elementary bodies and some larger coccoid forms, which have the morphology and the tinctorial characters of agents of the lymphogranuloma-psittacosis group.

It is true that a careful study of the agent of heart-water fever as observable in intima smears, by individuals accustomed to the agents of the lymphogranuloma-psittacosis group, revealed that certain morphological structures, particularly the ring forms,[5] predominate so among the different morphological forms of the agent as to distinguish it from those of the lymphogranuloma-psittacosis group. Moreover, Cowdry[4] and Jackson[5] both mention bacillary forms which never occur in the agents of the latter group. Nevertheless, the morphological and chemotherapeutic similarities are so great as to suggest to the present authors that further inquiry into a possible relationship should be made.

That relationship among members of the lymphogranuloma-psittacosis group of agents is not limited to morphology and tinctorial characters has been demonstrated by the cross reactions found to occur in the complement fixation test.[6,7,8,9] Sera from 5 cases of heart-water fever in sheep were collected by one of us (R. A.) and tested for complement-fixing activity with an antigen prepared from the agent of lymphogranuloma venereum growing in the yolk sacs of embryonated chicken eggs.

On the occasion of first testing the heart-water fever sera, these were all found to be anticomplementary. A serum from a known case of lymphogranuloma venereum, used as a control in the test, gave fixation at a dilution of 1:160. All other controls were satisfactory. Before retesting, all sera, including that from the known case of lymphogranuloma venereum, were heated at 60° C for an hour on two consecutive days. This procedure rendered all the sera free from anticomplementary action even at a dilution of 1:2 except one which was not anticomplementary at 1:5. When these sera were now tested none of them gave any evidence of fixation of complement even at the highest concentration. The anti-lymphogranuloma serum which had been exposed to the same treatment at 60° C still gave fixation at a dilution of 1:160.

It is clear then that these sera from sheep, that had reacted to heart-water fever 39, 66, 71, 110 and 110 days earlier, respectively, had no antibodies capable of fixing complement in the presence of the agent of lymphogranuloma. This would suggest a lack of antigenic relationship between the agent of heart-water fever and those of the lymphogranuloma-psittacosis group. However, this is not necessarily the case since, as Eddie and Francis have pointed out,[10] the serum of pigeons infected with meningopneumonitis, or at least giving complement fixation with this agent, failed to give cross reaction with lymphogranuloma antigen. Such a species peculiarity could theoretically exist in sheep and account for the results.

It would seem most probable that the agent of heart-water fever, while not distinctly either a Rickettsia or a member of the lymphogranuloma-psittacosis group, is related to both. The relationship of the Rickettsiae and the lymphogranuloma-psittacosis group of agents even in morphology[11] is becoming more and more clearly recognized.

SUMMARY

Sera from sheep which were infected with heart-water fever from 39 to 110 days before the serum was withdrawn failed to fix complement in the presence of lymphogranuloma venereum antigen.

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THE COMPARATIVE ANTIFOULING EFFICACY OF DDT

CONSIDERABLE publicity has resulted from the recent announcement[1] that experimental paints containing DDT (2,2-bis(chlorophenyl)-1,1,1-trichloroethane) showed positive suppression of fouling by Balanus species on panels exposed for from three to six months in Yaquina Bay (Oregon). It is perhaps unfortunate that the average reader automatically associates efficacy against barnacles with a "cure-all" for the fouling of ships' bottoms. This is of course untrue.

The United States Navy, for example, in its Docking Report Manual[2] describes at least eight different phyla and classes of marine flora and fauna known to contribute importantly to the fouling phenomena. Thus:

[5] C. Jackson, 12th Rept., Dir. Vet. Serv. and Anim. Indust., Union of S. Africa, p. 161, 1931.
[6] G. Rake, M. D. Eaton and M. F. Shaffer, *Proc. Soc. Exp. Biol. and Med.*, 48: 528, 1941.
[7] G. Rake, M. F. Shaffer and P. Thygeson, *Proc. Soc. Exp. Biol. and Med.*, 49: 545, 1942.
[8] J. A. Baker, *Jour. Exp. Med.*, 79: 159, 1944.
[9] C. Nigg and M. D. Eaton, *Jour. Exp. Med.*, 79: 497, 1944.
[10] B. Eddie and T. Francis, Jr., *Proc. Soc. Exp. Biol. and Med.*, 50: 291, 1942.
[11] A. M. Begg, F. Fulton and M. van den Ende, *Jour. Path. and Bact.*, 56: 109, 1944.
[1] SCIENCE, 102: 2640, 10, August 3, 1945.
[2] Bureau of Ships, Navy Department, Washington, D. C., "Docking Report Manual," 1942.

