not, of course, a problem peculiar to medical research. The vast expenditures on basic and applied research and on development by the armed forces and the Atomic Energy Commission are critically important to the nation's defense. The effect of this accelerated program will permeate the entire structure of higher education. Universities and colleges will be feeling the same financial pinch that medical schools have lived with for some time. It seems quite likely, therefore, that the balance between research and teaching will be a matter of increasing concern. A continuing reappraisal of the net effect of expanded research upon the teaching function, and of the steps required to sustain the quality of both, is urgently needed. We, as well as other agencies, need the guidance of the National Science Foundation and other qualified organizations.

We have explored only a few of the questions of policy that confront us. We have not, for example, been able to explain the Public Health Service research fellowships. In our view, expansion of the pool of highly trained research manpower is as important as the support of work in progress. We believe that the 1,400 fellows whom we have aided to date will, within a few years, contribute significantly to the furtherance of medical research and teaching.

By discussing some specific questions we have tried to indicate what we believe our role to be and how we propose to carry that role out. Underlying all the specific problems is a sense of living and working in an era of transition to patterns that cannot now be foreseen, but which will be different from those of the prewar years. As this evolutionary process moves forward, we are deeply conscious of our responsibilities as public servants. We must keep open the channels of communication between educational institutions and the Public Health Service, and we must formulate our policies on the basis of the most sensitive and intelligent appraisal of trends in medical research and education of which we are capable.

Although we have dealt primarily with unresolved problems, they should not obscure the far more important fact that medical research is advancing rapidly. We believe, indeed, that the medical research of the country is now as alive, intellectually vigorous, and productive as in any period of our history.

Technical Papers

The Effect of Temperature on the Molluscacidal Activity of Copper Sulfate

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In recommending copper sulfate as a molluscacide, Chandler (*1*) states:

> There are a number of factors which influence the effect of copper sulfate on organisms in water, the most important being temperature, presence of algae, alkalinity, and organic matter in solution. As regards temperature, no extended experiments were carried out, but experiments with a 1 to 1,000,000 solution were carried out at temperatures of from 15 to 27° C, and the snails apparently succumbed as quickly at the lower as at the higher temperature.

The contradictory nature of these two statements regarding the effect of temperature has never been satisfactorily resolved. It is the purpose of the present study to show that the first of Chandler's statements rather than the second is correct insofar as the effect of temperature on the molluscacidal activity of copper sulfate is concerned.

Observations by other workers as to the bearing of temperature on the activity of molluscacides have been infrequent and inconclusive (*2, 3*). More recent work by Kuntz and Wells (*4*) and by the present authors has led to the conclusion that temperature is a factor of primary importance in determining the activity of molluscacides.

In the present series of experiments the response of *Biomphalaria boissyi*[2] was observed at five temperatures in the range 14°–26° C, using concentrations of copper sulfate pentahydrate varying from 0.05 to 100 ppm. The selected temperature range approximates the seasonal variation in water temperatures in Egypt (*5*).

Snails for these tests were collected from an irrigation drain near Cairo. The collections and tests were carried out between Feb. 24 and May 18, 1951. Four hundred selected snails measuring from 9–14 mm in diameter and weighing 200–350 mg were kept for 48 hr in a battery of four 15-liter aquaria, which, in turn, were surrounded by a water bath maintained at 25 ± 0.5°. Oxygenated tap water was circulated through each aquarium at the rate of approximately 100 ml/min; an excess of a local variety of spinach (*sabaneh*) was also supplied. Continuous illumination was furnished by two 15-w daylight lamps suspended 10 in. above the aquaria. Snails that had undergone this conditioning treatment appeared to give a more nearly uniform response than those used immediately after collection.

Samples of water from local canals and drains har-

[1] The opinions or assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

[2] The intermediate host of Egyptian *Schistosoma mansoni*.

boring abundant snail colonies showed pH values ranging from 7.3 to 8.5. Molluscacide solutions were made up in distilled water (pH 6.3 ± 0.2), since solutions of copper sulfate in tap water were found to be unstable, principally because of the precipitation action of dissolved carbonate. The copper sulfate solutions used in these experiments varied in pH somewhat irregularly from 5.7 ($CuSO_4 \cdot 5H_2O = 40$ ppm) to 6.8 ($CuSO_4 \cdot 5H_2O = 0.07$ ppm). The pH values were always higher following the 24-hr period during which the snails were in contact with the copper sulfate; these postexposure values ranged from 6.4 to 7.4.

