there remain three or more independent variables, the difficulty still persists.[3] Hence we must assume that all our situations relative to a utility function must not contain more than two independent variables, or else we must introduce directly a postulate of integrability. It seems an arbitrary limitation.

Having obtained or assumed such a function, let us suppose that we make it a maximum. We are inclined to set dI equal to zero, and without further consideration to regard the problem as solved. But if the maximum occurs on the boundary of the region of variation of the variables, as is likely, for instance, in the case of an individual who is trying to corner the market, there is no need for dI to be zero. Usually, also, there are various subsidiary conditions —restraints, "obstacles," necessary relations between the variables, which have to be satisfied at the same time. And altogether, these equations and the equations given by $dI = 0$ furnish as many equations as there are unknowns. But this is purely an automatic process. If we overlook a restraint, $dI = 0$ merely furnishes us one more equation than it did previously. It is absolutely no check on the correctness of statement of the problem that the number of equations is the required number.[4]

Finally, if we are to study group phenomena and distinguish between cooperative and competitive elements in the system, we must, as we have already remarked, introduce also group utility indices or group "ophelimities," and these have no transparent relation to the individual ones. The individual can not make his individual utility a maximum at the same time that society makes the sum of all the utilities a maximum, for the maximum of a sum is not in general the sum of the maxima of the separate terms. The group utility function can not, therefore, with this interpretation of the problem, be the sum of the utility functions of its members. And from this point of view the doctrine of "laissez faire" lacks mathematical foundation.

It is apparent, from what we have said, that the use of a utility function reduces us to the study of a very special case. The special case may, of course, be worth while. But in the terms heretofore used this study is entirely abstract; moreover, if it is to be made sound, it is dependent on the introduction of a number of special conditions which are not statable by means of economic concepts. The result is merely a collection of equations which have no relation to economics, except in the names that are used. Would it not be better than to abandon the use of the utility function, and investigate situations more directly in terms of concrete concepts, like profit and money value of production, in order to take advantage of the fact that money is fundamental in most modern economics and to use the numbers which it assigns to objects?

Concrete concepts suggest concrete hypotheses.

[3] This apparently is not a unanimous opinion among economists; *Cf.* the review of the author's "Mathematical Introduction to Economics" by Professor Henry Schultz (*Journal* of the American Association, December, 1931). It is assumed that a decision is possible as to which of two situations is preferable, or better, or more satisfying, even though each depends on several variables and without regard to processes of transformation; but we notice that this is itself merely the assumption of integrability. It is warrantable only for a limited class of problems. How many individuals, for instance, can decide, without reference to process, which of the two situations he desires—peace, or justice, in China?

[4] That we have the same number of equations as unknowns is a more or less adequate check on the correctness of statement of a problem when each relation comes directly from the problem or its intuitive analysis. At best the method is not satisfying, even when restricted to geometric or algebraic relations. But economists have been tempted to carry the idea over into these problems of maxima and minima, where, for the reasons given above, it is absolutely worthless.

CRITERIA AND METHODS IN THE INVESTIGATION OF AVIAN COCCIDIOSIS

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WHILE the economic importance of coccidial infection in domestic fowls is quite generally recognized, much of the investigation in this field has yielded only conflicting results and all too little in the way of actual accomplishment. The chief difficulties appear to have been due to the failure to recognize that a number of distinct species of *Eimeria* occur in poultry, even in a single host species, and also to the failure to employ adequate controls. Thus the coccidial infections encountered in various domesticated birds have been commonly attributed to a single poorly defined species, usually alluded to as "*Eimeria avium.*" While the usual text-book description of the coccidium life cycle appears to have been understood and widely utilized, certain well-established principles have been frequently ignored.

It is the purpose of this communication to review some of the methods employed by the author in previous work in this field and also to discuss certain criteria which have been found to have application in a more recent investigation carried on in collaboration with H. Theiler and E. E. Jones.[1] The recognition of the fact that a single avian host may harbor more than one species of *Eimeria* appears essential to a proper approach to this field of work. In order to learn the reaction of the host to each species of parasite, or indeed to determine to which ones the more serious disease conditions are attributable, it has been found advantageous to work with infections produced experimentally with single species. Since coccidia do not lend themselves to artificial propagation outside the bodies of their respective hosts, the determination of their specific characters makes it necessary to substitute for the test-tube of the bacteriologist a suitable experimental animal. Hence the isolation of a given species is accomplished by the selection of proper material, while its propagation is carried on by experimental infection.

