healthy tobacco plants from which again all normal buds had been removed. It should be recalled that these shoots were composed of tumor cells and, hence, were organized tumors. The new growth that resulted from these rapidly growing shoots gradually became more and more normal in appearance. The tips of the shoots were again removed and grafted to healthy plants. They developed rapidly and appeared normal in every respect, ultimately flowered, and set seed. Fragments of tissue isolated from the normal-appearing stems derived from tumor tissue buds grew poorly in culture, as does healthy tobacco tissue. In these instances recovery appeared to have been complete. It was a gradual process that progressed in the direction of the normal as affected shoots developed and were forced into rapid growth.

Our findings suggest that the factor which causes crown-gall tumor cells to develop abnormally becomes diluted in, and is eventually lost from, affected cells that are forced to grow and divide with sufficient rapidity. Details will be published elsewhere.

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Structural and Insecticidal Relationships in Rotenone, Methoxychlor, and DDT

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In the course of investigating the relationship of chemical structure to insecticidal activity, molecular models of known insecticides were constructed, using Fisher-Hirschfelder-Taylor atom models. In this way an interesting structural similarity among rotenone, DDT,[1] and methoxychlor[2] was encountered. This similarity is not at all obvious without the use of the models.

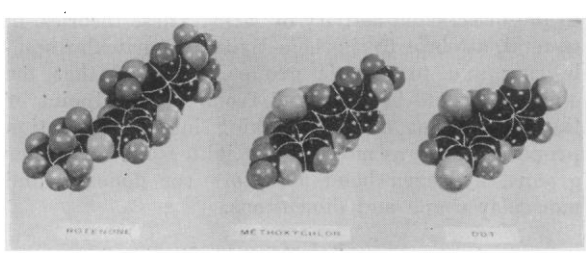
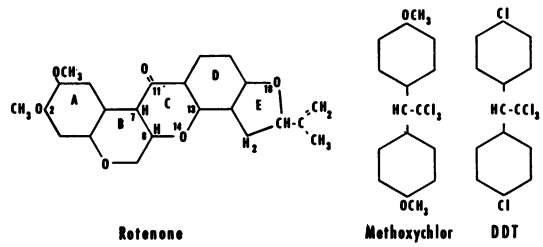


FIG. 1. Molecular models of rotenone, methoxychlor, and DDT.

Fig. 1 shows the molecular models of rotenone, methoxychlor, and DDT. The configuration of rotenone, (*1*) shown is *cis* at the 7–8 bond. The structural formulas of these compounds are:



La Forge *et al.* (*2*) have discussed a series of reactions of rotenone involving hydrolysis of the 13–14 bond followed by oxime formation and ring closure with a nitrogen between the 11 and the 14 positions. Study of the models indicates that this ring closure is strongly hindered sterically for the *trans* position and can be effectuated readily only if the configuration is *cis* at the 7–8 bond. Moreover, the ease of dehydrogenation of rotenone at the 7–8 bond would also seem to indicate that the configuration of the natural product is *cis*.

For the three molecules pictured in Fig. 1, the notable points of similarity are the angles of intersection of the axes of the benzenoid rings and the comparable slopes of the planes of these rings. In rotenone the benzenoid rings are essentially fixed with relation to each other, because of the interconnecting ring structures. In DDT and methoxychlor also, steric hindrance by the trichloromethyl group restricts the benzene rings to a relatively fixed position. In general one of the rings will be quite fixed, whereas the other may oscillate but not perform a complete, free rotation. The configuration of DDT and methoxychlor shown in the figure is, of course, only one phase in the oscillatory movements of these molecules. The rotation-hindering trichloromethyl group forms a "bump" on the molecule which coincides with a similar "bump" in the rotenone molecule resulting from puckering of ring B.

Further comparison of the molecular models indicates a close correspondence in intramolecular distances in these three substances. For example, the distance between the oxygens at positions 2 and 19 in rotenone is very close to the distance between the 2 methoxyl oxygens in methoxychlor and between the *p, p′* chlorines in DDT. The models are made to approximate scale, and these distances correspond to within 1 A. It is interesting to note that, regardless of rotation or oscillation in the DDT-type molecule, the distance between atoms in the *p, p′* positions remains constant. The importance of such molecular

[1] 1,1,1-Trichlor-2,2-bis(*p*-chlorophenyl) ethane.
[2] 1,1,1-Trichloro-2,2-bis(*p*-methoxyphenyl) ethane.