For estimation of the LD_{50} at a given temperature, a series of 4 tests, each at 7 to 9 different copper sulfate concentrations, was carried out. Limitations of space in the constant-temperature bath[3] made it necessary to carry out most of the tests on separate days. For a given test, 16 conditioned snails were placed in each of a series of 1-liter beakers containing 800 ml of aqueous copper sulfate. A band of adhesive tape[4] effectively prevented the snails' escape from the molluscacide solution. For tests at temperatures below 25°, the snails and molluscacide solutions were cooled to the temperature in question before being brought together. After 24 hr at the test temperature the snails were rinsed well in tap water, and the copper sulfate solution was replaced by oxygenated tap water (pH 7.8 ± 0.2), wherein the snails remained for an additional 24 hr at the test temperature.

After rinsing in tap water, those snails that appeared to be alive were placed in a beaker (L) containing 300 ml of oxygenated tap water and a few sprigs of pond weed (*Potamogeton*). The snails that appeared to be dead were put in a similar beaker (D), after which the beakers were placed under a daylight lamp in a constant-temperature bath of 25°. Twenty-four hr later any living snails in beaker D were transferred to beaker L, and any dead snails in beaker L were put in beaker D. All snails were then rinsed well, transferred to fresh oxygenated tap water and returned to the constant-temperature bath for an additional 24 hr. Changes in the number of living and dead snails following such a 48-hr observation period were small. In one experiment involving 288 snails the observation period was extended to 96 hr. The number of snails considered to be dead at the beginning of the observation period (P) and at successive 24-hr intervals was as follows: P, 171; $P+24$, 180; $P+48$, 182; $P+72$, 182; $P+96$, 183.

In order to ascertain the range of temperatures in which death might occur even in the absence of copper sulfate, a series of control studies, each involving 100 snails, was carried out under the same conditions as those in which copper sulfate was employed—i.e., 48 hr at the test temperature followed by 48 hr (observation period) at 25°. The percentage mortality found was as follows: 26°, 0%; 29°, 13%; 32°, 45%; 35°, 59%; 38°, 100%.

[3] The water bath of a modified Aminco Climatizer.

[4] Bauer & Black Industrial Tape No. 803Y214.

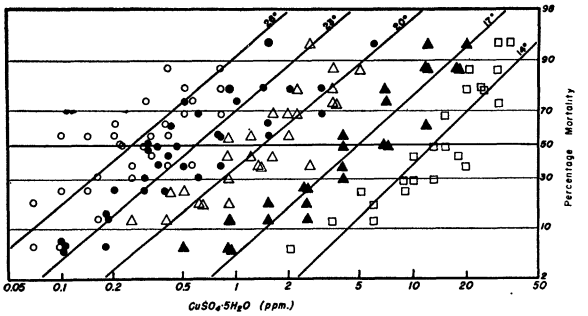

FIG. 1. Response of *B. boissyi* to copper sulfate as a function of temperature.

The response of *B. boissyi* to copper sulfate at the several temperatures and under the conditions described above is shown in the form of a scatter diagram (Fig. 1) in which concentration of copper sulfate is plotted against percentage mortality[5] on logarithmic probability paper (*6*). An over-all linear regression is evident, although from test to test there is considerable variation in response at a given dosage level, particularly at the higher temperatures. Because of the considerable heterogeneity just referred to, estimates of confidence limits and of the slope of the dosage response curve have been reserved for future tests of improved experimental design. It is nevertheless clear that the LD_{50} decreases sharply with increasing temperature, showing approximately a fiftyfold variation over the 12-degree temperature range investigated. The estimated LD_{50} values are as follows: 14°, 13 ppm; 17°, 4.8 ppm; 20°, 1.4 ppm; 23°, 0.58 ppm; 26°, 0.25 ppm.

When the logarithm of the LD_{50} is plotted against the reciprocal of the absolute temperature a straight line is obtained (Fig. 2). From a comparison of this curve with the Arrhenius plot obtained by von Brand, Nolan, and Mann (*7*) for variations in the oxygen consumption of *Australorbis glabratus* with temperature it is evident that, within the temperature range common to both studies, LD_{50} (*B. boissyi* vs. copper

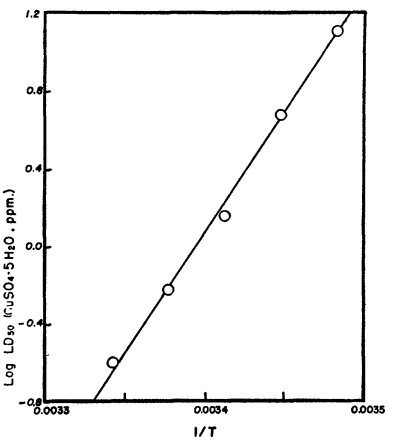

FIG. 2. LD_{50} (*B. boissyi* vs. copper sulfate) as a function of temperature.