Isolation may be accomplished in various ways. On occasion, infections with a single species of *Eimeria* present themselves, thus doing away with the necessity of artificial isolation. In such cases, sufficient acquaintance with the organism and a series of observations carried out on carefully conducted experimental infections are necessary in order to be sure that one is not dealing with mixed infections.

In some instances the selection of material from a given region of the intestine is all that is necessary to isolate a species. For example, in a mixed infection with *E. acervulina* and *E. tenella,* the fact that the development of the latter is commonly confined to the caeca makes possible the isolation of the former by collecting oocysts from the first portion of the intestinal tract. On the other hand, *E. tenella* may be isolated from such a mixture by taking the caecal mucosa for the source of oocysts after prolonged and thorough washing in running water to remove the *E. acervulina* oocysts that pass into the caeca from the small intestine. By this method we have been successful also in separating *E. necatrix* Johnson from associated *E. acervulina* infection.

By collecting the earliest oocysts to appear in an experimental mixed infection, it is possible to separate out the species having the shortest period of development. Likewise selection may be based on differences in the time required by the oocysts of various species to undergo sporulation.

In certain combinations of species, the most feasible method for the isolation of a species may be to obtain single oocysts. One way of accomplishing this is by the dilution method as employed by Miss Jones.[2] This is done by transferring material containing the mixture of oocysts into a succession of drops of fluid on a thin strip of moistened gelatin, which for convenience is placed on a sterile microscopic slide. When a drop is obtained containing a single oocyst of the type desired, the portion of the gelatin strip including the oocyst in question is then cut out and immediately fed to an uninfected bird. It will be readily understood, however, that it may be a time-consuming task to obtain by the dilution method an oocyst of a species which is poorly represented in a given mixture. Another method was employed when *E. maxima* was first encountered in a mixture with *E. acervulina,* in which its oocysts formed only a very small percentage of the total number present. Since the large size of the *E. maxima* oocysts rendered them readily distinguishable, single oocysts were isolated by the Barber micropipette, transferred to a small disc of moistened gelatin which was then lifted by sterile tweezers and placed far back in the pharynx of an uninfected chicken to make sure of its being swallowed.

Should a mixture of two organisms be encountered such as *E. tenella* and *E. necatrix,* which produce oocysts that are not readily distinguished one from another and that develop in the same portion of the intestinal tract, the most feasible procedure would appear to be to immunize birds against either one of the organisms which may be available in pure culture. Then on feeding the mixture of oocysts to the immunized birds, a pure strain of the other species may be obtained.

In reviewing the criteria that we have considered in recognizing species, attention should be called to the common fallacy of differentiating species on the measurements of oocysts. First of all, the measurement of oocysts furnishes no certain index as to the purity of the material. Slight representation of additional species may have no appreciable effect on the curve plotted and, unless other characters are taken into account, there is no means of knowing whether a curve obtained is typical of any species. There is also considerable evidence indicating the occurrence of size strains within a given species. It has been shown by Miss Jones[3] that an infection derived from a single oocyst furnishes oocysts that give a distinctly bimodal curve when the measurements are plotted and that this character is maintained throughout successive transfers. She has also shown that the oocysts may be larger in light infections than in heavy ones.

