the same family or household, etc.) and every known feature of its epidemiology is common to the mosquito-borne diseases, such as yellow fever,[4] malaria[5] and equine encephalomyelitis.[6,7] It shows "a lack of obvious connection between the cases as to contagion, water supply, food supply, or milk supply." In 1933 and in 1937 the disease seemed to appear simultaneously in widely separated areas in St. Louis County and City. The same areas were involved in the two years. Throughout both epidemics the predominance of the cases was in those areas in which it first appeared. It does not occur every year, occurs only in the period of the year between July and October and ends with cold weather. The disease is concentrated in the vicinity of the small streams in St. Louis and St. Louis County in areas characterized by proximity to weeds, refuse dumps, open sewage and ponds.

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LIFE-CYCLE OF A SPOROZOAN PARASITE OF THE OYSTER[1]

SINCE 1930 serious oyster mortalities have occurred in five different coastal regions from Mobjack Bay, Va., to Lake Barre and vicinity in Louisiana. In each instance the oysters have shown an unusually weak condition of the adductor muscle and inability to maintain closure of the shell during dredging, transplanting and shipping operations. Though the exact cause of these epidemics has not been definitely established the microscopical examination of weak and dying specimens from each region has disclosed a heavy concentration of spores in the tissues of the muscle, gills and mantle, the number per oyster frequently amounting to several million. These resistant, thick-walled spores, ovoidal in form, are generally grouped in variable numbers (1 to 16) in hypertrophied host cells and surrounded by a crescent-shaped epispore. The mature spore (length 20 μ, diameter 11 μ) contains a single vermiform sporozoite folded twice on itself and is the resting or final developmental stage in the oyster.

Studies conducted under natural and laboratory conditions show that the meats of dying, infected oysters are readily devoured by the common mud crabs, *Panopeus herbsti* and *Eurypanopeus depressus,* in the intestine of which hatching of the spores takes place. The sporozoite escapes through a micropyle and migrates to the epithelium of the gut, where it becomes attached by a globular epimerite. In 15 to 20 hours it develops into a very small, delicate, cephaline gregarine which soon detaches and undergoes precocious coupling with other sporonts (primary sporadins), forming syzygies of 2 to 10 individuals in chain-like formation. The chains break up and the young gregarines, after another short period of attachment, develop into short, cylindrical sporonts (hypersporadins) having a length of 18 to 30 μ. The characteristic gregarine stage in the crab has a granular, spherical protomerite with a lens-shaped, epimeric cap of hyalin material. The long deutomerite, rounded at the end, has a more dense, granular cytoplasm containing a large vesicular nucleus with single nucleolus. A clear, well-defined cuticle surrounds both parts and forms a wedge-shaped "muscular collar" or septum at the point of junction.

The sporonts grow to a considerable size and form syzygies of two individuals of unequal length in which the primites attain a length ranging from 275 to 342 μ and the satellites from 220 to 286 μ. These migrate to the rectum of the crab, and after becoming attached to the cuticle by an adhesive disc, coil up and form strong, thin-walled gametocysts, varying in diameter from 81 to 192 μ. The two gregarines in each gametocyst undergo extreme nuclear division into gametes which, after a period of mixing, fuse in pairs forming zygotes that become arranged radially in small groups around slightly larger central cells. These rosettes of zygotes, or gymnospores, 4 μ in diameter, are released into the water with the rupture of the gametocysts and are carried into the shell of the oyster by the feeding current. The possibilities of heavy oyster infections are great considering the general abundance of the crabs and their close association with the mollusc, and the fact that 40 to 86 gametocysts, containing from approximately 8,000 to 90,000 gymnospores each, may be produced in a single crustacean host.

Experiments with vitally stained gymnospores show that they attach to and penetrate the epithelium of the oyster gill by means of a pseudopod projected from the central cell. Though the zygotes may develop here to maturity they generally are picked up by the phagocytes and transported in the circulatory system to nearly all parts of the body. In the blood vessels and sinuses of the gills, mantle and muscle the infected phagocytes accumulate in large numbers and increase to a considerable size (diam. 30 to 100 μ) with the rapid growth of the zygotes and their transformation into sporozoites. After each sporozoite has surrounded itself with a heavy, double-walled sporocyst, the parasite has reached the characteristic resting or dissemina-

[4] Walter Reed and others, "Yellow Fever, A Compilation of Various Publications," Government Printing Office, Washington, 1911.

[5] Sir Ronald Ross, "The Prevention of Malaria," John Murray, London, 1911.