[5] Zero and 100% effects have not been plotted.

sulfate) is inversely proportional approximately to the cube of the oxygen consumption rate (*A. glabratus*). Some justification for comparing the LD_{50} of one genus of snails with the oxygen consumption rate of another is found in the fact that the oxygen consumption curve corresponds closely with the normal curve which Krogh (*8*) found to be valid for a wide variety of cold-blooded animals.

In view of (*a*) the prevalence of bilharziasis (*9*), (*b*) the fact that copper sulfate is currently the only chemical in large-scale use as a molluscacide,[6] and (*c*) the fact that the number of snails in a given canal, as estimated by the use of dip nets or palm-leaf traps, may decrease as much as 80% during the hot summer months without *any* external treatment (*10, 11*), the importance of temperature as a factor in snail control work can scarcely be overemphasized.

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[6] More than a million pounds per year are used in Egypt alone.

Chick-Growth Stimulation Produced by Surfactants[1]

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Certain surfactants have been found to produce an increased growth response in chicks. As part of a broad study on the use of distillers solubles in animal nutrition, it has been observed that these surfactants, when fed at levels ranging from 13 to 454 g/100 lbs mixed ration, will promote an increase in growth ranging to 12% above the controls. (Surprisingly, many commercial preparations for home laundry and dishwashing use are among the active types.) These results have been obtained in laboratory battery trials of more than two years' duration. A total of 125 individual test groups of 20 chicks each has been studied to date, all chicks being carried on experiment to 10 or 12 weeks of age. Practical-scale field trials have been conducted to check important laboratory findings.

[1] A preliminary report.

Tables 1 and 2 give the basal rations used and experimental data obtained in a typical test series on a rather thoroughly studied surfactant, an ethylene oxide condensate of coco fatty acids.

Evidence collected to date on B_{12}–antibiotic–surface-active-agent supplementation, both alone and in

TABLE 1

ALL-VEGETABLE BASAL DIETS USED FOR CHICK TESTS (Table 2)

Ingredient	Lbs/100 lbs	
	Basal for Series I and II	Basal for Series III
Ground yellow corn	60.0	60.5
Soybean oil meal (41%)	18.0	35.0
Corn gluten meal	10.0	—
Alfalfa meal	4.0	—
Distillers solubles	5.0	—
Feeding limestone	1.3	1.5
Steamed bone meal	1.0	2.0
1,500 A/400 D oil	.35	.50
Salt	.35	.50
$MnSO_4$	.02	.02
Riboflavin	—	(150 mg)
Total	100.02	100.02

TABLE 2

COMPARISON OF A SURFACE ACTIVE AGENT WITH B_{12} AND ANTIBIOTICS IN AN ALL-VEGETABLE–TYPE BROILER RATION

Series	Group	Supplement*	Amt Supplement fed for 100 lbs ration (grams)	Final† chick wt (lbs)	Lbs feed/lb gain
I	A	Control basal #1	None	2.82	2.71
	B	As "A" plus aureomycin supplement	50	3.22	2.57
	C	As "A" plus lauryl ethylene oxide condensate	50	3.09	2.84
II	A	Control basal #1	None	3.00	2.84
	B	As "A" plus terramycin supplement	50	3.14	2.67
	C	As "A" plus lauryl ethylene oxide condensate	50	3.31	2.85
III	A	Control basal #2	None	3.06	3.14
	B	As "A" plus vitamin B_{12}	50	3.33	3.26
	C	As "A" plus bacitracin supplement	50	3.34	3.08
	D	As "A" plus lauryl ethylene oxide condensate	50	3.34	2.97

* Antibiotic supplements used had a guaranteed potency of 5 g antibiotic/lb; B_{12} supplement used had a potency of 6 mg B_{12}/lb.

† Final chick weights in Series I and II were taken at 70th day; in Series III, on 84th day. Weights shown are the male-female average.