In view of such variation within a species, the consideration of other features in addition to the dimensions of the oocyst appears to be essential for the differentiation of species. For this purpose we have found the following characters useful: the

[1] A full account of this work is in the hands of the publishers and will appear in the *American Journal of Hygiene.*

[2] E. E. Jones, "Size as a Species Characteristic in Coccidia: Variation under Diverse Conditions of Infection." To appear in *Archiv für Protistenkunde.*

[3] E. E. Jones, *loc. cit.*

period required for development, *i. e.*, the time from the feeding of oocysts to the discharge of oocysts; the sporulation time; the gross topography of the infection; the distribution of organisms in the epithelium, *i. e.*, whether scattered or in colonies, superficial or deep, in free surfaces or in glands, *et cetera;* the gross and microscopic pathology of the infection; the morphology of the developmental forms of the organisms; and finally the absence of cross immunity. Notwithstanding this rather formidable array of characters, differentiation of the individual species is not difficult once they have been recognized, since certain combinations of characters are practically specific. Thus the occurrence of superficial, whitish, transversely extending, elongate spots composed of oocysts in the mucosa of the upper portion of the intestine furnishes a reliable indication of *E. acervulina,* while the ocurrence, in association with hemorrhage, of rounded whitish spots, occurring in greatest number in the middle portion of the intestine, seen best from the serous surface and composed of numbers of cells containing large schizonts furnishes a diagnosis of *E. necatrix.*

In addition to the difficulties arising from the confusion of species, the failure to recognize certain fundamental principles in many instances vitiates the results of investigation. In contrast to the experimental bacteriological infections in which no elaborate precautions for the isolation of stock animals are necessary, in experimental studies of coccidial infection, the possible occurrence of adventitious infection must always be taken into account. The ubiquity of coccidial infections, their possible introduction by the attendant, or in food material, or by insects, rats and mice, is apparently often disregarded. The demonstration that the ingestion of a single sporulated oocyst may result in infection serves to indicate the necessity of carefully planned controls for all crucial experiments in this field. While it seems to have been recognized that coccidial infection tends to be self-limited, the duration of single infections in the absence of any opportunity for reinfection appears not to have been determined heretofore. We have found that various Eimerian infections, even in the absence of any appreciable protective reaction on the part of the host, disappear spontaneously, following the completion of the developmental cycle. This type of infection, in contrast to bacterial infections, is thus dependent for its continuance on reinfection through the ingestion of oocysts. That a certain proportion of sporulated oocysts may pass through the intestine unhatched is often disregarded, although this fact may be readily demonstrated either by direct examination of fecal discharges or by placing control birds in the same cage with those fed oocysts.

That the severity of infection is primarily dependent upon dosage is also readily demonstrable; light infections with even the most pathogenic species furnish no symptoms and no more than microscopic lesions. The term "dosage," however, should apply to the number of infective forms which invade the tissues rather than to the number swallowed. Thus it has been found that approximately the same number of organisms fed to birds of one age will furnish a much heavier infection than when fed to birds of another age. It has been found also that greater protection is afforded the host by a heavy infection than by a light one. Among other things to be considered with reference to dosage is the movement of material through the alimentary tract of the bird. Material fed to the chicken commonly makes its appearance in the feces in slightly more than an hour's time. Since no very coarse material is ever found in the caeca, it is apparent that not all material passing through the small intestine enters these tubes, but there is a sampling of the more finely comminuted material. Thus many of the sporozoites of *E. tenella* hatching in the small intestine fail to enter the caeca, and are lost in the fecal discharges, as may be demonstrated by microscopic examination. Likewise, by far the greater proportion of the merozoites produced in the small intestine by *E. necatrix* pass out in the feces. In fact, merozoites are regularly demonstrable in the discharges, even in light infections of this species.

There are certain precautions that should be taken as a matter of routine in experimental coccidial infection, and others that may be taken with special objectives in view. It is a fortunate circumstance that the day-old chicks which may now be purchased at all seasons of the year are usually free from coccidial infection. On arrival, they should be furnished a sterilized equipment, consisting of cage, heat unit, feed and water dishes, and thenceforth kept in a room apart from infected chickens. All mash, grit and litter which they receive thereafter should be made into packages of appropriate size and sterilized in the autoclave as a matter of routine. Water may be taken from the hot water tap. The attendant should have nothing to do with infected birds, which preferably should be personally cared for by the investigator. The rooms in which either stock or experimental birds are kept should be well screened and free from cockroaches, flies and other insects. Access of mice to cages and food material should be carefully prevented. Propinquity is another important feature to take into consideration; the activity of chickens in scattering material about makes accidental infection a matter of frequent occurrence, especially when lots of birds are kept in the same room with other lots that are discharging oocysts. The proof of the success of measures to protect experimental birds from accidental infection rests on the freedom of stock from infection as determined by periodic examination of discharges. Accidental infection does not, however, necessarily vitiate one's results, especially if it is immediately recognized. The time of its occurrence may indicate an accidental infection, and its morphological characters may make possible its differentiation from the experimental infection.

