

PRESIDENT'S ADDRESS.

THE PROBLEMS OF LIFE AMONG PARASITIC ANIMALS.

Howard E. Enders.

The development of parasitology as a special phase of zoology has been made possible through a recognition of its economic applications in agriculture, horticulture, veterinary medicine and public health. The applications in medicine and public health help to re-establish the close relationship to the science of medicine from which zoology originally developed into the importance of a separate science.

Need for the further development of the field of parasitology was thoroughly emphasized in the recent war, through the work accomplished by the parasitologists of the Sanitary Corps in eradication of the lice, which became active agents in the spread of typhus and trench fevers that levied a heavy toll throughout all of Serbia and more or less elsewhere. Before the war few colleges offered courses in this work but with the return of men to the educational duties new courses were undertaken and the older courses were given new life and renewed activities in a field in which so much remains to be investigated.

A generation or two ago, when the presence of amiable flies about the table was a token of the hospitality and general kindness of the hostess, the louse and the flea and other more or less personal attendants were regarded at most only as petty annoyances. Most of these forms are now regarded as parasites. In its original use the term "parasite" was employed to describe those who sat about the tables of the rich of ancient Greece, by virtue of their fawning and flattery. It does not require a wide stretch of the imagination to understand how a similar relation was ascribed to the animals which lived upon other animals and there maintained a thievish existence at the expense of the host. How they came into being, or how they came to be where they were was as readily accounted for as was the origin of Topsy, in "Uncle Tom's Cabin", and each had as real a purpose in life as was expressed by "David Harum" of the fleas: "A reasonable amount of fleas is good for a dog; it keeps him from brooding over being a dog."

The idea that life could spring suddenly into existence made it as readily possible to account for the origin of any parasite within or upon a host, as for the host itself. The belief in the spontaneous origin of parasites and "other vermin" from filth or other "formative materials", was so firmly held that formulas were given for the production of certain forms of life, and to doubt it was to question reason and truth.

Development within the field of biology in a period possibly only a little longer than the lifetime of the oldest person here, has been made possible through the epoch-making discovery of protoplasm as the physical basis of life; the formulation of the cell-theory; the exposition of the theory of evolution of plants and animals; the development of the

science of bacteriology and with it the proofs that life does not arise spontaneously, and finally the formulation of the modern theories of heredity. Thus the old theories have been proven untenable so that now the period from generation to generation represents a definite sequence or a series of steps in a definite life-cycle.

The term "parasite", now one of the common terms in biological literature, is so difficult to define that it seems almost impossible to have two workers agree without a series of qualifications of its meaning. Megnin has defined parasites as those which live at the expense of others which are living. The definition recognizes a symbiotic relationship between the parasite and its host, upon which or within which it may maintain its existence for a shorter or longer time, possibly only for an occasional visit or for the whole of a lifetime.

Whatever the relationship to its host the parasite, if it is successful, lives and grows and in turn reproduces its kind, but to do so it must solve the problems of life. These may be serious ones, and the hazards of gaining a foothold and maintaining itself and reproducing are out of all proportion to those with which man, his domesticated animals and most other free-living forms must cope.

The parasite may be a permanent or a temporary resident upon the outside of a host that mingles little or much with others of its kind; it may live within the digestive tract or kidneys, liver, lungs or in the circulatory apparatus, within which it may move with more or less ease but from which escape to a new host becomes more difficult; it may live within the tissues from which escape seems even less certain, unless the host is eaten by some predaceous form, or its carcass is devoured by some scavenger.

If it is on the outside of a host how does the parasite maintain its place or avoid dislodgment?

How does it maintain itself inside the body without being strangled, if respiration is necessary?

How does it maintain itself in a digestive tract in which it encounters the inhospitable digestive enzymes that act upon other substances like those of its own body?

How does it perform the fundamental functions of life, as reproducing itself, etc.?

If it or its young find the way to the soil or water how are the new conditions withstood?

If neither it nor its eggs or the young can escape from the host, what of the future?

What chance do the progeny have of securing a foothold and what difficulties do they encounter, or how do the progeny come to find a similar or suitable host?

Above all, how did the particular parasite come to live as it does?

These are some of the problems that the successful parasite solves when it maintains itself and reproduces its kind.

The last of these questions, "Above all, how did the particular parasite come to live as it does?" may be considered first, in a general way, as it applies to a few of the permanent ectoparasites. From the investigations of others and from my own observations I have been able to obtain a large volume of data on various aspects presented in different states of symbiosis which have been included under the term parasitism.

