what upset by the presence of a stranger. Sick animals that are lying down should never be made to get up just to see how they look. Animals with fever lose strength rapidly even when they are kept quiet. Exercise increases the rate of loss of strength and is harmful. A mild febrile disease may soon become serious if the sick animal is forced to exercise.

The owner or handler should pay close attention to any sick animal that is placed in strange quarters or held under unusual circumstances. Cattle or horses (and other livestock, to some extent) may become quite nervous if their usual routine is changed. Isolating them from the herd or flock is often disquieting. Every effort should be made to prevent or overcome the unrest that may come from such changes.

Sometimes placing a companion animal in an adjoining stall or paddock is a good solution to the problem. If the restlessness is marked and cannot be overcome, it may be advisable to put the sick animal back in its original pasture or quarters.

When owners of livestock realize the full importance of adequate supporting treatment of their sick animals, the results of direct therapy will be far more effective. Good animal husbandry will do much to hasten the recovery and reduce the losses from animal disease. In itself, it will effect no cures but it will give the ailing animal the best chance for recovery in response to therapy.

B. T. Simms is the director of livestock research, Agricultural Research Service.

Special Principles of Parasite Control

AUREL O. FOSTER

PARASITES and parasitic diseases are of a nature that sets them apart and is the basis of special principles that determine and explain the measures used to control them.

Animal parasites are a universal hazard to livestock production, although individual species are limited in distribution and intensity by a sensitive adjustment to climate (and other factors) and by the kinds of animals in which they develop.

They are abundant in numbers and kinds and are chiefly injurious because of the inapparent, unrecognized loss from subclinical parasitism. They are, then, especially dangerous because of their insidious and unspectacular effects despite the fact that they are generally better known for their ability to cause disease and death in livestock.

They are also commonly injurious to their hosts in a quantitative way. In most instances, as in the case of almost all the parasitic worms, or helminths, they do not multiply in or on affected animals. Even in protozoan and arthropod parasites (the major groups other than helminths), the individual cycles of development within the host animals are so limited, fixed, and finite that, despite multiplication in and on their hosts, the damaging effects generally are directly correlated with degree of exposure and magnitude of infection—which cannot be said exactly of exposure or infection involving bacteria, viruses, and other disease-causing organisms.

Parasitism is essentially a herd or flock disease rather than one of individual animals. Measures to control parasites
are effective therefore only if applied to a whole herd or flock as though it were but a single animal.

That is clearly true of sanitation—a broad term that includes about every means of minimizing exposure short of chemicals that have specific and selective action. But it is also true of preventive medication, because the kind and extent of such medication depend on the hazards of specific parasitism. It also is true (with minor exceptions) of the use of chemotherapeutic, or curative, agents. Those agents often are unreliable in heavily parasitized animals and should therefore be used when parasitism in a flock is most responsive to control by them, but the urgency of treating all animals of a flock or herd is dictated by the fact that parasitism ordinarily is recognized first in one or a few animals when it is incubating in all the others.

Every parasite, moreover, has a relatively fixed cycle and rate of development, despite the abundance of different species, each of which has its own forms, habits, modes of life, and potentialities for causing disease and injury.

Each species therefore must fight its own battle for survival. The strongest attack must be made on the parasite’s stage of development which is most vulnerable.

Immunological techniques cannot be used as a major aid to systematic control. That circumstance, more than any other, forces us to rely mainly on chemical measures of prevention and eradication.

**Parasite control** is the judicious use of feasible, profitable measures to minimize the losses and the hazards of parasitism.

The term “parasite control” connotes something quite beyond “keeping parasites in check,” “holding the line” against them, or “maintaining the status quo.” By modern standards, eradication is the only rational goal, however remote that prospect or possibility may be.

Eradication of most parasitic infections is unfeasible in practice—if not impossible. Measures are available, nevertheless, to effect attrition, prevention, or containment of most of the injurious species. The measures are based largely on sanitation and medication, the keystones of parasite control, which, if applied strongly enough, must ultimately spell eradication. There is therefore no logical basis for compromise or adjustment in the control of parasitic diseases.

