding this site she discards her wings and henceforth becomes sedentary like the wingless workers which she will produce. The whole colony rests satisfied with the nesting site selected by its queen if the environmental conditions remain relatively constant. If these become unfavorable, however, the colony will move as a whole to a new site. In most species such movements are rather limited, but the

nomadic driver and legionary ants are almost continually moving from place to place and must cover a considerable territory during the year. After the queen has selected the nesting site, she immures herself in some earthen or vegetable cavity, lays a number of eggs, supplying them with yolk derived by metabolism from her fat-body and now useless wing-muscles, and feeds the hatching larvæ on her salivary secretion, which, though highly nutritious, is, nevertheless, very limited in quantity, so that the offspring when mature are dwarfed and very few in number. They are in fact, workers of the smallest and feeblest caste; but they set to work enlarging the nest, break through the soil or plant tissues, construct an entrance on the surface and seek food for themselves and their famished mother. This food enables her to replenish her fat-body and to produce more eggs. Her expansive instincts and activities now contract, so to speak, and become reduced henceforth to a perpetual routine of assimilation, metabolism and oviposition. She produces brood after brood during her long life which may extend over a period of ten to thirteen years. Her workers assume the duties of foraging, of feeding the larvæ and one another, and of completing the nest. Their size and polymorphism increase with successive broods, till the soldier forms, if these are characteristic of the species, make their appearance. Then the individuals which correspond to the reproductive cells of the personal organism, namely, the virgin males and females develop, and the colonial organism may be said to have reached maturity. Like the personal organism, it may persist for thirty or forty years or, perhaps, even longer without much growth of its soma, since the workers and soldiers of which this consists are exposed to many vicissitudes and live only from three to four years and probably, as a rule, for a much shorter period. If the queen grow too old or die the colony, as a rule, dwindles and eventually perishes unless her place is taken by one or more of her fertile daughters.

This is the ontogenetic history of most ant-colonies. It is so similar to the phylogenetic history derived from the sources mentioned above that we have no hesitation in affirming that it conforms in the most striking manner to the biogenetic law. The

very ancient behavior of the solitary female Hymenopteron is still reproduced during the incipient stage of colony formation, just as the unicellular phase of the Metazoon is represented by the egg. A further correspondence of the ontogeny and phylogeny is indicated by the fact that the most archaic and primitive of living ants form small colonies of monomorphic workers closely resembling the queen, whereas the more recent and most highly specialized ants produce large colonies of workers not only very unlike the queen but unlike one another.

In order to complete the foregoing account it will be necessary to consider some interesting modifications of the usual method of colony formation and growth, especially as these modifications furnish additional and striking evidence in favor of the contention that the ant-colony is a true organism. In many species, after the colony has reached maturity and especially if the food-supply continue to be abundant, several of the virgin females may be fecundated in the nest, lose their wings and remain as members of the colony. This may, indeed, contain half a dozen and in extreme cases as many as forty or fifty or even more fertile queens. But often the growth of the colonial organism becomes excessive through an increase in the worker personnel and passes over into a form of colonial reproduction, when the young fertilized queens, each accompanied by a band of workers, start new nests in the vicinity of the parental formicary. In this manner a very large and complex colony may arise and extend over many adjacent nests. For some time the new settlements may remain in communication with the home-nest through files of workers, but eventually the daughter settlements may become detached and form independent colonies. The resemblance of this method of reproduction, which is essentially the same as the swarming in the honey-bee, to the asexual reproduction of many unicellular and multicellular organisms by a process of budding, is too obvious to need further comment.

