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ANIMAL PARASITES OF MAN AND THEIR CONTROL[1]

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SOME years ago a party of travelers lost its way on a by-road down South, coming finally to a cross-roads store. Against one corner leaned a lethargic, malaria-ridden cracker, meditating over the chewing of a straw. The driver of the automobile hailed him, "Is that the highway yonder?" "I don't know." "Where does the road go at the fork ahead?" "I don't know." "You don't know much, do you?" "No, I don't know much, but I'm not lost." That is our position to-day with reference to the animal parasites of man. Their tremendous number and fecundity, the mystery of their origin, our lack of specific or any treatment in many cases, our defective knowledge of their natural history, our ineffective methods of control, our feeble prognosis of their future relations to man—these things make us humble in the face of this great broadcast system of parasitism. It is worthy of study for three reasons: because of pure academic interest, because of the clinical and public health need of control, and because in it is written the foundation of human history.

Parasitism is a term coming down from the ancient Greek days of parasites—sharers of the feast, or messmates, to whom no stigma attached, or reproach or contempt. Religious parasites were attached as assistants to the priests to collect the corn dues from farmers on the temple lands or from other sources. It was their province to provide food for temple visitors, to care for certain offerings and to arrange the sacrificial banquets. On the other hand, civil parasites were persons who received invitations to

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dine in the prytaneum as distinguished from those who had the right to dine there *ex officio*. (The prytaneum was the official and religious center of the community.) Much later, the term parasite evolved to mean a person who would submit to any indignity or humiliation in order to obtain a good dinner, in other words, a "sponger." Plautus describes such parasites in his comedies. Alciphron and Athenaeus detail the various insults they endured from hosts and guests alike. Some of these parasites became professional jesters, like the court fools and buffoons of a later age. Some relied on flattery to secure free feasts. Others practiced various degrading vices to achieve their end.

The evolution of the word "parasite" more than suggests the story of the evolution of parasitism as used in biology. In each case the species begins with a free-living form, independent and with diversity and good development of functions. By natural accident, these free-living forms were placed in temporary close relationship with potential hosts. Some few sacrificed independence, locomotion, individual defense and various special senses (moral or physical), in order to secure an abundant food supply and protection. This led to a one-sided development of adaptation or sycophancy, with a stimulation of reproduction and simplification of structure and function. In the end, in each case, we find a parasite incapable of existence aside from its host, and so modified by adaptation to its host that little resemblance remains to its free-living ancestors. Thus we consider as parasites such animal organisms as live upon, within or at the expense of other animal organisms. Parasitism means the relationship obtaining between the parasite and its host.

Origin and Evolution of Parasitism

Chiefly for want of a better thesis, it is commonly assumed that the animal parasites of man originated from free-living forms. For each parasitic form there is a considerable and often very large number of closely related free-living forms. There is no such thing as a group or class of parasites since almost every animal group contains actual or potential parasites. Fantham says that parasitism, biologically, is in no sense a matter of structure, but is very definitely a manner of existence. It is a habit which theoretically may be assumed by almost any living organism.

The usually accepted mode of parasitic evolution assumes that free-living forms of animals are older than parasitic forms, since free-living forms must have been in existence before they could find hosts to parasitize. This is almost a paranoid type of argument because it may well prove to be founded on a false hypothesis. No one ever saw a free-living animal change into a parasitic form. The pure theory of mutation of species has proved a serious stumbling block in general evolution and is just as great an obstacle in the evolution of parasitism. We *know* absolutely nothing as to the real origin of parasitism and processes of change which we observe in fleeting glimpses may be proceeding either forward or backward. It is possible to change the habits of a free-living animal so that it adapts itself to a variable degree to a host in a parasitic relation. It is also possible to take a parasitic form and train or adapt it to a more or less independent free-living form. Which is the archetype? We do not know. We assume and infer, and our *method* is correct because we plant a germ of observation and out of it grows stalk and leaf of hypothesis, and then the blossom of full-grown theory, and a promise eventually of obtaining a modicum of fruitful truth. So that while we must theorize, it must be with the effort to improve the theory with wider and keener observation and experiment, realizing that the final truth is far off and possibly very different from the ideas we entertain en route toward it.

Having assumed that animal parasites originated from free-living archetypes, we are next confronted with the difficulties of the general evolution theory itself. Three major types of general evolution have been advanced and each of these offers interesting and self-evident bearings on the problem of the evolution of animal parasites. First of these is the Darwinian theory of mutation through continuous and long-continued variation. The second theory of DeVries considers species to have arisen through sudden and irregular mutation as environmental circumstances for a time became favorable to such changes. The third theory has recently been propounded by the Dutch botanist, J. P. Lotsy, who believes that new species have arisen by crossing of dissimilar parents. Lotsy insists, in spite of the plausibility of the mutation theories, that it has never been really proved that a new species arose in this manner. The only new forms produced experimentally, have been a result of hybridization. He considers it quite possible that the main divisions of organic life originated from hybridization. A fourth theory from a completely new view-point challenges attention for its novelty, close-knit argument and the unique application to biology of the present-day knowledge of atomic physics. Those interested should read the recent volume entitled "What is Life?" by Dr. Augusta Gaskell, and the thought-provoking introduction by Raymond Pearl. Dr. Gaskell applies the principles of atomic physics to the problem of the origin and nature of life. It is her contention that species may arise *de novo*. Her argument raises many interesting questions in connection with the development of parasitism.