The assumption that chicks kept on false cage-bottoms of wire mesh will not become reinfected is unwarranted. While this measure may lessen the opportunity for reinfection, nevertheless fecal material adheres to the wire so that it is likely to become mixed with scattered food and later ingested or it may contaminate the feet and be picked off subsequently by the bird. Fecal material is commonly found in food dishes, thus furnishing ample opportunity for reinfection. Practically the only way to prevent reinfection is to change to successive sterile environments at periods less than the sporulation time of the oocysts, *i. e.*, within each twenty-four hours. The continued absence of infection in normal control birds after their introduction into the cage with the infected ones furnishes evidence as to the efficacy of the above measures.

In the course of our investigations on immunity, the question arose as to whether the birds that were resistant to reinfection were also no longer discharging organisms. While it would appear that no test thus far tried out for the presence of organisms in the fecal discharges is wholly infallible, yet certain procedures carried out at frequent intervals probably furnish a reliable indication. Infection may be disclosed by the direct method of microscopic examination, by which may be discovered not only oocysts, but also merozoites, and it not infrequently happens, at least with some species, that the merozoites may be present when no oocysts are demonstrable. The flotation method of concentration, using strong salt solution, works well for determining the presence of oocysts, but after such treatment the oocysts are often unsuitable for subsequent transmission experiments. By keeping fecal discharges for two or three days in 2.5 per cent. potassium dichromate solution and then feeding the material to normal birds, it is frequently possible to demonstrate the presence of oocysts in material in which they could not be found microscopically. Since by this method the samples fed represent only a fraction of the discharges of the bird tested, it is quite possible that the existence of light infections may not always be discovered. Even on combining both the microscopic and feeding tests for the presence of infection, it can not definitely be demonstrated that a bird on a given occasion harbors no infection, for the discharge of organisms is subject to considerable fluctuation. However, in groups of birds such tests made repeatedly furnish an indication of the trends of infections, *i. e.*, whether increasing in intensity or dying out.

Failure to employ adequate precautions to prevent accidental coccidial infections or to recognize them when they occur doubtless accounts for many of the fallacies and ill-founded conclusions that appear from time to time. For example, reports on the transmission of coccidial infection to quite unrelated host species are not uncommon in the literature. A scrutiny of such reports yields no evidence of proper isolation of the test bird or sterilization of its food, while the possibility of the intestinal contents of the donor containing oocysts from other sources than itself appears not to have been considered. Concerning the latter possibility, Krijgsman's[4] success in infecting rabbits with *Eimeria stiedae* from the feces of rats that had been fed this organism is noteworthy. Another source of error is the failure to identify accurately the infection that may appear in the recipient in the course of cross-infection experiments. The mere occurrence of coccidial infection is hardly acceptable without definitely identifying it by further morphological and pathological studies. The time of occurrence of infection is of considerable significance, and in order to determine this, daily examinations for organisms in the discharges are necessary. Gross pathological features associated with coccidial infection should not be relied on without supporting evidence. For example, extensive fatal hemorrhage into the caeca and small intestine has been noted in turkeys, but we are not justified in regarding this as *E. tenella* infection without demonstrating organisms with the morphological and biological features of this species.

Unwarranted assumptions are frequently encountered in measures proposed for coccidiosis control. Thus the dipping of eggs for incubation purposes in antiseptics is advocated without determining whether it is possible for the oocysts to survive on the shell of the egg throughout the period of incubation. The absence of coccidia in most of the day-old stock on the market appears not to have been recognized. Furthermore, it is commonly assumed that coccidial infection, since it is of such serious consequence in poultry, should be wholly eliminated from the flock. The conclusion has been reached, however,

[4] B. J. Krijgsman, "Overbrenging en prophylaxis der coccidiose." *Tijdschr. Diergenessk.*, 56e (19): 1032–43. 1929. (Author's summary, *Biol. Abst.*, 5, No. 4, April, 1931.)

in our recent investigations that the exposure of birds to light infection early in life protects them against serious injury from infection later on.