To each of us—though with certain reservations—it has been a matter of common observation that the mosquito, the blood-sucking fly, or the bed-bug and flea, or a tick, may make an occasional levy for blood, but that any warm-blooded animal may serve equally well as a temporary host, only long enough to secure their fill, or until they are interrupted in the act. The length and strength of the piercing beak here seems to guarantee an ample supply of food from any warm-blooded animal whose skin is not too thick to be penetrated, so the food problem is not a difficult one. Sooner or later they lay their eggs which develop apart from the host, and in time the young of only one of these return for the food that is necessary to maintain a livelihood, and for them the food question is simple, for they share the same bed with their host. The progeny of the flea and the mosquito forage in a free environment but the ticks, numbering from two thousand to ten thousand from a single mother, crawl up stems and blades of grass and there wait. If a new, warm-blooded animal passes, or if they chance to attach themselves to a favorable host, they may gain a meal and live, but the hazards are great, and on the average there are no more ticks in one season than in another, which means that a little tick has scarcely one two-thousandth, or even one ten-thousandth of a chance of reaching maturity.

As one leafs over a series of volumes and reprints he may observe little flat-bodied, wingless book-lice that have been disturbed in their meal upon the glue of the bindings, and in them he may recognize the same characteristics of structure that occur in a host of forms that live as parasites, permanent parasites, on our domestic poultry and on our wild birds. Other relatives of these free-living book-lice are found upon the bark of trees, and in some manner they may have found their way to the bodies of the ancestors of our present-day birds. The whole organization and structure is so similar that we have good reason to conclude that the bird-lice, the Mallophaga, fifteen hundred different species, have descended from the ancestors from which the book-lice have come. The food which they now take consists of the small fragments of feathers and dead skin, instead of the glue or other animal or plant products of their free-living relatives.

The eggs of the Mallophaga are glued to the feathers, or to the hairs, for about one hundred of the fifteen hundred known species have taken up their abode on mammals, by a clasping action of the posterior end of the abdomen of the female. The young feed from birth upon hairs or feathers and free scales of skin as the parents do, and neither they nor their parents leave the body of the host except under unusual circumstances. It is only very rarely that straggling lice are found on the perches, or the roosting places on seaside rocks from which scores

of abundantly parasitized birds, such as cormorants, gulls or pelicans, have been frightened.

Normal migration from bird to bird occurs when in contact, among gregarious groups, or at mating from female to male, or *vice versa*, or to the fledgling birds at the time of brooding.

Upon the death of the host some of the lice wander off the cold body with little chance ever to become relocated within the three or four days in which they can live under the most favorable conditions. Many usually remain, but only to perish within ten days, firmly gripping feather barbules between their jaws. Those which could have subsisted upon the foods of their ancestors in a free range have long since passed away, and only these remain whose food and living conditions have been unchanged for so long a time that individuals having variable tastes have been bred out.

The Mallophaga are capable of living on certain hosts toward which they have developed a certain physiological fitness. The curious sensitiveness to differences in composition of host hair and feathers or skin and oil, etc., is so marked that those of our number who, in the course of a hunting trip, or in their collection, inadvertently became the temporary hosts of bird- and mammal-infesting mallophaga and anoplura found these parasites as eager to escape as we were to have them do so—or in the failure of which they died in a few hours. The real reasons for failure to live are not apparent and we conclude that it represents a particular physiological fitting in addition to the presence of the number, size and shape of claws and conformation of clinging devices or spine-hairs set at a particular angle to afford security of position on the body. If the species common to wild birds are transferred experimentally to guinea pigs, which ordinarily support two species of mallophaga, or to our common poultry, they are unable to maintain themselves even though the skin and hair, or the feathers, would seem to serve the same purpose, as food. It is likewise true that birds of prey do not fall heir to the parasites which were common to the birds or mammals upon which they prey, though to this there are occasional exceptions.

The progeny of permanent ectoparasites represent a closely inbred strain that is isolated biologically from the rest of the individuals comprising the species which it represents and with it go all the possibilities that are associated with the fixation of hereditary qualities. In a sense the relationship represents an environment that is comparable to island life. On such island the individuals pass a life that is monotonously alike whether the bird is aerial, terrestrial or aquatic.

Kellog, who has described hundreds of new species of mallophaga, asserts that the relative isolation plays a conspicuous rôle in the formation of species. He and other workers ascertained that closely related birds, whatever their geographical range, are the hosts of closely related mallophaga. Thus, the species, *Lipeurus baculus*, which occurs on the domesticated pigeon, has been collected from nineteen of the forty pigeon host-species that range through Europe, Asia, Africa, North America, Malaysia, Australia, Madagascar, and the Galapagos Islands, and that of the twelve species which occur on the domesticated

fowl four are commonly found on the reputed wild ancestor, the jungle fowl.