It is usually believed that external or ecto-parasitism evolved before endo-parasitism, the reason being that the change from free-living to ecto-parasitic existence seems less radical and abrupt than the change to endo-parasitic existence. For instance, some more occasional or partial parasites took their human host solely at mealtime as in the case of the leech (Hirudo) and the bedbug (Cimex). This is more a predatory relation and is much less difficult to establish than the relation necessary for a parasite in the intestine or the blood stream. The parasitic habit seems to have arisen separately and independently in most large groups of animals and therefore might be considered of rather common occurrence in the course of general evolution. This is shown by the presence of free-living as well as parasitic types in most large animal groups.

We must consider that, in general, parasites belong to animal groups more primitive than their hosts, that is, to groups of a less specialized and less highly developed type. In the case of protozoa, the rule still holds because protozoa are parasitized by plant organisms. Some ecto-parasites are not limited to one species of host. Others are so limited and some even to a single part of the host's body. These types are assumed to be evolutionary stages of ecto-parasitism. The most primitive stage is probably where the ecto-parasite is able to migrate from one species of host to another. With more specialization it becomes limited to a single host species, and finally to a single part of that host.

The relation of ecto-parasites to endo-parasites affords much food for speculation. Many believe that symbiosis and commensalism lead to parasitism. For instance, an organism that takes its meals in a state of mutualism with another organism, may easily become a food robber, and then a parasite. Or again, symbiotic relations may be disturbed so that one organism gradually becomes pathogenic for the other. Such a situation would help explain the moot question of pathogenicity of *Entamoeba coli,* for example. In general we assume that endo-parasitism arose (1) from ecto-parasitism, (2) from commensalism, or (3) from symbiosis. An endo-parasite restricted to one species of host is probably no older in race than its host and changes in the parasite have probably been coincident with changes in the host. An endo-parasite found in several species of hosts probably is older racially than these hosts, and has adapted itself to hosts which evolved after its parasitic habit was established.

Faust has introduced the logically correct term "guest," for a parasite in relation to its host. In the case of helminths, he suggests that the relation was first one of chance contact only, whereby a free-living guest was carried from one feeding ground to another. Sooner or later the guest began to use food procured by the host, and gradually became more and more dependent on such food Some of the guests then began to consume the tissues or juices of the host itself, either by use of suctorial organs or by actual penetration of and residence in the host's tissues. This resulted in a very degenerate and dependent parasite. Forms living in the blood or lymph, such as filaria and blood flukes—in the muscles, such as trichina—or in the pleura and peritoneum, such as hydatids—are usually most highly modified or adapted and may therefore be considered the oldest parasitic species. Other forms living in the mouth, bladder and other epitheliated organs, or as ecto-parasites on the skin, are frequently very young in parasitism. This is demonstrated by their relatively slight modification from the archetypes of the group and from related free-living forms. It often happens that the adult parasite undergoes only slight modification, while the larva, or intermediate form, is highly modified.

Greater length or age of parasitism means greater modification away from the archetype of the species. This means practically greater simplification of the parasite. Change of environment from a free-living existence to one of abundant and assured food supply, and increased protection against enemies, leads to atrophy of certain functions and structures. This is not degeneracy, but evolution; not retrogression, but orderly change. Herein, perhaps, lies a warning to the advocate of return to a so-called simple life. The simple life connotes protection and a free-lunch counter. The result is social parasitism.

Faust states that simplification, which is synonymous with adaptation, is illustrated in the helminths by reduction in organs of locomotion, except in free-living larval stages. An even more radical reduction takes place in the organs of alimentation. In tapeworms, for example, the digestive tract has entirely disappeared except for possible vestiges in early larval stages. The integument has been simplified to afford protection against digestion and abrasion by the intestinal contents, and to permit attachment to the intestinal wall by suckers, hooks or by penetration. On the other hand, the reproductive system has increased enormously and this makes a serious public health problem. The nervous and excretory systems have suffered little change. There is a striking contrast between the influence of an easy life on reproductivity in parasites and most of the animal kingdom, and in man. In man it is as Adam Smith said, "Poverty seems favorable to generation. But poverty, though it does not prevent generation, is extremely unfavorable to the rearing of children."