The important rôle of nutrition in the development of the colony will be clear from the foregoing remarks. It becomes even more striking in the methods adopted by the queens of certain parasitic species in starting their colonies. Some European

observers and myself have found a number of queen-ants that are unable to found colonies without the aid of workers of allied species. These queens may be separated into four groups, as follows:

1. The queen which enters a colony of an alien species and decapitates its queen or is the occasion of her being killed off by her own workers. The intrusive queen is then adopted by the workers and a compound colonial organism arises, consisting of the germ-plasm of one species and the soma of another. The queen proceeds to lay eggs, which are reared by the alien workers, thus relieving her of all the labor and exhaustion endured by the independent typical ant-queen during the early stages of colony formation. *Pari passu* with the development of the worker offspring of the intrusive queen, the worker nurses grow old and die, so that the colony eventually comes to consist of only one species, the soma of the host being replaced by that of the parasite. This method of colony formation, first observed among our American ants and later among certain European and North African species, I have called temporary social parasitism. Now many of the species, which behave in this manner, have extremely small queens, or queens provided with a peculiar pilosity or sculpture that tend to endear them to the workers of the alien colonies which they invade. If we regard the large fertilized queens of ordinary ants, which are supplied with a voluminous fat-body and wing-musculature, as representing eggs provided with a great amount of yolk, and the diminutive queens of the temporary social parasites as the equivalents of alecithal eggs, we have another striking resemblance between the personal and colonial organisms, for the large queens, like the yolk-laden eggs of many vertebrates, are produced in small numbers but are able to generate the colonial soma independently, whereas the small queens, which are produced in great numbers, in order that some of them may survive the vicissitudes of a parasitic life, correspond to the small yolk-less eggs of many parasites, which have to be deposited in plant or animal tissues in order that the imperfect young on hatching may be surrounded by an abundance of food.

2. The queen of the blood-red slave-maker (*Formica sanguinea*) adopts a different method. She enters the colony of an

allied species, snatches up the worker brood and kills any of the workers or queens that endeavor to dispute her possessions. The ants hatch with a sense of affiliation with their foster mother and proceed to rear her eggs and larvæ as soon as they appear. Here, too, the colony is formed by a mixture of two species, but the workers produced by the intrusive queen inherit her predatory instincts and therefore become slave-makers. They keep on kidnapping worker larvæ and pupæ from the nests of the alien species, carry them home, and eat some of them but permit many to mature, so that the mixed character of the colony is maintained. This, however, is not invariably the case, for old and vigorous sanguinea colonies may cease to make slave-raids and the slaves may die off and leave a pure colony of the predatory species. The advantages of this method of colony formation are obvious, for the colonial soma, being composed of two species, grows more rapidly and is much more efficient as a nutritive and protective support to the colonial germ-plasm, which is restricted to the predatory species.

3. The colony-founding queen of the amazon ants of the genus *Polyergus* resorts to a modification of the method adopted by *sanguinea*, as has been shown by Emery's recent observations. She enters the colony of an alien species, perforates its queen's head with her sickle-shaped mandibles and permits herself to be adopted by the workers. She pays no attention to the brood but begins to lay eggs, the larvæ from which are carefully reared by the workers. The *Polyergus* offspring inherit the pugnacity of their mother, but, like the *sanguinea* workers, have the ability to kidnap the brood of other ants. They are, in fact, slave-makers of a very deft and ferocious type. Like their mother, however, they are unable to excavate the nest, to care for their own young or to take food except from the mouths of the workers that hatch from the kidnapped larvæ and pupæ. The mixture of the two species is therefore obligatory, and the slave personnel, which represents the nutritive and nest-building portions of the colonial soma, has to be maintained throughout the life of the colony.

4. Certain feeble queen ants belonging to a few aberrant genera (*Anergates*, *Wheeleriella*) invade populous nests of an alien species and are adopted in the place of their queens, which are

destroyed by their own workers. The parasites then proceed to lay eggs but these give rise only to males and females as the worker caste is entirely suppressed. The colony retains a mixed character, the parasitic species usurping the functions of the germ-plasm, while the host is purely somatic. As there are no means of prolonging the lives of the host-workers and as they do not reproduce, the whole colony is short-lived and the maturation of the parasitic sexual individuals has to be accelerated so that it will fall within the brief life-time of the worker hosts. This condition I have called permanent social parasitism.