The goal has been achieved in a few instances. Tick fever—a disease that caused an estimated loss of 73 million dollars in 1906—was eradicated from the United States after an unrelenting campaign against two ticks, *Boophilus annulatus* and *B. microplus*, transmitters of the microparasite of the blood, *Babesia bigemina*.

Dourine and surra of horses, trypanosome infections that occur all over the world, were eradicated by slaughtering affected horses. One can resort to that costly procedure only when the hazard is great and the number of affected animals is small. It is the one sure method of controlling diseases of whatever cause that have not yet secured a foothold in our animals. Its usefulness depends on recognition of diseases at the very beginning and on vigilance against their importation into this country.

But those cases are exceptions. Economic and other basic influences lead to compromise and indifference in many quarters where weapons of a sort are at hand for more vigorous onslaught.

We could feasibly eradicate scabies from cattle, sheep, and swine. We could eradicate lice, warbles, screwworms, sheep nose bots, horse bots, and sheep keds. Almost within reach is the control of anaplasmosis and bovine venereal trichomoniasis. It is likely that by an all-out attack we could eradicate lancet flukes and common stomach worms of sheep and cattle, stomach hairworms of cattle,
Special Principles of Parasite Control

and nodular worms of sheep. We could also eradicate trichinosis and hydatid disease, both a constant risk to man. That we have not ended them is a measure of the job ahead in research and education.

The development of control measures requires a full knowledge of injuriousness, parasite-host relationships, life cycles, sources of infection and means of transmission, epizootology, bionomics, immunity, factors that augment host resistance, and geographical distribution.

To eradicate tick fever it was necessary to have many basic facts: That the microparasites in the blood of sick animals were the sole cause of the disease; these organisms were tick-borne and were transmitted by only one kind of tick; this tick was a one-host species; there were no uncontrollable reservoirs of infection; the disease was transmitted by successive generations of ticks rather than by successive stages of the same tick; the disease could not exist if the ticks were eradicated; the developmental cycle of the tick was such that successive, definitely timed treatments would destroy all ticks before they could produce a new generation; and that efficient chemical measures could be devised for destroying the ticks. All those facts and more were used in devising the simple scheme of dipping of cattle south of the quarantine zone twice a month in a prescribed arsenical solution.

That is the "life cycle approach." A concerted attack on all fronts achieves best results, but "breaking the chain at its weakest link" is the essence of every effort directed against parasites.

Nearly every species has an environmental phase outside its host, which alternates with the parasite's stages in or on the animal. The former may involve an intermediate host—for example, the cattle tick in the instance of the microparasite of cattle fever. There are one or more intermediate, reservoir, or vector hosts of many other parasites—the trypanosomes, anaplasms, histomonads (blackhead organisms of turkeys and chickens), leishmanias, liver flukes and other trematodes, tapeworms, many stomach worms, filarial worms, thorn-headed worms, and numerous others, including even an arthropod species, the tropical warblefly. These, like the parasite of tick fever, almost always are more subject to indirect attack by destruction of their intermediate hosts than by direct attack on the organism.

Often there is no intermediate host. In the direct cycle, the environmental phase may consist of free-living, preinfective, and infective stages (as in gastrointestinal nematodes) or it may be the adult stage, as in flies that produce myiasis (screwworms, blowflies, cattle grubs, horse bots, the sheep nose bots, and others).

In any, there are successive host stages—preadults, adults, eggs, larvae and embryos, in the case of parasitic worms—that alternate with extra-host stages, such as the free-living preinfective and infective larvae.

A parasite usually is more vulnerable to attack at one stage of this cycle than at another. Anthelmintics, for example, are commonly employed to destroy the adult stage of worm parasites in their hosts. Free-choice and low-level administrations of phenothiazine, however, act primarily upon the eggs and preinfective larvae of parasites outside the host, although there are also other significant actions, such as depression of the reproductive potential of female worms in their hosts.

The radiobiological attack on screwworms is an attack on the egg stage of flies on potential hosts and also on the reproductive potential of adult flies.