As we approach the problem of the host in relation to the parasite, it seems probable that parasites using intermediate hosts have evolved from parasites having but one host. At first, the parasite would have merely tolerated the second host, then would have adapted itself to the second host, and finally established itself in some stage in the second host. Nature provides numerous examples of the entrance of exogenous stages of parasites into other animals and therefore abundant opportunity exists for parasitism to develop and for intermediate hosts to enter the cycle. Adaptations often of unusual nature are necessary to permit the parasite in its larval or oval form to reach the intermediate host. This is nicely portrayed in the life cycle of the guinea worm, of flukes and of hookworm.

The problem of intermediate hosts is far from settled. R. Leuckardt believed that the present intermediate hosts were the original or primitive hosts both for larval and adult forms. Parasites then gradually differentiated and developed into later and more numerous stages, which in turn gradually sought out new definitive hosts. The earlier stages remained in the original hosts, now called intermediate hosts. This theory at once meets with objections.

On the contrary, R. Moniez considers the present definitive hosts to have been the original ones, and that ascaris, trichinella and enterobius, for instance, have continued this primitive relationship. In most other cases embryos, which were potential parasites, were unable to resist or endure the chemical and mechanical influences of the intestinal tube. They therefore left the intestine by penetrating its walls and burrowing through into the tissues of their carriers or the primitive hosts. Here they could attain a fair degree of development, but were mechanically prevented from returning to the intestine where their eggs could be deposited. Most of them died out as parasites, just as their young stages do now if they reach a wrong host. Nevertheless some of them passively were carried into the intestinal tract of beasts of prey. Many perished in the process of digestion, but a few reached the intestine undamaged. These grew, became more resistant and developed into adult forms. Gradually this process became established by heredity, and became usual and normal. This is an attractive theory and has in it much to commend.

Under unusual or special conditions parasites may invade unusual hosts. They then tend to aberrant locations and are often very dangerous, as shown by *Cysticercus cellulosae,* for instance. A common example is also seen in the so-called larva migrans, or creeping eruption, due to larvae of non-human nematodes, such as the dog hookworm, penetrating human skin and crawling about in the subcutaneous tissue. It is possible that *Loa loa* may represent a similar condition.

In general, true or strict parasites have specific hosts. The great exception to this rule is *Trichina,* which is found in man, pig, bear, rat, mouse, cat, fox, badger, skunk and marten, and can be artificially cultivated in the dog, rabbit, sheep, horse, other mammals and in birds. Intestinal and ecto-parasites are usually less dangerous than blood and tissue parasites. The origin of host-parasite specificity is the same as the evolution of parasitism.

Faust emphasizes that, as a host, man, like other animals, suffers more from parasites if they are relatively new to him. Long acquaintance brings tolerance, here as everywhere. In fact, we might well paraphrase the insight of Pope's famous lines in his "Essay on Man," and say:

> Parasites are monsters of so frightful mien,
> As to be hated, need but to be seen;
> Yet seen too oft, familiar with their face,
> We first endure, then pity, then embrace.

Negroes are less disturbed than whites by intestinal worms. Chinese are commonly little affected by clonorchis. The Asiatic child is less upset by ascaris. Perfect adaptation of parasite to host means a complete absence of symptoms. This principle is seen clinically illustrated in the case of infection with *Entamoeba histolytica.* If the parasite is poorly or badly adapted, symptoms arise. Millenniums of association in the host-parasite relation definitely seem to decrease pathogenicity. This gradual racial immunity has many counterparts in clinical parasitology. Even California fleas prefer the fresh blood of newcomers. We have no answer, as yet, to the question as to why insects exercise a selectivity at times in the individuals they select as donors for transfusion. Yet such selectivity exists at least in the case of fleas, bedbugs, mosquitoes and sandflies.

Enough has been said to indicate the extreme complexity of the world of animal parasites. With so little definite information on the subject of the origin and evolution of parasites, we are forced to base practical measures of control on studies of parasitism as it exists to-day. Certain features of parasitism are of special interest, therefore, when we come to consider the principles on which specific control may be based.

HOST-PARASITE RELATION

Granting a condition of parasitism, the optimum habitat for the parasite is provided when there is the least possible or no damage to the host. The host-parasite relation must be considered as a finely adjusted balance of biology, in which the parasite must preserve itself and perpetuate its race, and in which the host must not be sufficiently irritated or damaged to react in such a way as to prevent achievement of these two objects by the parasite. This is illustrated with nicety in the case of *E. histolytica* in relation to its host.

For infection of the host, it is necessary that host and parasite have the same geographic distribution, the habits of the host must bring it in relation with the infective stage of the parasite, and the infective stage in the life cycle of the parasite must be reached at the precise time the host is available to be parasitized. Numerous remarkable adaptations occur as a result of the need of meeting these requirements. Some of these can be indicated as follows:

1. Guinea worm—Cyclops—ingested by man.
2. *Leishmania* and *Loa* in skin (Sandfly and *Chrysops*).
3. Leeches (*Hirudinei*). *Limnatis nilotica* in drinking water, lodges in nose and pharynx. (See Alfred Russell Wallace and Loos, *Haemadipsa* species.)
4. *E. histolytica*—cysts to exterior—to new host.
5. Hookworm—intermediate cycle.