These four peculiar types of colony-formation all lead to the formation of compound colonial organisms, comparable to certain compound personal organisms which, with few exceptions, can be produced only by artificial means. In temporary social parasitism the colonial egg can develop its soma only when grafted on to the soma of another species. This soma eventually perishes and the colony then assumes a normal complexion. This condition reminds us of certain tropical plants, like the species of *Clusia* and *Ficus*, which develop as epiphytes on other trees but after killing their hosts take root in the soil and thenceforth grow as independent organisms. The slave-makers of the *sanguinea* or facultative type are also unable to develop the soma except when grafted on to the soma of another species, but in this case the cooperation of both somas in nourishing and protecting the germ-plasm is maintained for a much longer period. This kind of colony may be compared with a graft made by uniting the longitudinal half of one plant with that of another so that both take nourishment through their roots. To make the resemblance more complete one of the grafted halves would have to be pruned in such a manner as to prevent flowering. In the amazons or obligatory slave-makers and the permanent social parasites the alien soma alone has a nutritive function, so that the conditions are like those in ordinary vegetable grafts, in which the stock retains the roots and the scion produces the flowers and fruit.

I have dwelt on the various methods of colony formation not only because they give us an insight into colonial reproduction, but because they throw light on the colonial organism from the

standpoint of parasitology. That the four types of queens and their offspring are directly comparable with entoparasitic persons is not so remarkable as the fact that in ants the host and parasite form a mixed organism which could only be obtained with persons by jumbling together the component cells of host and parasite like two kinds of peas shaken in a bottle. Notwithstanding this mixture the parasitic colony not only retains its identity and the anticipatory character of its behavior but castrates the host colony and constrains its soma either to coöperate in many of its activities or to specialize as a purely nutritive or nest-building auxiliary. The host is thus reduced to the status of a nourishing or protective organ of the parasite. This behavior has many striking analogies among persons. Giard long ago called attention to the fact that when the cirriped *Sacculina* settles under the abdomen of a male crab and sends its rootlike haustoria into the tissues of its host, the latter undergoes castration, and its narrow abdomen expands to form a protection for the soft-bodied parasite. In other words, the parasite acts as if it were a mass of crabs' eggs and the male crab behaves as if it had changed its sex and develops an abdomen of the female type.

Not only are there ants, like those already considered, that may be regarded as colonial entoparasites, but there are also a number of species that may be called colonial ectoparasites. These form the so-called 'compound nests,' in which two or more species live amicably side by side, or may even mingle freely with one another, but rear their broods in separate nests, thus indicating in the clearest manner the integrity of the colonial organism. This is also shown by the vast number of myrmecophilous insects, which are, of course, ento- or ectoparasitic persons, and behave towards the ant colony as if it were a rather incoherent and therefore more vulnerable, or exploitable personal organism.

Finally we come to what the neovitalists regard as the most striking autonomic manifestations of the organism, namely the regulations and restitutions, and face the question as to whether these, too, have their counterpart in the colonial organism. I believe that the following facts compel us to answer this ques-

tion in the affirmative. If the worker personnel be removed from a young ant-colony, leaving only the fertile queen, we find that this insect, if provided with a sufficiently voluminous fat-body, will set to work and rear another brood, or, in other words, regenerate the missing soma. And, of course, any portion of the worker or sexual personnel, that is removed from a vigorous colony will be readily replaced by development of a corresponding portion of the brood. On the other hand, if the queen alone be removed, one of the workers will often develop its ovaries and take on the egg-laying function of the queen. In ants such substitution queens, or gynaeoid workers are not fertilized and are therefore unable to assume their mother's worker- and queen-producing functions. The termites, however, show a remarkable provision for restituting both of the fertile parents of the colony from the so-called complemental males and females. In ants we have a production of fertile from normally infertile individuals, but the incompleteness of the result does not disprove the existence of a pronounced restitutorial tendency.

