regulations do *not* say that an organization to be exempt must "be operated primarily for fundamental research," as stated in your editorial. The Internal Revenue Service has apparently had the wisdom to see that the dividing line between "basic," "fundamental," and "applied" research is something that scientists themselves do not agree on, and to see that it does not provide a proper basis for taxation.

The newly proposed regulations do set forth as a test of whether research is "scientific" that the results of such research must be made freely available to the public. This strikes me as a curious definition of the term *scientific*, since it makes the method of dissemination rather than the scientific nature or content of the research the test of whether the research is scientific. Of course, the significance of this definition of *scientific*, as stated in the new proposed regulations, turns on what is meant by the "freely available" test. The proposed regulations seem to intend to limit this test by a concept which sets as the standard that the research is directed not toward promoting private gain but rather toward benefiting the public.

There is a shocking fallacy implicit in a concept which places private gain in opposition to public benefit. The economic and political system of this country is founded on the principle that there are public benefits from the opportunities for private gain. Certainly the public is benefited where the opportunity for private gain leads to the promotion or support of scientific research. As I understand it, all that the tax laws require as a qualification for exemption from tax is that the net earnings of an exempt organization should not inure as a private gain to the members of the exempt organization; but the fact that research leads to someone else's private gain (that is, gain for industry and, in fact, for the public itself) does not mean that research is directed any the less toward benefiting the public.

The concept expressed in the regulations goes to the root of other tax exemptions. The editorial itself points to the danger and inconsistency in the proposed regulations in this regard. In indicating which organizations will be affected or not affected by the regulations, the editorial points out, for example, that universities will not be affected, and in this connection you state that their exemption includes "income derived from applied research that is not available to the public." At the same time the editorial indicates that independent research institutions carrying on the same activities will be affected. If such activities are not in the public interest when conducted in such institutions, will not this conclusion strike at the basis for exemption for all other organizations conducting research? If science itself is found unworthy of the protection of tax-exempt status because private gain may be derived from the application of scientific research, then neither education nor any other purpose will long provide an effective tax screen, for the conduct of research in any institution would then inevitably be considered to be in the domain of taxable business enterprise. I am sure that the American Association for the Advancement of Science cannot remain indifferent to this prospect.

The proposed regulations raise another fundamental question that the association may very well want to ponder. As pointed out in the editorial, under the proposed regulations any research done for a government agency would be considered of an exempt character, but research conducted for industrial sponsors would generally not be. This would make the course of future research organizations dependent upon government programs and would require that they primarily serve government agencies as a price for tax exemption. The freedom heretofore enjoyed of pursuing scientific research in the interest of increasing scientific knowledge, regardless of who sponsors the research, would be lost, and in its place would be the necessity of committing the institution to the mercy of government programs in order to maintain tax-exempt status. This loss of scientific freedom poses a question of great importance for those interested in the advancement of science in a free society.

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*The proposed regulation is, indeed, complex; but with reference to the question of fundamental research it has this to say: ". . . for purposes of the exclusion from unrelated business taxable income provided by section 512(b)(9), it is necessary to determine whether the organization is operated primarily for purposes of carrying on 'fundamental,' as contrasted with 'applied' research."*
—ED.

## Population Control by Release of Irradiated Males

The article by E. F. Knipling in *Science* [**130**, 902 (1959)] on possible methods of insect control by treatment of males with radiation or chemicals is interesting and illuminating. It should be pointed out, however, that where males are irradiated and released in the field, the restriction of monogamy in females of a species is not a requirement for

controlling population size, since sterility of the males (*sensu stricto*) is not necessarily the radiation effect which causes the population decline. Even with multiple matings by every female, the population collapse would be as inevitable and rapid as when the females are monogamous.

The effect of radiation which probably is most important is the induction of dominant lethality in the sperm, not male sterility. For illustration, let us consider an insect population made up of ten males and ten virgin females. Ninety irradiated males are introduced into this population. The females mate only once. When perfect randomness is assumed in this simple example, the probability exists that nine of the females will mate with irradiated males and produce no viable offspring, and that one will mate with a normal male and produce normal offspring. One hundred percent of the eggs from one female and 10 percent of the total batch of eggs will survive. In this case, it will not matter whether dominant lethals are induced in the sperm or the males are made sterile.

Now consider the same conditions, but let every female mate ten times. Each female will mate with ten males, nine of which contain dominant lethals and one of which has normal sperm. Ten percent of the eggs from each female and 10 percent of the total batch will survive; this is in accord with the rule of strict monogamy, even though polygamy is the case here. If the irradiated males are sterile, 100 percent of the total batch of eggs survive.