It has been mentioned that parasitology has a contribution to make to the prehistoric record of man. This is illustrated by a type of reasoning first developed by von Jhering in 1902.[2] In the case of parasitic worms von Jhering argues that if the same or nearly the same species of worm parasitizes two or more species of hosts, then the hosts descend from a common ancestor. The similarity of the helminth parasites indicates their origin also from a common ancestor. Thus, apparently, the different species of hosts involved all descended from a primitive ancestor which was parasitized by the original ancestral parasite.

Zschokke has applied a similar argument to the distribution of certain cestodes in marsupials. He also claims that the original home of the salmon is in the salt ocean because the larger proportion of its endoparasites are marine. Thus the path of salmon migration and its breeding grounds are no index as to whence it came. Zschokke says, "Each parasite fauna comes to be to some extent a mirror-image of the biology of the host, of the host's habits of life, and especially of the host's relations to those creatures that share the habitat with it. Each change of nourishment and residence of an animal finds its echo in the changes in the helminthic condition."

Metcalf has discussed the distribution of the family *Leptodactylidae*. These are frogs characteristic of tropical and sub-tropical America, and also of Australia and Tasmania. They have been reported from no other parts of the world. Only two explanations of this distribution are possible. (1) Assumption of an earlier land bridge across Antarctica, connecting South America with the Tasmanian-Australian plateau. (2) Convergent or parallel evolution. This frog family harbors an opalinid rectal parasite of the genus *Zelleriella* which is present in both geographic groups of frogs. So nearly alike are these opalinids that their species separation is most difficult. It is possible that either the frogs or the opalinids arose by parallel or convergent evolution. But it seems utterly impossible that *both* frogs and opalinids developed such a similarity in the two geographic areas. Therefore we must assume a primeval land bridge.

Kellogg has applied this reasoning to bird lice, Johnston to trematodes and cestodes. Darling studied the migrations of the human race from data on hookworm distribution. The method is valid and opens the way for much valuable new work on human geography and evolution. This is especially hopeful because parasites include the latest known examples of biologic evolution (Metchnikoff).

The principles of parasite control are to-day too specialized, varied, empirical and ineffective because of insufficient data in certain definite lines. These are chiefly: (1) Data on evolutionary development and individual life stages as influenced by external factors. (2) Distribution of parasites and extent to which they can and do enter other hosts than the principal one. (3) The extent to which behavior of parasite and of host influences or determines specific relations between the two (Hegner). (4) The factors in the host which favor invasion and establishment of so-called natural parasites and obstruct similar entry and establishment of foreign parasites (Hegner). (5) Reasons for laboratory, experimental and accidental infections in foreign hosts (Hegner). (6) Understanding of immunity and susceptibility in hosts, racially, from heredity, difference between individual hosts of same species, and between young and adult hosts. (7) The reactions between host and parasite which terminate an infection or cause latency

[2] See Hegner, Root and Augustine.

or relapse. Better data on these points will greatly improve methods of control.

The extremely small number of infective forms which reach a new host necessitate an enormous fecundity in parasites. Transfer to new hosts may be purely passive, by contaminated food or drink, by direct contagion, by inoculation, or may be pre-natal. *Therefore simple sanitary measures are usually sufficient to prevent individual infection.*

Before taking up the specific problem of parasite control it will round out the entire subject to review, briefly, current ideas on the antiquity of animal parasites, especially helminths, in man. Faust states that parasitism was well established before the dawn of human history. All the common species of human parasites are much older than the genus man. This statement is based on the following considerations: (1) Many infections of man are also common in animals, and man is only incidentally or accidentally infected. (2) Some infections are decidedly pathogenic for man but not for other animals. (3) Many parasites which now use two or more hosts, including man, probably originally used only one host, the one in which their larval stages now appear. (4) Certain groups of parasites of man and other mammals have a similar or identical morphology but widely different physiologic processes. This indicates that the parasite has been established in man long enough to have acquired a relatively fixed adaptation. (5) Strongylus, for example, is a fairly recent parasite of man because its free-living stages, which are reproductive, can probably continue indefinitely outside the human host. Hookworm has a much longer parasitic history, while ascaris, trichocephalus and enterobius are extremely old in parasitism and their entire life history is carried on in man. Parasites of the blood and lymph are the oldest of all and have undergone much more profound adaptations, especially in physiology.