Key to the Organisms Important in the Fouling of Ships' Bottoms(2)

I. Organisms with hard, often limy shells:
- A. Coiled or twisted tubular shells ..... Annelids
- B. Cone-shaped shells attached directly to the hull, or shells with a long muscular stalk ..... Barnacles
- C. Flat, spreading, granular discs or patches ..... Bryozoa
- D. Paired shells, such as clams, mussels, oysters, etc. ..... Mollusks

II. Organisms without shells:
- A. Green, brown, or red filaments or leaf-like structures, generally near the water-line ..... Algae
- B. Branching tree-shaped growths, the branches not expanded at the tips ..... Bryozoa
- C. Straight or branching growths, each thread terminating in an expanded tip ..... Hydroids
- D. Round soft spongy masses ..... Tunicates

The presence of one or more of these kinds of fouling organisms on a hull is deleterious because (1) the increased weight and friction reduce speed and/or increase fuel consumption; (2) the tendency to fouling overgrowth by other organisms on the areas of bottom paint "insulated" by the precursor organism is severe; and, (3) even non-shell-forming organisms may be directly or indirectly disruptive of the underlying anti-corrosive paint system.

It is thus imperative that specific sensitivities to certain toxicants, demonstrated by some few types of fouling organisms, not be given too great importance in evaluating over-all antifouling efficacy. Professor Dimick did not himself err in this respect; unfortunately, published reports of his observations on DDT in the popular press and elsewhere were not equally conservative.

We have demonstrated conclusively that DDT is relatively ineffective, if not completely inert, to all forms of fouling organisms prevalent in Florida waters with the exception of Balanus species. We understand that this finding is completely in agreement with that of the Oregon investigators, who report DDT to be negative against algae, mussels, oysters, hydroids, annelids and probably bryozoans.[3]

In Table 1, we summarize illustrative data and observations obtained during an 8-month Florida exposure of a typical antifouling paint in which the usual toxicant was replaced with DDT. We present, in comparison, the same formula containing a commercial cupriferous pigment and a control in which there is no toxic pigment present.

TABLE 1

RESULTS OF VISUAL INSPECTION (c)

Pigment (a)	Immersion period	Barnacles	Mollusks	Annelids	Hydroids	Bryozoa	
						Encrusting	Filamentous
DDT	1 month	10	8	7	6	4	10
DDT	2 months	10	6	6	4	3	9
DDT	4 months	10	4	6	5	3	6
DDT	6 months	10	2	6	9 (b)	3	8
DDT	8 months	General rating = 0					
Cu_2O	1 month	10	10	10	10	10	10
Cu_2O	2 months	10	10	10	10	10	10
Cu_2O	4 months	10	10	10	10	10	10
Cu_2O	6 months	10	10	10	10	10	10
Cu_2O	8 months	10	10	9	10	10	10
Fe_2O_3	1 month	4	7	8	6	4	10
Fe_2O_3	2 months	3	6	7	5	4	9
Fe_2O_3	4 months	3	3	7	7	4	6
Fe_2O_3	6 months	4	3	7			
Fe_2O_3	8 months	General rating = 0			9 (b)	4	9

(a) 50 per cent. pigment. 50 per cent. vehicle solids in antifouling paint formulation.
(b) Hydroids sloughed, perhaps by spreading of other organisms.
(c) Marine Fouling Rating Scale: 10–0.
10 = no fouling. 0 = completely fouled.

The steel panels were brush-coated in the usual manner with two coats of a commercially available anticorrosive paint and one coat of the antifouling paints. They were immersed from October 23, 1944, to June 25, 1945, at Daytona Beach, Florida. Details of racking and exposure techniques employed at this test site have been previously described.[4]

The conclusion is obvious, that DDT has a high order of specificity against barnacles, as reported by Professor Dimick. Against other fouling organisms, the DDT is apparently inert. It thus seems unlikely that this toxicant can effectively displace cupriferous and/or mercury pigments in the usual ships' bottom paints.

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[3] R. E. Dimick. Private communication.
[4] G. H. Young and coworkers, *Ind. Eng. Chem.*, 35: 432, 436, 1943.