Very striking examples of this tendency are exhibited when colonies are injured by parasitic myrmecophiles. I shall consider only the case of the peculiar beetle *Lomechusa strumosa*, which breeds in colonies of the blood-red slave-maker (*Formica sanguinea*). Though the beetle and its larvæ are treated with great affection, the latter devour the ant larvæ in great numbers, so that little of the brood survives during the early summer months when the colony is producing its greatest annual increment to the worker personnel. The ants seem to perceive this defect and endeavor to remedy it by converting all the surviving queen larvæ into workers. But as these larvæ have passed the stage in their development when such an operation can be successful, the result is the production of a lot of pseudogynes, or abortive creatures structurally intermediate between the workers and queens and therefore useless in either capacity. It is instructive to compare this case with the regeneration of the lens from the iris in the Amphibian eye. In his recent analysis of the stimuli of restitution in personal organisms Driesch reaches the conclusion that "the specificity of what is taken away certainly forms part of the

stimulus we are searching for, and it does so by being communicated in some way by something that has relations to *many*, if not *all*, parts of the organism and not only to the neighboring ones." He also says that "each part of the organism assigns its specific share to an unknown something and that this something is altered as soon as a part is *removed* or absolutely *stopped* in its functional life, and that the specific alteration of the something is our stimulus of restitutions." These quotations and Driesch's further discussion of the problem are even clearer in their application to the colonial than to the personal organism, for in the former it is much easier to see how each individual insect "can do more than one thing in the service of restitution" than it is to understand how each cell of the person can do more than one thing in restoring a lost organ.

I fear that I may have wearied you with this long attempt to prove that the ant-colony is a true organism, especially as this statement must seem to some of you to be too trite for discussion, but when an author like Driesch writes a large work in two volumes on the "Philosophy of the Organism" and ignores the colonial organisms altogether, an old-fashioned zoologist may perhaps be pardoned for calling attention to a well-founded, though somewhat thread-bare, biological conception.

If it be granted that the ant-colony and those of the other social insects are organisms, we are still confronted with the formidable question as to what regulates the anticipatory coöperation, or synergy of the colonial personnel and determines its unitary and individualized course. The resemblance of the ant- or bee-colony to the human state long ago suggested a naive reply to this question. Aristotle naturally supposed the colonial activities to be directed and regulated by a *βασιλεύς* or *ἡγεμών*, because these personages managed affairs in the Greek states. After the sex of the fertile individual had been discovered by Swammerdam, the word 'queen' was naturally substituted for *βασιλεύς* or 'king,' and as queens in human states do not necessarily govern and are often rather anabolic, sedentary and prolific persons and the objects of much flattering attention, the term is not altogether inapt when applied to the fertile females of insect colonies. It

has been retained although everybody knows that these colonies represent a form of society very different from our own, a kind of communistic anarchy, in which there is "neither guide, overseer nor ruler," as Solomon correctly observed. In this respect too, the colony is essentially the same as the personal organism, at least in the opinion of those who do not feel compelled to assume the existence of a 'soul' in the scholastic sense. For it is clear, that to primitive thinkers the soul was supposed to bear the same relation to the person as the *βασιλεύς* to the insect colony and the king to the human state. This supposition is still held though in a more subtle form, by writers of the present day. Some of these, like Maeterlinck, clothe the postulated controlling agency in a mystical or poetic garb and call it the 'spirit of the hive.' The following passage from the Belgian poet's charming account of the honey-bee will serve to illustrate this method of meeting the problem:

What is this 'spirit of the hive'—where does it reside? It is not like the special instinct that teaches the bird to construct its well planned nest, and then seek other skies when the day for migration returns. Nor is it a kind of mechanical habit of the race, or blind craving for life, that will fling the bees upon any wild hazard the moment an unforeseen event shall derange the accustomed order of phenomena. On the contrary, be the event never so masterful, the 'spirit of the hive' still will follow it, step by step, like an alert and quickwitted slave, who is able to derive advantage even from his master's most dangerous orders.