According to Kellog's well-sustained thesis we are led to the conclusion that the progeny of the present-day species of lice are the direct lineal descendants of the lice which began as parasites upon the ancestors of these birds and, in so far as identical species appear upon closely related birds, it implies an alteration of the bird without that of the parasite, while in other instances, on identical species of birds of wide geographical range, mallophaga have been found that exhibit either varietal or even specific differences. It follows, then, that phyletic relationship may be determined in some cases of doubtful relationship of host, by a close study of its wingless, permanent ectoparasites. In this connection it is of interest to recall that certain anthropoid apes harbor two of the three species of pediculid lice which are common to man, and that one of the anthropoids bears another species of the same genus of pediculoid louse, but which does not occur on man.

The blood-sucking lice, or Anoplura, to which the pediculid lice belong, seem to be derivable from the mallophaga from which they differ structurally and chiefly in a modification of the mandibles into piercing organs which serve to perforate the skin of the host and to make the blood available for food. The same general sensitiveness to host relationship exists as was expressed of the mallophaga. The chemical composition, as shown by the blood serum reactions, which indicate a specificity of blood, seems to be one reason why the four hundred known species are as widely distributed on the mammals and that none have been taken from birds. It aids us to understand why man and the anthropoids may have closely related forms.

Migration from parent to young and from host to host occurs as was stated of the mallophaga, and with some of the same limitations. Here, however, the individuals maintain their relation upon the host more by the form and size of their claws than by grasping mandibular structures such as occur among the mallophaga.

The frantic efforts of a vigorous host would serve to dislodge individuals less well prepared to grasp the hairs. One may well conceive that the struggle for life, the free-for-all, in the louse world was one like that in which the stronger Spartans were produced by destruction of the weaklings, and that after an extended period of such elimination a race was bred that could maintain a foothold with clasping claws that fit a hair with the nicety of a caliper. A careful examination of these clasping organs shows that they can be used upon a hair of almost definite diameter and even of a definite shape. A hair much larger than those of the accustomed host frequently would be too large even to permit the presentation of the claspers, while a hair much smaller could not be held tightly at all.

The next large group of ectoparasites which is known principally in the free state, but which has a large number of members that have undertaken to live upon other animals, as well as upon plants, are known as mites. Instead of feeding on dry plant products and dead animal products, or upon the body fluids they have undertaken to go more deeply into the body. We know them as the itch mites, mange

and scab, and while some of our number may confess an unfamiliarity with either of these it is more than likely that we may have undertaken unwittingly to raise another variety that grows in the skin of the face, and is referred to as the face mite, or demodex.

I shall not undertake to detail the steps by which the free-living forms, in four instances, may be traced more or less definitely to a parasitic condition. We may readily understand that a mite that served as an active scavenger might maintain the habit, and by its continuance upon an animal could readily find a supply of dead skin, hairs and oils, and without the necessity of any unusual power of locomotion could become the itch mite that burrows into the skin. Imbedded as it is, in the epidermis—as of human itch—it is removed from ready access to air, to a degree that respiration is practically impossible.

Within the bodies of our poultry we find an interesting, relatively large mite that lives and thrives in the lungs, tracheae and the air-sacks of the bird. Their life is rather unusual in that they are able to migrate about the tissues of the host, or even out of the mouth without apparent inconvenience. They are taken in with the food of the bird. The parasites feed upon the tissues of the host and give birth to living young, thus reducing to a minimum the hazards to which many of the other forms are subject.

Experiments to determine the power of mites to carry on respiration yield rather negative results, and it is held that many of these which imbed themselves in the body of the host are able to secure sufficient oxygen from the tissues to maintain their bodily activities. In an attempt to determine whether the total exclusion of air would have an effect upon the organism I mixed in vaseline several hundred of the feather-eating analgesid mites that were secured from a dead ostrich, and compared their activities with control specimens that had migrated from the body of the host to form a dense mass about the ocular of a microscope and the neck and shoulder of a bottle that stood upon the laboratory tables upon which the dissection of their host had occurred. At the close of the tenth day about half of the number were still struggling in an effort to creep out of the vaseline and in the course of the next two days the movements ceased completely. The last of the individuals that were not imbedded in vaseline died within fourteen days after their migration from the host. It would appear that the earlier death of the last individuals, by so much as two days, was due more to the exhaustion of the parasites in an effort to escape from the vaseline than to the complete exclusion of air. Therefore, if species of external mites which live normally in the air are so little affected by complete exclusion of air the effect must be less marked upon those which burrow deeply into the tissues and out of reach of free air. The tracheal respiratory organs are reduced or missing, among mites.

The face mites, demodecidae, seem quite thoroughly adapted to live imbedded in the oily secretions in and about the minute hairs of the face of several mammals, and even of man. Here they feed upon the sebaceous secretion, and I have observed instances in which they seem to have chewed the hair bulbs with their mandibulate jaws. To suggest that a person might unintentionally harbor parasites, whatever

the kind, is to invite as vehement a denial as though he were charged with the act of receiving stolen goods. The interest and surprise are even greater when I suggest to you that one-fourth of the faces here have these elongate, six- or eight-legged mites in the pores over the nose, at the side of the nose, and in the furrow between the lower lip and chin, if I may judge from a twenty-eight per cent and a thirty-three-and-one-third per cent infestation in two classes of my students in parasitology.