Infestation by the most damaging gastrointestinal roundworm parasites is transmitted by means of the feces. Measures to prevent and destroy contamination of pastures, such as light stocking, resting and rotating pastures, stock rotation, chemical disinfection, and general sanitation, consequently are the basis of many recommendations for control.
The time and environmental conditions that a parasite needs to develop are significant. Some parasites, such as cattle grubs and swine kidney worms, take so long to complete their life cycles that marketing the host animals often interrupts the cycle. Marketing practices, then, can influence parasitism, but time factors have greater significance in defining when, how often, and at what intervals medication can best destroy the parasite. Cattle thus are dipped or sprayed twice at an interval of 10 days for scabies, and swine are treated twice at an interval of 10 weeks to combat large roundworms.

Temperature, precipitation, and the other factors of climate determine the distribution, seasonal occurrence, and abundance of many parasites. Warmth and moisture generally favor their development. Many internal worm parasites must overwinter in breeder animals because the free-living infective stages cannot survive the cold of winter on pastures. They can be destroyed by anthelmintics between grazing seasons; so it is possible to put clean animals on clean pastures in the spring.

External parasites often exhibit just the opposite pattern. Lice, for example, survive in small numbers in the summer but become abundant in the winter. It is quite easy, therefore, to eradicate them by efficient treatment of animals in early fall. These off-season treatments are the basis of many measures of systematic, preventive medication. Generally it is advantageous to drain, fill, or fence swampy areas of pastures because they propagate parasites. Irrigation of arid lands favors parasitism and thus creates special problems of control. Always, however, good control measures take advantage of environmental influences.

Parasitic infections usually provoke more or less immunity, yet they are not controllable by vaccines, serums, or other biologicals that are successful against some of the infectious diseases. Immunization has been practiced with uncertain success in poultry coccidiosis. The cross-immunity conferred by a comparatively benign species of Anaplasma has been utilized in some countries to protect cattle from anaplasmosis. A comparable procedure has offered some promise in controlling East Coast Fever, a disease of cattle in South Africa caused by the microparasite, Theileria parva. Breeding of resistant stock has been encouraged as a control measure for African bovine trypanosomiasis.

It is hard to evaluate the potential significance of factors of immunity among helminthic infections. There is no doubt that acquired immunity is a practical force. It may largely account for the unusual susceptibility of young animals to severe worm parasitism. Investigators in this country and England have demonstrated that immunity to lungworms can be transferred to calves by injections of serum and gamma globulin from actively immunized animals. Scientists in Australia have described an "anthelmintic" effect in parasitized, hypersensitive sheep that results from exposure to living infective larvae of the large stomach worms and intestinal hairworms. Such findings bolster our hope that methods of immunization shall one day be evolved. Their practical use in the control of helminthic disease still is negligible, however.

External, or arthropod, parasites offer little prospect of being amenable to control by immunizing technics. Phenomena of immunity influence the development and appraisal of control measures, however. Cattle grubs, for example, are less abundant in older animals than in yearlings. Sheep keds are more numerous on lambs than on breeder stock.

Improper feeding and grazing, overstocking, unsanitary conditions, and inattention to illnesses in early stages favor parasitism. On the other hand, good feeding and the removal of
adverse influences increase the resistance to the invasion and establishment of parasites. The factors of health often are specific as well as general. Sometimes, as with stomach-worm disease and trichostrongylosis of sheep, good diet often cures the disease.

Some investigators, indeed, do not regard clinical parasitism as a "primary" disease. They consider it secondary to and induced by one or more predisposing influences. However, the notable significance of factors that predispose to parasitism and of the benefits from remedial measures do not obscure the fact that the real battle must be waged against the offending parasites.

**Antiparasitic chemicals are powerful aids to control.** They are not synonymous with control or substitutes for it. Some efficient measures of parasite control do not depend for their success on the use of these agents. Examples are the sanitation system of controlling worm parasites in swine, portable pens for controlling coccidiosis and other fecal-borne infections of calves, and artificial insemination in the control of bovine trichomoniasis. Conversely, few parasites have been successfully controlled by medication alone. Chemotherapeutic and other chemical measures for destroying or otherwise attacking parasites, however, have a prominent place in parasite control programs. In the same degree that the concept of control embraces all measures aimed at the weakest links in the cycles of parasites, the concept of antiparasitic chemicals includes all agents that accomplish, or help accomplish, interruption of the cycle at stages where parasites are open to attack by them.