It disposes pitilessly of the wealth and the happiness, the liberty and life, of all this winged people; and yet with discretion, as though governed itself by some great duty. It regulates day by day the number of births, and contrives that these shall strictly accord with the number of flowers that brighten the country-side. It decrees the queen's deposition or warns her that she must depart; it compels her to bring her own rivals into the world, and rears them royally, protecting them from their mother's political hatred. So, too, in accordance with the generosity of the flowers, the age of the spring, and the probable dangers of the nuptial flight will it permit or forbid the first-born of the virgin princesses to slay in their cradles her younger sisters, who are singing the song of the queens. At other times, when the season wanes, and flowery hours grow shorter, it will command the workers themselves to slaughter the whole imperial

brood, that the era of revolutions may close, and work become the sole object of all. The 'spirit of the hive' is prudent and thrifty, but by no means parsimonious. And thus, aware, it would seem, that nature's laws are somewhat wild and extravagant in all that pertains to love, it tolerates, during summer days of abundance, the embarrassing presence in the hive of three or four hundred males, from whose ranks the queen about to be born shall select her lover; three or four hundred foolish, clumsy, useless, noisy creatures, who are pretentious, gluttonous, dirty, coarse, totally and scandalously idle, insatiable, and enormous.

But after the queen's impregnation, when flowers begin to close sooner and open later, the spirit one morning will coldly decree the simultaneous and general massacre of every male. It regulates the workers' labours with due regard to their age; it allots their task to the nurses who tend the nymphs and the larvæ, the ladies of honour who wait on the queen and never allow her out of their sight; the house-bees who air, refresh, or heat the hive by fanning their wings, and hasten the evaporation of the honey that may be too highly charged with water; the architects, masons, wax-workers, and sculptors who form the chain and construct the combs; the foragers who sally forth to the flowers in search of the nectar that turns into honey, of the pollen that feeds the nymphs and the larvæ, the propolis that welds and strengthens the buildings of the city, or the water and salt required by the youth of the nation. Its orders have gone to the chemists who ensure the preservation of the honey by letting a drop of formic acid fall in from the end of their sting; to the capsule makers who seal down the cells when the treasure is ripe, to the sweepers who maintain public places and streets most irreproachably clean, to the bearers whose duty it is to remove the corpses; and to the amazons of the guard who keep watch on the threshold by night and by day, question comers and goers, recognize the novices who return from their very first flight, scare away vagabonds, marauders and loiterers, expel all intruders, attack redoubtable foes in a body, and, if need be, barricade the entrance.

Finally, it is the spirit of the hive that fixes the hour of the great annual sacrifice to the genius of the race: the hour, that is, of the swarm; when we find a whole people, who have attained the topmost pinnacle of prosperity and power, suddenly abandoning to the generation to come their wealth and their palaces, their homes and the fruits of their labour; themselves content to encounter the hardships and perils of a new and distant country. This act, be it conscious or not, undoubtedly passes the limits of human morality. Its result will sometimes be ruin, but poverty

always; and the thrice-happy city is scattered abroad in obedience to a law superior to its own happiness. Where has this law been decreed which, as we soon shall find, is by no means as blind and inevitable as one might believe? Where, in what assembly, what council, what intellectual and moral sphere, does this spirit reside to whom all must submit, itself being vassal to an heroic duty, to an intelligence whose eyes are persistently fixed on the future?

It comes to pass with the bees as with most of the things in this world; we remark some few of their habits; we say they do this, they work in such and such fashion, their queens are born thus, their workers are virgin, they swarm at a certain time. And then we imagine we know them, and ask nothing more. We watch them hasten from flower to flower, we see the constant agitation within the hive; their life seems very simple to us, and bounded, like every life, by the instinctive cares of reproduction and nourishment. But let the eye draw near, and endeavour to see; and at once the least phenomenon of all becomes overpoweringly complex; we are confronted by the enigma of intellect, of destiny, will, aim, means, causes; the incomprehensible organization of the most insignificant act of life.