The ancient story of parasitism is nicely summarized by Faust. Long before the dawn of history, at least 100,000 years ago, hunters of wild oxen and boars became infected with tapeworms, ascaris and trichina. Primitive fishermen, eating raw fish, acquired *Diphyllo bothrium* and the liver fluke. Herdsmen were infected with hydatids from sheep and dogs. Guinea worm infection and filaria have a similar antiquity. As man settled down and began to till the soil, he came in closer contact with his own race and bad hygiene exposed him to fecal contamination. Hookworm, strongylus, ascaris and tricocephalus became endemic. In the great valleys of the Nile and Yangtze, fishermen and farmers wading in stagnant water were infected with schistosomes. Man's associate, the rat, conveyed hymenolepis, and became a reservoir for trichina, while the dog flea conveyed dipylidium. Thus at the dawn of history, helminth infection at least was distributed through the inhabited world, but more intensely through the tropics.

Vesical schistosomes have been found in Egyptian mummies of the 13th century B. C. Moses separated clean from unclean animals on the basis of their visible infection with parasites. This was especially so in the case of goats and kids offered for sacrifice and later eaten. Syrian goats are heavily infected with *Fasciola hepatica* and persons eating infected raw livers get a disease called "halzoon," or pharyngeal fascioliasis. All scavenger birds and beasts were prohibited as food, including hogs, camels, birds of prey, reptiles, snails and others. They were prohibited because their flesh was infected with parasites. All animals not on the prohibited list, whose flesh was found infected, were to be burned. Moses warned against infected water, containing cyclops and cercariae. He taught the people by his brazen images of the fiery serpents how to extract the guinea worm. Later the people were instructed to drink water from their hands instead of lapping it up, possibly to avoid leeches. Many references record the acquaintance of the ancients with animal parasites.

CONTROL OF ANIMAL PARASITES

Nearly every group of fauna has in it parasitic species. From the social point of view, this is also eminently true for man himself and brings up the whole field of social human parasitism which has been very insufficiently studied from the biologic point of view and from the standpoint of human geography. In the phyla of the animal kingdom, some have only a few parasitic forms, but three phyla contain a large number, in fact, a majority of animal parasites. These are the protozoa, arthropoda and several phyla of worms.

The general principles on which control must be based have already been discussed. It remains to consider broadly the large parasite groups, commenting on control methods in relation to each. We deal with Worms, Protozoa and Arthropods.

I. WORMS: The spread of helminths requires the presence of proper intermediate hosts, of suitable climate and moisture, available definitive hosts, and proper interrelations between these and the general environment.

The spread of helminths is determined largely by certain factors which are more or less subject to human control and which therefore offer the practical points of attack on the problem.

1. *Food:* Faust gives many examples of the importance of the type of local native food. Thus the Chinese and Hindus thoroughly cook most of their food, which is largely eaten hot. (Note also the importance of the tea habit.) However, in China and India some cooked food stands in stalls and restaurants, covered with flies and dust, and exposed to domestic animals, roaches and vermin. To all this the people are oblivious, since they completely lack a sanitary sense. We see analogous food exposure in nearly all countries: in Italy and France, the bread; in England, the milk; in the United States, berries, vegetables, fruits and salads are often exposed to flies, dust, expectoration, dogs, cats, rats and mice, etc. In the orient and most of the tropics, all foods raised in the ground are invariably contaminated. Many are kept fresh in the bazaars by sprinkling with dirty water applied by whisks or blown by the mouth. In China, water chestnuts, the gigantic Chinese radishes, lotus roots and bamboo shoots are eaten raw. From Egypt to Iraq sticky sweetmeats, drowned in flies and dust, are consumed by rich and poor alike. Sugar-cane sections are kept fresh in dirty water. China gives a hypo of dirty water to oranges beginning to wither, just as she soaks melons and cucumbers in dirty water after tapping their skins with stiff bristle brushes, and then sells them honestly by weight. Fresh berries, celery, lettuce and other salad plants are anathema in the tropics, yet the plain laws of common-sense and sanitary sense are ignored by native and foreigner alike.

Chinese and Indians eat the water ling and chestnut by peeling off the outer petals with their teeth, and become infected with the cysts of *Fasciolopsis buski*. In China and Formosa, the same result follows eating certain raw grasses. It is common knowledge among the farmers of central China, where *Fasciolopsis* is abundant, that hogs raised in the courtyard escape it, while those raised on the hillside get it. Yet the farmers do nothing whatever about it. The situation reminds one of our own ignoring of well-known sanitary facts in sewage disposal on the farm, as well as in garbage disposal in the city.

In general the Chinese do not eat raw fish and arthropods as do their neighbors around the China Sea, but in some parts they eat large quantities of dried fish. Raw fish and arthropods spread flukes, especially metagonimus, clonorchis and paragonimus, broadcast in Japan, Formosa, Korea and Tonkin. In the wetter parts of China, clonorchis and metagonimus are found in cats and dogs. Several central provinces of China, especially Fukien, Kiangsi and Hunan, have paragonimus infection in tigers, panthers and wild cats, just as in Korea, Siam and Assam. Attention must be drawn also, in connection with food as a spreader of parasites, to the importance of the dirty fingers or utensils with which the food is eaten. The chopsticks of eastern Asia are more sanitary than the vilely contaminated fingers of Mongolia, the Near East and Arabic countries.

