substances in cellars and when heavily enveloped by lead. Nodon, it is true, attributed his "ultraradiation," as he called it, to the sun; but he reports some effect even at night (which he is at pains to interpret), as one would anticipate from the results of Millikan.

It may be recalled that rock analysis shows that, assuming percentage composition similar to that on the surface, there is enough radioactive material in a depth of only twelve miles of the earth's crust to supply by its daily disintegration all the heat the earth radiates daily into space. If atoms of number above eighty-two exist beneath this twelve-mile shell, and if they are distintegrating as actively as at the surface, we are forced to the logical conclusions of Joly, who supposes that the heat of radioactive origin will accumulate until the earth's hot interior, after a process of eversion, will disburden itself of its store of heat by radiation into space during one of the earth's "incandescent periods," and thus make ready for a fresh geological aeon. Such catastrophic events are, however, no longer inevitable if we alter one of the premises in the logic, and grant that the radioactivity of the heavy chemical atoms is not entirely spontaneous but is conditioned, in part at least, by irradiation by Millikan rays, which would penetrate only a limited distance into the earth's crust. One must suppose that workers in laboratories are so well and so constantly screened that fluctuation in rate of radioactive change has escaped them.

However this may be, further experiments on the possible acceleration of radioactive change by these very high frequency radiations would appear to be of great interest, and we hope Professor Millikan is planning such experiments.

ALAN W. C. MENZIES
C. A. SLOAT
PRINCETON, N. J.

INSECT TOXICOLOGY

THERE is a growing tendency to supplement field experiments on insecticides with tests and comparisons in the laboratory where, under controlled conditions, more exact observations and deductions may be made. This development in economic entomology is exemplified particularly by the work of Moore, Richardson, McIndoo and Tattersfield. The writer believes that laboratory research on the effects of insecticides would develop more rapidly and fruitfully if laboratory and field workers alike had a single, definite conception of its purpose and potential importance.

The purpose of laboratory research on the poisoning of insects has been obscured in part by the lack of a significant name for it. At times it has been classed under insect physiology; again it has been allied with chemical field control work in economic entomology. The writer proposes for it the name, *insect toxicology,*[1] to include the results of all investigations which deal in a quantitative manner with the effects of insecticides on insects. The term, insect toxicology, is not entirely free from ambiguity, because it also suggests the effects of poisons elaborated by the insects themselves; but, with the foregoing definition, it should be satisfactory.

Insect toxicology should have for its purpose the development of a body of knowledge comparable to vertebrate toxicology or pharmacology. Just as in medicine, pharmacology supplies a rational, scientific basis for applied therapeutics, so in entomology, insect toxicology should be expected to supply a similar sound basis for insecticide practice. The need for an insect toxicology fashioned in the manner of pharmacology has been recognized, consciously or unconsciously, by workers with insecticides who turn to manuals of pharmacology for suggestions, although they know that the vertebrate toxicology of such manuals may not be applicable to insects, even in a qualitative sense. The quantitative conception of insect toxicology is especially important. Innumerable insecticide "cage experiments" have been carried out by many workers. The results have been more or less useful at the time and place of completion, but because they were not obtained under carefully controlled conditions by quantitative methods they have no value for building up the fundamental laws of insect toxicology which could be applied to the analysis of insecticide poisoning under any combination of natural conditions.

The writer has been devoting his time and thought to insect toxicology for several years, and has become convinced that it is practicable to build up a quantitative system of insect toxicology both for stomach-poison and contact insecticides on a few suitable laboratory insects. This conviction, for stomach-poisons at least, will be supported by subsequent publication of methods and results, which the writer believes compare favorably with those of vertebrate toxicology.