It is obvious that, if the primary action of radiation is that of inducing dominant lethality in the sperm, the results are identical whether female monogamy or promiscuity obtains. In practice, one of course can imagine circumstances whereby monogamy or polygamy could influence the rate of decline, and according to the circumstances, polygamy actually could be an advantage for population collapse.

It is generally known that at levels of radiation of about 10 kiloroentgens to either the fly *Drosophila* or the wasp *Habrobracon*, dominant lethal events are induced in over 99 percent of the sperm. However, to obtain complete killing of the sperm, radiation levels of about 200 kr are required [for observations on *Habrobracon*, see Whiting and von Borstel, *Genetics* **39**, 317 (1954)]. It has been observed in *Drosophila* that dominant lethals are induced in mature sperm and spermatocytes in later stages of spermatogenesis, and that after these are exhausted a period of sterility sets in, from which, at doses of about 10 kr, the flies never recover [see Welshons and Russell, *Proc. Natl. Acad. Sci. U.S.*

43, 608 (1957)]. The process of sperm exhaustion following irradiation requires about a week of continuous multiple matings, but *Drosophila* males that have not been mated for 19 days after irradiation still have sperm reserves containing dominant lethals [Demerec and Kaufmann, *Am. Naturalist* **75**, 366 (1941)]. With the simple cytological procedures now available for determining, at different doses of radiation, the components of dominant lethality [von Borstel and Rekemeyer, *Genetics*, in press] and sterility [Welshons and Russell, *Proc. Natl. Acad. Sci. U.S.* **43**, 608 (1957)], there should be little difficulty in determining dose-effect relations for any insect.

Knipling pointed out in an earlier paper [*J. Econ. Entomol.* **48**, 459 (1955)] that competition of sperm from irradiated males with that of normal males can replace strict monogamy as a prerequisite for success of the irradiated-male technique for eradicating insect populations. He also quoted the observation of Bushland and Hopkins [*J. Econ. Entomol.* **46**, 648 (1953)] that fertilization of eggs by irradiated *Callitroga* males occurred in the screwworm experiment. Death of the *Callitroga* embryos must have been through induced dominant lethality in the studies of Bushland and Hopkins. Admittedly, if monogamy is the rule, dominant lethality and sterility are equally effective, but the two effects of radiation must be neither lumped nor confused. By a curious historical quirk, the dominant-lethality concept was completely shadowed by the well-executed and dramatic experiments of Baumhover and his associates [*J. Econ. Entomol.* **48**, 462 (1955)] in eradicating the screwworm from Curaçao, since *Callitroga* apparently mates once. Since the males were irradiated as early pupae, it is possible that both dominant lethality and true sterility were contributing factors to the success in Curaçao and the recent success in Florida of efforts to eradicate the screwworm.

The reason for again drawing attention to the feature of dominant lethality induced by radiation is that the restriction of monogamy has been fixed in the minds of many entomologists with whom I have discussed this problem. Also, the author of a theoretical discussion on the eradication of the tsetse fly [Simpson, *Biometrics* **14**, 159 (1958)] is concerned about the monogamous restriction, since Nash [*Bull. Entomol. Research* **46**, 357 (1955)] has evidence that multiple matings take place in the tsetse fly.

With the potential of the induced-dominant-lethality method for insect eradication barely explored, and since with radiation the dosage can be con-

trolled so accurately, the radiation method should be exploited more fully, even while Knipling's suggestion (1959) for seeking chemical compounds for inducing sterility in the field (species-specific? accurate dosage?) is being undertaken. There are of course many problems faced by entomologists when they inquire into the economic suitability of methods for control of any particular insect species. But with monogamy not necessarily a restriction with the irradiation-of-males method, it seems possible that this could often become the procedure of choice when the most economically desirable method for eradication is being determined, as with experiments now in progress to rid Guam and Hawaii of fruit-fly infestations. It seems possible that the tsetse fly could even be eradicated from Africa by this method; besides radiation biological supplementation of the excellent investigations now being carried out, what would be required is sufficient money for developing large-scale methods of artifical rearing, irradiation, and release.

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**Note**

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The points brought out by von Borstel are good, and I am pleased that he is commenting specifically on the relative effect of monogamy and polygamy in the application of the sterility method of population control when the effect produces dominant lethals in the sperms. I have for some years attempted to correct the misconception that monogamy is a prerequisite to successful application of the approach to population control. In our investigations with several species of insects, including tropical fruit flies and *Anopheles* mosquitoes, there are indications that among such species having polygamous mating habits, the male-sterility method may provide an effective means of control. However, the depressing effect on the population among these species is less than in the screwworm, which is monogamous in mating habits. The probable reason is that irradiation may reduce the number of the sperms or their ability to compete with normal sperms.

In the absence of adequate information on the effects of irradiation on sperms, I stressed the theoretical possibilities of population control among species monogamous in mating habits.

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