2. *Water,* as a means of transfer of helminths, is never safe in the orient or tropics, and often unsafe elsewhere. Examples of water transfer are seen in the cercariae of various flukes and the larvae of the guinea worm.

3. *Nightsoil* is perhaps the chief potential source of human helminth infections. In the orient and tropics nightsoil is universally used as a fertilizer for the fields. The sights and smells of this traffic beset the landscape and offend the senses in city and country alike. By this means virulent bacteria and numerous parasites are propagated and broadcast over the land. Not only are the farmers and coolies subject to infection, but field produce, vegetables, fruits and melons, are all grossly contaminated and carry contagion to those who eat and drink without thought for the morrow. The use of nightsoil as fertilizer is a logical and economical system. In the West the form of fixed nitrogen most valuable for plant use is entirely wasted by our wasteful and short-sighted conservancy methods. The Chinese method is effective, saving, logical, but unesthetic and disease-breeding. Parasite control must go hand in hand with good economics and a reasonable degree of esthetics.

4. *Migration and Travel:* Negro slaves from Mozambique and the Gold Coast probably brought hookworm and Manson's schistosome to America. The former needed no adaptation and the latter found *Planorbis* snails awaiting it as intermediate hosts. The fish-tapeworm was carried to Switzerland a thousand years ago by Swedish emigrants and to the United States and Canada by Scandinavian emigration. Wherever Islam spreads, *Taenia solium* disappears and *Taenia saginata* becomes endemic. Travel and migration are of great importance in spreading all parasites. Conversely, parasites are important in diverting or causing emigration. In the seventh century the Moslem invasion of North Africa did not cross the Sahara because all livestock was inoculated with trypanosomes by the tsetse fly at the southern borders of the desert.

5. *Influence of racial and local habits,* food customs, manner of eating, bathing, clothing, housing, conservancy, occupation and religion. These things all have an important bearing on helminth spread and practical means of control.

6. Spread of helminths depends to a considerable

degree on the presence of vectors and proper intermediate hosts. Plants may act as vectors as where they harbor encysted fluke larvae, and where heavy fleshy roots are parasitized by plant nematodes and then eaten by man. Invertebrate intermediate hosts belong to the two large phyla of molluscs and arthropods. Vertebrate intermediate hosts include fish, reptiles, amphibians and occasionally birds and mammals.

The public health aspect of parasite control is highly important. Carriers, either as intermediate hosts or as simple vectors, with or without symptoms, must be prevented from introducing parasites to new hosts. Studies of reservoir hosts need to be pushed. Human parasites in animals are important and little is known about them. A helminth can easily become epidemic in an area because of massive dosage or unusually favoring climatic conditions. Generally helminth infection is endemic and when once established with intermediate hosts, if needed, constitutes a vicious circle extremely difficult to break. One must search for the weakest point locally in the life cycle, with considerable knowledge of the evolution and biology of the parasite, in order to decide the most amenable point of application for preventive measures. In all parasitology, prevention is vastly more important than an attempt at control by cure. Human exposure can be minimized by public education in methods of spread and manner of entry into the body, as has been done in the case of hookworm disease. Wholesale treatment of patients has its function (1) in the clinical needs of the patients themselves, and (2) more vital from the public-health view-point, in protection of intermediate hosts and vectors from infection, and in preserving water and earth from infection. Control measures therefore may be directed to the intermediate hosts as in the schistosome problem of Egypt; to protection of the intermediate host from infection, as in the prophylactic use of quinine against malaria; to protection of man from entry of the parasite, as in the case of guinea worm and numerous other parasites; to cure of the infection in man; to improved personal hygiene, sanitation and conservancy.

I. Helminth Parasites: This field is fairly familiar to medical workers and can be summarized briefly. Of the parasitic worms, we deal chiefly with the following groups: trematodes; cestodes, including hydatid; round worms, subdivided into the hookworm group including strongylus, ascaris and enterobius, and the filariae. The principles already reviewed are applied to each of these in its local setting with reference to environment both physical, biologic and social. In the case of filaria, we have to admit little progress and less knowledge. This widespread and dangerous group of worms has so far been refractory to control because of unknown factors of evolutionary development, life history, biology and psychology. The need and opportunity for new experimental work here is obvious.

II. Protozoa: Turning now to the second great parasitic group, the protozoa, we find practically every point applicable which was mentioned under the general control of parasites. These need not be repeated. The groups of protozoal parasites most important to man are as follows:

1. *Malaria:* Here it must not be forgotten that it is perhaps more important to protect the mosquito than man against malaria. If human disease is controlled there will be no transmission. If certain species of anophelines alone are controlled, others will take up their duties.