[6] C. Ten Broeck, F. W. Hurst and E. Traub, *Jour. Exp. Med.*, 62: 677, 1935.

[7] M. H. Merrill and C. Ten Broeck, *Jour. Exp. Med.*, 62: 687, 1935.

[1] Published by permission of the U. S. Commissioner of Fisheries.

tion stage commonly found in *Ostrea virginica*. The spores were also found in the following pelecypods: *Pecten, Anomia, Ostrea equestris, Modiolus, Venus ziczac* and *Martesia* and in the gastropod, *Urosalpinx*.

The life history and morphology of this sporozoan parasite resembles that of the *Porosporidae* described on the French coast by Leger and Duboscq[2] and Pierre Hatt.[3] It is a heterogenetic gregarine with alternation of hosts, having the vegetative and reproductive phase in the intestine of decapod crustacea and sporogony in molluscs, particularly in lamellibranchs. The resistant, monozoic spores found in *Ostrea* are similar to those first described as *Nematopsis* by Schneider[4] in 1892. The American form, which will be described in detail in a forthcoming paper, is a new species for which the name *Nematopsis ostrearum* is proposed.

Studies of the effect of the parasite on adult oysters were conducted in the laboratory, where heavy infections could be produced by keeping them in close association with mud crabs carrying gametocysts or by the introduction of ripe gymnospores. In bulk experiments with several hundred oysters, losses of 66 to 73 per cent. were obtained over a period of 3 months. Kymograph records of shell movement of 35 heavily infected oysters showed abnormal and frequent contractions of the adductor muscle followed by loss of holding power and death of the molluscs. Retraction of the mantle, cessation of shell growth and weak attachment of the muscle to the shell are also characteristic of mortalities in the field and laboratory. The injury to the oyster host may be due to a toxin given off by the developing sporozoites, particularly in the sensitive mantle tissue, or to actual physical obstruction of the circulation by the masses of enlarged, infected phagocytes found in the blood vessels of the gills and muscle.

Practical prevention of the infection of oysters by this parasite is possible by control of the primary host, the mud crabs, and by exercising care in the selection of uninfected seed oysters for restocking growing and maturing areas. The crabs do not migrate and can be easily removed, before the beds are planted, by the use of dredges or scrapes equipped with fine mesh bags. In certain regions where valuable oyster beds have been abandoned or their productivity seriously reduced because of damage by this microscopic pest it should be possible to reestablish and increase production by the procedure suggested above.

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[2] L. Leger and O. Duboscq, *Trav. Stat. de Wimereux*, T. 9: 126–139, 1925.
[3] P. Hatt, *Arch. Zool. Exp.*, T. 72, 341–415, 1931.
[4] A. Schneider, *Tabl. Zool.*, T. 2: 1892.

FIELD TRIPS FOR THE TEACHING OF GEOLOGY

FIELD experiences of some kind have long played a part in courses in geology. These experiences vary greatly in amount of time spent, in methods and in results obtained. Since this is the case, it is well to evaluate from time to time such geological experiences in terms of their educational possibilities.

In the endeavor to make his own field class trips most productive for his students, the writer, during a period of years, has made a study of field class procedure. As a result of this study certain conclusions have been reached and are briefly presented here.

Since much of the procedure depends upon the aims or objectives of the field trips, a concise statement of attainable and worth-while objectives is desirable. Objectives for a course in general geology to which carefully planned field trips may contribute are the following:

(1) A genuine interest in the science of geology.
(2) Some ability to correctly interpret certain geological phenomena.
(3) Some appreciation of the geological environment of mankind.
(4) The contribution of earth materials and the substances derived therefrom to man's progress, his pleasure and his comfort.

While each trip will have a part to play in the attainment of these more general objectives, it will also have some specific aim of its own. For example, the major emphasis on one trip may be devoted to only a part of Objective No. 2, yet the trip as a whole will further the realization of Objectives 1, 3 and 4.

The methods employed in the classroom, the laboratory and on the field trips should all contribute to the attainment of the objectives set up for the course. How then shall the field trip be conducted so as to bring about the greatest possible realization of these objectives?

According to the writer's experience the field trip that is to contribute as much as possible to the attainment of the foregoing objectives and which is arranged with them in mind will be such as will require a maximum of participation, interest and industry on the part of each student. Active student participation may be secured most naturally through the use of a carefully planned activity program and selected problems. The use of such a program on a field trip is challenging and highly instructive as well as interesting to students. It directs the attention of each student to the materials for study and gives him an opportunity to independently observe for typical characteristics, to note similarities and differences and to be ready to