The face mites are barely able to move about by means of their short, chubby legs. When not in the sebaceous secretion of the hair follicles, therefore, how do they migrate? How do they find a new host? More forceful than the question, "How might they spread from myself to others?" is the one, "How did they spread from others to me?" The substance which one might press out of the skin as a "comedone" or a "blackhead" is not either a worm or a mite, but in that material they may be found in numbers ranging from a single individual to several, if a person is infested. I have found as many as one hundred in a single follicle from a dog infested with follicular mange. It is possible to expel the mites by pressure or by friction applied to these regions of the face, and it is not beyond the realm of the possible that the friction, as of wiping the face with a towel, may serve to dislodge specimens from the pores, or to pick up others that were in the act of migrating from pore to pore over the surface of the face, and thus to my own face, if I chanced to use a towel previously used by an infested person.

A heavily chitinized cuticle, which covers the whole body of the face mite, makes it possible to withstand dessication, or even the effects, for several minutes, of a ten per cent solution of caustic potash, before it is killed. I have observed a mature specimen, while lying on its back in a ten per cent solution of potassium hydrate, to move its four pairs of legs with the rhythm that suggested the co-operative action of the members of a crew of an eight-oared boat.

A brief reference to the parasitic worms will serve to indicate that the hazards of life are such that, in spite of the enormous number of eggs and young, the total number of adult forms does not increase markedly from year to year. It is estimated that *Taenia saginata*, the tapeworm which man may acquire by eating infested rare beef, is capable of producing one hundred and fifty million eggs in a single year; that a liver fluke produces one hundred thousand eggs in its lifetime; and so the numbers might be multiplied at length to indicate that these, and other parasites, must meet handicaps that do not occur in the life of larger animals with which we are more familiar.

The intestinal worms, which by rare chance find their way into the digestive tract of any host, are plunged into digestive ferments that would digest materials like those of the parasite, and in fact this does occur if chance brings them into some animal with a more vigorous digestion, as, for example the introduction of hog lung-worms into the digestive tract of a rat, where a large number are digested. The experimental work of Birge and Birge of the University of Illinois throws some light upon the question of the non-digestion of such forms as

tapeworms, and round-worms, ascarids, which occur in the digestive tract of dogs. The digestive juices were extracted from the pancreas of a dog; they were properly activated and kept in containers maintained at the temperature of a dog's body. Live worms that were taken from dogs were unaffected by the fluid, but if worms were added after first killing one-half, or one-third or the whole of the body by passing a strong electric current through it, only such killed portions were digested, the balance remaining active. What could be the assignable reason? To say it occurred "because they were alive" was not a solution, but when a section of the tubular body of the ascarid, which is scarcely the diameter of the quill of a chicken feather, was slipped over a small porous cup coated with platinum black and filled with hydrogen peroxide, such dead portion was not digested by the digestive fluids. Thus we are led to the conclusion that so long as the tissues are saturated with oxygen or that an oxidizing substance is available the digestive enzymes are broken down and are rendered ineffective. It is believed that the body of the live worms produces materials that oxidize the digestive enzymes as effectively as was done by the platinum black and the hydrogen peroxide, in the experiment that has been quoted.

The progeny of the intestinal worms are discharged by way of the digestive tract of the host, either in the form of eggs that hatch in the soil, or only after being eaten by a new host, or they may be in an advanced stage of development when they pass out of the host. In the moist soil they may live and move with almost the same ease as the free-living forms with which they mingle. Here they may remain alive for long periods, whether they remain moist or wholly dried, some to force their way through the skin into the body of the host and finally into the digestive tract, as the hookworms of dogs and cats, or of man; others to be taken up by hogs, and after a devious course to reach the digestive tract or lungs and there to become adults and in turn to discharge other thousands of eggs.

If time permitted one might outline, in a similar manner, the mode of life and adaptations of the parasitic protozoa, the one-celled animals, to show how they also encounter hazards that relate to food, temperature and dispersal, to each of which the parasite must become adjusted in the period of transition from a free-living state to that in which it depends solely upon a host or a series of hosts for its existence.

The problems of life of the successful parasites, whatever their kinds, are numerous and critical, but each, in its free-for-all struggle, survives if it is resistant, and leaves progeny that resemble it, or it fails in the struggle and thus passes out of existence. It has had its thousandth of a chance, or a ten-thousandth of a chance or less, and failed, while some other competitor, only slightly better fitted for the conditions, will survive and perpetuate its heritage.

Purdue University.