2. *Leishmania:* Here we have theoretically two methods of control, by eradication of sand-flies and by cure of patients. The former can not be done. The latter is effective on a wholesale scale.

3. *Coccidiosis:* Coccidial infection is so rare that little can be said as to its control. Probably, however, it is a late example of parasitism which longer adaptation may spread more widely and make more serious. It therefore needs detailed study to allow exact control to be instituted before it becomes a serious human parasite.

4. *Trypanosomiasis:* Space forbids even mention of the exceedingly interesting work being done in Africa on the control of trypanosomiasis. Various governmental institutes and numerous private organizations and individuals are involved and the outlook finally is hopeful. For American trypanosomiasis, or Chagas disease, not so much can be said.

5. *Rabies* is world-wide in its distribution and is rampant in the orient and all tropical countries, largely because of religious *beliefs* or indifference, which allow a large predatory and scavenging dog population. Similar factors are operative in the United States. For human purposes, control lies in dog control. This is to-day an impossibility in most countries, especially in hot latitudes. Even in the United States we are afflicted with that superparasite, highly adapted and late in evolution, the sob-sister of science, Sentimentalism. Her disguises cover Eddyites, anti-vivisectionists, maudlin animal lovers and a host of misguided ignoramuses. The total effect of all these differs only in degree from the effect of Buddhist, Hindu and animistic beliefs, so far as disease control is concerned. At present the problem of the dog population, like many another sanitary problem, is insuperable in most parts of the world. Nevertheless, Pasteur Institutes are found in every

chief city and treatments are given in wholesale numbers.

6. *Intestinal Protozoa of Man:* The principles of control have been covered under helminth control and do not need repetition.

III. ARTHROPODS AND ECTO-PARASITES: In this third heterogeneous group of animal parasites are included many familiar pests and strange histories. To some extent the principles of control we have reviewed come into account, but there is much more departure from rule in this group and greater diversity and originality in the parasite's relations to the human host. A brief note, following Ewing's text, on some of these ecto-parasites is all that time will allow.

1. *Mites* (*Acarina*): Of these there are enormous numbers of very small animals. Several million individuals may occupy a few cubic inches. They are found from northern Greenland to the Antarctic. Each group has been derived apparently from a different type of free-living ancestor. The common habit of parasitism has brought frequently similar adaptations of structure and physiology which give different racial groups a close superficial resemblance. They attack land and aquatic hosts, both vertebrate and invertebrate. Every small rodent is apt to harbor several species. Because of their range and intensity of parasitism, it is believed that parasitic species far outnumber free-living forms. In species they may even outnumber the insects. Some mites are very old in parasitism and the morphologic adaptations are profound. Such differences mark off, for example, the itch mites and the ticks.

The reasons for such frequent parasitism in the mites are to be found in their minute size, enormous abundance, wide distribution and great variety of habits in the free-living forms. Nascent parasitism is seen now in certain living forms as in *Pediculoides*, where a single species may be either a predator, a parasite or a scavenger. It may be one or all three with equal facility depending on the hazards of environment.

2. *The Ticks* (*Ixodidae*): These are a small group, numbering less than 300 species altogether. In number of individuals this is one of the largest and most important groups of all ecto-parasites. They originated from mites and even now the two groups show many structural similarities. *Spelaeorhyncus praecursor* on bats is an excellent example of an intergrade between mites and ticks and may be classified with either. They are important disease carriers, as of spotted fever, and protection against them even yet is chiefly mechanical.

3. *Biting Lice* (*Mallophaga*): These spend their entire life on the host, laying eggs on feathers or hair. They feed chiefly on the barbules of feathers, on epidermal scales and oily secretions of the skin, but at times blood is found in them. They are closely related to the sucking lice. They are characteristic on Australian marsupials, are common on nearly all birds, and are conspicuously absent from several large mammalian groups. The most ancient group of land birds (Galliformes) have the most generalized types of lice which are almost identical with those of the Australian marsupials. The marsupials probably were infected from birds, just as the domestic dog of North America got one louse (*Heterodoxus longitarsus*) from Australian marsupials.

4. *Sucking Lice* (*Anoplura*): This is one of the smallest insect orders with less than 200 species, and is confined to mammals. One family (*Haemato mysidae*) has one species only, and this is found only on elephants. Marsupials, bats and a few other groups have no sucking lice. Blood is almost the exclusive diet of the *Anoplura*. They are therefore important disease carriers, especially in relapsing fever, the typhus fevers and trench fever. Their origin is an unsolved mystery. Their mouth parts resemble those of the true bugs (*Hemiptera*). Their control lies in individual treatment primarily, with disinfection of clothing, personal cleanliness and good housing.