Accordingly, the list of antiparasitics includes the usual protozoacides, anthelmintics, insecticides, and acaricides that are commonly used to destroy adult parasites and vectors of disease and also the ovicides, larvicides, repellents, and other agents for destroying developmental stages, preventing fulfillment of the cycle, and disinfecting premises. It also includes many chemical agents that ameliorate and suppress parasitic disease or militate against the survival and propagation of parasites.

Chemical measures generally are immediate in their effects, economical, and simple. They may not be desirable if other means are adequate, but changing concepts about antiparasitic agents and their applications are a measure of progress in parasite control. Antiparasitic chemicals, above all else, must be used preventively and systematically to the fullest extent possible. The reclamation of heavily parasitized animals is not "a stitch in time." We have increasing evidence, moreover, that medication cannot be relied upon to check the outbreaks of parasitic diseases, or even to cure worm parasitism in weakened animals. Under such conditions, the veterinarian must advise vigorous measures.

People generally recognize the need for more, better, and safer antiparasitic chemicals; for sounder and wider application of programs of systematic, preventive medication; and for more imaginative and effective use of chemical agents against other than adult stages of parasites.

Yet in most instances the best applications of chemical agents can only be determined by complete knowledge of a kind that marked the campaign against tick fever. Furthermore—to repeat—the expanding knowledge of parasites and their relationship to livestock makes it clear that efficient control goes hand in hand with sanitation, good feeding and grazing, proper stocking, intelligent breeding, surveillance, and good management.

Motivation is a practical factor in the control of parasites. Without it, measures of greatest efficiency and simplicity are of little avail. Regulatory programs with legal backing are the exception. In short, to be feasible, parasite control measures must return a profit to the producer. More than anything else, the increased recogni-
tion of the magnitude of preventable loss from parasites is the chief stimulus to an awakened interest.

Aurel O. Foster is head of the Parasite Treatment Section, Animal Disease and Parasite Research Branch, Agricultural Research Service. He was trained as a parasitologist in the Johns Hopkins University School of Hygiene and Public Health. He received the degree of doctor of science from that institution in 1933. He taught in Baltimore and conducted research in Panama before entering the Department in 1939.

Chemotherapeutic Agents for Internal Parasites

Aurel O. Foster

Chemicals are our oldest weapons for combating the parasitic infections. They are also the most practicable and powerful weapons in modern use.

The Ebers Papyrus—the oldest medical document, dating from about 1550 B.C.—mentions the use of pomegranate against intestinal worms. Pomegranate is listed for the same purpose in a late edition of the United States Dispensatory, an official document, which gives "original information about new drugs and current data about drugs already in use." Both volumes also mention castor oil as a purgative.

Pomegranate is listed because of longevity, not because of newness or because of uses that we can recommend. Castor oil is still without a peer in its line.

But specific treatments ordinarily are products of the times and for the times. None of the treatments currently in wide use against internal parasites was known two decades ago. There is the probability and the hope, therefore, that we shall have many new and better ones a decade or two hence.

Methods of using drugs against parasites also change. The effects of new approaches and viewpoints are fully as significant as new drugs. Today, in consequence of a better understanding of the nature and gravity of parasitism, the strictly curative use of antiparasitic chemicals is becoming rare. Emphasis is on prevention rather than cure, and the concept of parasite control embraces all feasible steps that minimize economic losses from parasites.

A corollary viewpoint is that antiparasitic chemicals may attack any vulnerable stage of a parasite and are best and most efficiently employed as adjuncts to other control measures rather than as substitutes for them: However necessary and useful these agents are for treating heavily infested animals, they are used most profitably in proved programs of systematic, preventive medication. We see this at its highest development in the extensive use of free-choice and low-level systems of medication to control the gastrointestinal parasites of cattle, sheep, and horses, and in programs of continuous and intermittent medication for controlling coccidiosis and blackhead of chickens and turkeys.

Chemotherapeutic agents, or chemicals used in treatment or control of parasitic infestations and infectious diseases, ordinarily come into use only