If the objection be made that the analogy between insect toxicology and pharmacology is not sufficient proof for the potential importance of the former, instances may be cited of the practical results already secured through insect toxicology. The impulse for the development of coated arsenicals for the Japanese beetle sprang from William Moore's observations on the repellant effect on the beetle of sublethal doses of

[1] This term does not conflict with *economic toxicology* proposed by M. R. Miller (SCIENCE, XLIV, p. 264) to include all aspects of work in which poisons are employed to economic advantage.

arsenic. Price showed quantitatively that honey-bees are quite susceptible to arsenic poisoning, and, therefore, it would be unwise to run the risk of killing bees by spraying trees in blossom. Richardson has done promising quantitative work on nicotine substitutes. The writer will offer quantitative proof for conclusions on some practical matters in arsenical practice. He intends to show that acquired individual tolerance to arsenic is very unlikely; that, on a unit weight of larva basis, young larvae are less resistant to arsenic poisoning than older larvae; that different species of insects may vary decidedly in resistance to equal doses of arsenic on a unit weight of insect basis, and that trivalent arsenic is more toxic than pentavalent arsenic.

In general, insect toxicology may be expected to analyze the complications of insecticide practice, and so help to explain failures and suggest improvements in field materials and methods. However, immediate practical results should neither be desired nor expected from every investigation in insect toxicology, since the more fundamental branches of science have invariably profited by an unlimited range of inquiry.

F. L. CAMPBELL

BUSSEY INSTITUTION

THE REQUIREMENT OF MATHEMATICS FOR COLLEGE FRESHMEN

NEXT to freshman "English," a year of mathematics is doubtless the most universal requirement in our colleges. Such preeminence requires unusual justification. Broadly speaking, mathematics serves two purposes: it is a tool for the solution of certain immediate problems, and it is an instrument for thought. Too few students ever attain the perfection of skill in technical manipulations to enable them to use mathematics in solving real—as contrasted with classroom—problems. If we are to justify requiring mathematics of every one or virtually every one, we must turn to the second purpose.

Mathematics is still justified as a formal discipline. It is considered to be fine training in accurate thinking. But the doctrine of formal discipline has undergone a good deal of modification under the buffeting of experimental study. We know, for instance, that no amount of purely formal or repetitive drill in accuracy will increase one's accuracy in general. To base the requirement of mathematics upon purely formal discipline is to play into the hands of the enemy.

Yet mathematics can be made a real training for thought. Clear, accurate and rapid thought depends largely upon the mastery of certain concepts, many or most of which are essentially mathematical in nature. To name but a few, how can one think clearly about certain problems without a grasp of the concepts of asymptotic approach to a limit, of maxima and minima, of independent and dependent variability and of functional relationship? Certainly one can attain to practical mastery of these concepts in circumscribed fields without the mathematical approach, but the surest route is surely through mathematics.

Is this to emphasize the obvious? Certainly, for mathematicians. But not for students. Mathematics has not succeeded in justifying itself to the student on these grounds.

More important, the point, however obvious, does not seem to have influenced the teaching of early courses in mathematics, either in secondary school or college. It is sound pedagogical principle to isolate for emphasis those factors in a study which are of greatest importance and which should form part of the permanent equipment of the student. Thus when the concept of functional relationship has been taught by means of specific instances, of problems to be solved according to a mathematical technique, the student should be led to *generalize* this concept as much as possible. Otherwise there is the gravest risk —rather the positive certainty—that it will remain a mere technical device for solving certain equations in "Math I." Yet how often is the notion of functional relationship correlated with Mill's so-called canons of induction in such a way that the student may see that this thing with which he has been dealing by means of abstract symbols is basic to all thought about cause and effect?

I therefore venture to suggest that an effort be made to list the fundamental concepts of mathematics which form the basis of clear, factual thinking. And that teachers of mathematics bend every effort to get the student to grasp the *universal* significance and applicability of these concepts. I can not believe that required mathematics will lose in popularity for this; nor does it seem that it will lose in effectiveness even in the teaching of technical manipulations. In any case, those who need the latter—engineers and physicists and so on—not less than others need to know the fundamental significance of their tools.

I am more uncertain about the second suggestion I have to offer. Great progress has been made in recent years in including certain statistical notions in freshman courses, but these courses are still oriented primarily towards mechanics. Now great as have been and probably will be the contributions of physical science to civilization, it has become a commonplace that the future of mankind for the next two or three centuries will depend less upon the con-