5. *Fleas* (*Siphonaptera*): Fleas are of perennial and especially autumnal interest in California. They are small, laterally compressed insects which are not closely related to any other order. They resemble biting lice in being found on birds and mammals. They are so highly specialized that they can not be traced back to their origin. They constitute an order of remarkable unity and can be divided into families with only partial success. The ordinary human flea is common in Europe, in parts of the Mississippi Valley and especially in California. Their life history is full of interest and their relation to plague transmission is a specialty in itself. While most genera have a favorite host they do not hesitate to bite another host. The rat flea (*Ceratophilus*) dislikes to bite men and the mouse flea does not bite man. *Ctenocephalus* of dogs and cats is not a plague carrier as it rarely bites rodents. The biologic situation in connection with plague is exceedingly complex and far from perfectly understood.

A small group of highly specialized and abnormal fleas is named chigger, jigger, chigoe or sand flea. Those which invade man are called *Tunga penetrans* or *Dermatophilus*. The female burrows under the skin, forms a cyst and lays a huge mass of eggs. Local irritation and secondary bacterial infection are often serious. It originated in South America but has been carried widely around the world. It attacks many animals, but especially, like *Pulex irritans,* in addition to man it loves the pig. Many biting insects for some strange reason associate man and the pig as hosts, possibly, however, because both have hairless bodies.

Flea control again leaves us dependent primarily on personal cleanliness of living quarters of dogs and cats, with the use of mechanical protection, including more or less effective insecticides. Flea eggs are laid on floors, in nests, dust and refuse and here they pupate. Sanitary cleanliness goes far to reducing the mass attack on man. Here, as in the case of many other animal parasites, there is need of investigation for sub-parasites to destroy the parasites. Excellent work has been done in adapting certain parasitic hymenoptera to this function and the subject is full of promise.

6. *Myiasis* is a condition in which certain fly eggs are laid in wounds or natural cavities of the body, leading to tissue invasion by the maggots and a frightfully severe course clinically. Protection against flies of these types is always important, and local treatment and removal must never be delayed.

CONCLUSION

We have reviewed in summary fashion the general field of the animal parasites of man, emphasizing the factors of origin and evolution on which adequate control must be based. We have seen how fragmentary is our knowledge and therefore how difficult effective control is under present conditions. Parasitism deserves a much more prominent place in general biology and in medical education. Research fields in urgent need of cultivation are along the following lines: (1) Study of natural enemies of parasites. (2) Economic methods of control of sanitary food supply and water provision. (3) Methods of protection of potential intermediate hosts and vectors, as well as soil and water, against infection. (4) Methods of public health control based on epidemiology and biology. (5) Development of new specific remedies. (6) Better conservancy methods in rural, tropical and oriental districts. (7) Popular education, not in parasitology, but in health preservation by avoidance of specific hazards.

Our review has been in general terms. No field, however, offers greater fascination and promise for the student and the research worker. The sociologist and economist also might well devote serious study to parasite and disease control in the world as a whole, because the irrepressible tide of nationalism all over the world is rejecting foreign ideals and ideas along with foreign domination. And in the tropical and oriental countries which contain most of the world's population, a sanitary sense is distinctly a foreign ideal.

NOTE: The texts of Hegner, Faust and Ewing have been drawn on freely in order to build up a general picture of animal parasitism. The purpose has not been to present original work or ideas but to furnish a survey of the field, and to orient the student and technician. For this reason, annotations have been largely eliminated and the authors noted, as well as others mentioned in the text, have been quoted extensively. See Hegner and Andrews, "Problems and Methods of Research in Protozoology"; Hegner, Root and Augustine, "Animal Parasitology"; Ewing, "Manual of External Parasites"; Faust, "Human Helminthology"; Reed, "Tropical Diseases in the United States."

OBITUARY

GEORGE McLANE WOOD

GEORGE MCLANE WOOD, formerly editor of the United States Geological Survey, died in Washington October 26, in his eighty-first year. Mr. Wood was born in Cumberland, Maryland, but spent most of his long and useful life in Washington. He was the son of Colonel William P. Wood, who was superintendent of the Old Capitol Prison during the Civil War and organizer of the United States Secret Service. One of his brothers was the late Samuel A. Wood, for many years the well-known shipping reporter on the New York *Sun*. Mr. Wood had a public school education, but beyond that the knowledge that served him so well was self-acquired. He was an eager student to the end of his life, delving into many subjects that appealed to him—geology in all its branches, languages, philosophy, botany, and particularly the art of expression in clear, terse, forceful English. Beginning at about his eighteenth year, he did stenographic work for private concerns and the government and was regarded as one of the best and most accurate shorthand writers in the city. For a few years he was secretary to the Chesapeake and Potomac Telephone Company. His life work, however, was done in the United States Geological Survey, of which he was a member for nearly forty years.

In his stenographic work he had already developed