Other authors like Driesch, give the postulated controlling agency the sharper outlines of a would-be scientific but in reality metaphysical entity and call it the 'entelechy.' It is true that the entelechy is deduced by Driesch from the autonomic peculiarities of the personal organism, but as the colony has all the essential attributes of the organism, he would undoubtedly assign it an entelechy, which according to the definition would have to be nonspacial, but working into space, nonpsychic, but conceivable only after analogy with the psychic, and non-energetic, but nevertheless capable of determining the specificity of the colonial activities through releasing and distributing energy.

I confess that I find the entelechy quite as useless an aid in unravelling the complex activities of the ant-colony as others have found it in analyzing the personal organism. This angel-child, entelechy, comes, to be sure, of most distinguished antecedents, having been mothered by the Platonic idea, fathered by the Kantian Ding-an-sich, suckled at the breast of the scholastic *forma substantialis* and christened, from a strong family likeness, after old Aristotle's darling *εντελέχεια*, but nevertheless, I believe that

we ought not to let it play about in our laboratories, not because it would occupy any space or interfere with our apparatus, but because it might distract us from the serious work in hand. I am quite willing to see it spanked and sent back to the metaphysical house-hold.

But, speaking seriously, it seems to me that if the organism be inexplicable on purely biological grounds, we should do better to resort to psychological agencies like consciousness and the will. These have at least the value which attaches to the most immediate experience. And even the subconscious and the super-conscious are more serviceable as explanations than such anaemic metaphysical abstractions as the entelechy. Of course, psychic vitalism is one of Driesch's pet aversions and he will have none of it, because he is a solipsist, but the fact that he is compelled to operate with a 'psychoid' and with an entelechy conceivable only *per analogiam* with the psychic, shows the inconsistency of his position.

Before we can adopt any ultrabiological agencies, however, except in a tentative and provisional manner, an old and very knotty problem will have to be more thoroughly elucidated. I refer to the problem of the correlation and coöperation of parts. If the cell is a colony of lower physiological units, or biophores, as some cytologists believe, we must face the fact that all organisms are colonial or social and that one of the fundamental tendencies of life is sociogenic. Every organism manifests a strong predelection for seeking out other organisms and either assimilating them or coöperating with them to form a more comprehensive and efficient individual. Whether, with the mechanists, we attribute this tendency to chemotropism or cytotropism, or with the psychic neovitalists, interpret it as conscious and voluntary, we certainly cannot afford to ignore the facts. The study of the ontogeny of the person, *i.e.*, the person in the process of making, in the hands of recent experimentalists, has thrown a flood of light on the peculiarities of organization, but the animal and plant colony are in certain respects more accessible to observation and experiment, because the component individuals bear such loose spacial relations to one another. Then too, the much simpler and more primi-

tive organismal type of the colony, as compared with that of the person, should enable us to follow the process of consociation and the resulting physiological division of labor more successfully. In the problem, as thus conceived, we must include, not only the true colony and society, and the innumerable cases of symbiosis, parasitism and cœnobiosis, but also the consociation and mutual modification of hereditary tendencies in parthenogenetic and biparental plants and animals, since in all of these phenomena our attention is arrested not so much by the struggle for existence, which used to be painted in such lurid colors, as by the ability of the organism to temporize and compromise with other organisms, to inhibit certain activities of the aequipotential unit in the interests of the unit itself and of other organisms; in a word, to secure survival through a kind of egoistic altruism.<sup>2</sup>

<sup>2</sup>Since this paragraph was written I have found that several recent authors have given more explicit expression to a very similar conception to the rôle of coöperation and struggle in the development of organisms. Especially worthy of mention in this connection are Kammerer (*Allgemeine Symbiose und Kampf ums Dasein als gleichberechtigte Triebkräfte der Evolution. Arch. f. Rass. u. Ges.-Biol.* 6, 1909, pp. 585-608), Schiefferdecker (*Symbiose. Sitzb. niederrhein. Ges. f. Natur. u. Heilk. zu Bonn*, 13, Juni, 1904, 11 pp.), Bölsche (*Daseinskampf und gegenseitige Hilfe in der Entwicklung. Kosmos*, 6, 1909); and Kropotkin (*Mutual aid, a factor of evolution*, London, 1902).