Once the multiplicity of the species of *Eimeria* infecting poultry is realized and the basic principles of such infections are understood, there is probably no other group of hosts in which coccidiosis may be studied so advantageously. While it is a rather difficult matter to maintain stocks of young mammals free from all such infections, "day-old" chicks are now available in reasonably large numbers throughout the year, and young turkeys, pheasants, *et cetera,* may be obtained at certain seasons. The uniform susceptibility of such hosts, the ease with which infection is produced and the regularity of results under laboratory conditions, all lend themselves to accuracy in this field of work. It is reasonable to expect that much may be learned also by the application of exact methods of observation and experiment to the practical problems in coccidiosis.

SCIENTIFIC EVENTS

SUMMER MEETINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SEVERAL years ago the council of the American Association for the Advancement of Science voted to hold summer meetings. The first of these meetings, held at Pasadena, California, last summer, will be remembered for its wealth of important scientific symposia and numerous excursions. Physicists, chemists and other scientists came from all parts of America to attend the scientific sessions held at that time.

The second meeting of this series of summer meetings will be held at Syracuse, New York, on June 20 to 25. For a meeting of national scope such as that of the association, Syracuse's geographical position is ideal. It is overnight from Eastern Canadian points, New England, New York, Washington, Baltimore, Philadelphia, Pittsburgh, Detroit, Cincinnati, and but slightly further from the South and Middle West. It is within 300 miles of one third of the population of the United States, and a ride of not more than eighteen hours will bring three quarters of the population of the United States to Syracuse. Such institutions as Syracuse University, Cornell University, the University of Rochester, Colgate University, Hobart, Wells and Union Colleges are within three-hour rides of Syracuse.

Preliminary indications are that the number of symposia at Syracuse will be much larger than the number at Pasadena. Extensive program plans are being made by a number of sections. Each of the fifteen sections of the association will plan to hold two or more sessions devoted to studies of special subjects. Already the programs of Section C (Chemistry) and Section N (Medical Sciences) are taking definite shape in this direction. Each local representative is working diligently with the secretary of the section which he represents. Indeed, the chairman of the local committee, Dean Hugh P. Baker, promises to replace any one who does not take an active part in the program planning. Only a few of the affiliated societies will meet with the Association at Syracuse, so that the section secretaries and the local representatives will be given the privilege of organizing the programs as they think best. Since the by-laws of the association forbid sections to hold programs competing with the programs of affiliated societies meeting with the association, this will offer to some of the section secretaries an opportunity which has never before presented itself.

The next summer meeting after that at Syracuse will be held in connection with the Century of Progress World's Fair at Chicago from June 19 to 30, 1933. The fair will make available a large sum of money which will enable the association to invite seventy-five distinguished foreign scientists whose expenses will be paid. From two to nine such guests will be invited for each section. It is planned to organize one symposium in the field of each of these distinguished guests and thus make it possible for American and European scientists to exchange views on subjects uppermost in their minds to-day. In addition to these sectional symposia, it is expected that the various affiliated societies meeting with the association at that time will hold sessions for the reading of papers.

Preparations for the World's Fair are rapidly nearing completion. The Hall of Science, covering five acres of land, will be the center of this mammoth undertaking. Indeed, here and throughout the fair the dependence of industry and civilization itself on science will be pictured. Nearly ten acres of floor space will be devoted to science exhibits.

CHARLES F. ROOS,
Permanent Secretary

THE ASTROPHOTOGRAPHIC BUILDING OF THE HARVARD OBSERVATORY

THE astrophotographic building of the Harvard Observatory was dedicated on Wednesday, March 23, and on that day there were scientific conferences and meetings in accordance with the following program:

I. MORNING SESSION. The Observatory Library at 10