TABLE 1

INSECTICIDAL TOXICITY OF ROTENONE, METHOXYCHLOR, AND DDT

Toxicant	Minimum 100% L_D (Lbs of toxicant/100 gal water)			
	Mexican bean beetle	Southern army worm	Bean aphid	Two-spotted spider mite
Rotenone	0.12	3.0	> 3.0	> 3.0
Methoxychlor	0.25	0.12	> 3.0	> 3.0
DDT	0.5	0.06	> 3.0	> 3.0
1,1-Bis(*p*-chlorophenyl) ethane	3.0	> 3.0	3.0	2.0

shape factors in reactions between biologically active molecules and proteins such as enzymes has been widely emphasized (Pauling [*3*] and Sexton [*4*]).

To give a mechanistic view, it may be visualized that rotenone "fits" in a lock-and-key relationship with some essential region of the polypeptide chain of an enzyme. The toxicant would be held in position by short-range forces such as van der Waals, dipole-dipole, or hydrogen bonding forces. DDT and methoxychlor can assume a position in which a number of functional groups in these molecules, including corresponding polar and hydrogen bond acceptor groups, are superposable on the rotenone structure. This seems to provide a logical basis for the insecticidal relationship discussed below. In addition to the above-mentioned structural features, these three compounds fall within a limited range (345–394) of molecular weight. The significance of this property has been discussed by Kenaga (*5*).

A marked parallelism in specificity of insecticidal action, as well as in structure, is noted among rotenone, methoxychlor, and DDT. This similarity is shown by testing the insecticides simultaneously under identical test conditions.

Cranberry bean plants were dipped in the insecticidal dispersions and then infested with third instar larvae of the Mexican bean beetle, *Epilachna varivestis* Muls., and third instar larvae of the Southern army worm, *Prodenia eridania* Cram., respectively, 1 hr after application of the toxicants. Cranberry bean plants and nasturtiums previously infested with adults of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, and adults and nymphs of the bean aphid, *Aphis fabae* Scop., respectively, were dipped in the dispersions. Insect mortality counts were taken 3–6 days after application of the toxicant and corrected for natural mortality by the use of Abbott's formula.

The insecticidal formulations used were wettable solid dispersions similar to commercial formulations of these insecticides.

A comparison of the toxicity of rotenone, methoxychlor, and DDT to 4 representative agricultural pests is shown in Table 1. These compounds display a marked similarity in that they are toxic to the same species of insects and ineffective against the same species. Methoxychlor is intermediate between rotenone and DDT in toxicity to Mexican bean beetle and Southern army worm, as it is in structural characteristics. Under the conditions of these tests, *residual* insecticides are usually the only toxicants that are effective against Southern army worm larvae. Rotenone is quite easily oxidized and therefore not as residual as DDT and methoxychlor. This may offer an explanation for the large break in toxicity against the Southern army worm. 1,1-Bis(*p*-chlorophenyl) ethane, which lacks the sterically restrictive trichloromethyl group contained by DDT and methoxychlor, is included for comparison. It shows a marked change in specificity and strikingly less toxicity against Southern army worm and Mexican bean beetle.

The relationship of structure to insecticidal activity may be illustrated by making a comparison of several compounds related to rotenone. Dehydrorotenone differs from rotenone by the dehydrogenation of the 7–8 bond, thus causing the molecule to flatten out and lose the typical angular relationship between benzene rings. Dehydrorotenone has essentially no insecticidal activity in comparison with rotenone, according to Shepard and Campbell (*6*). On the other hand, alteration of the isopropenyl side chain (off ring E) by saturation or removal of the groups causes no change in this angle. The resulting compounds, dihydrorotenone and elliptone, in insecticidal tests by Shepard and Campbell (*6*) and by Martin (*7*) show comparatively little change in activity from rotenone.

Since the oxidation (dehydrogenation) at the 7–8 bond in rotenone takes place with relatively mild oxidizing agents, this may explain the loss of activity on oxidation in field use. Another property that may prevent rotenone from being residual is hydrolysis at the 13–14 bond, which opens up ring C and destroys the locked ring structure completely.

All compounds containing 2 benzene rings linked through a saturated carbon atom will have nearly the same bond angle, and therefore the rings will be on the same axes; however, the lack of the trichloromethyl group in 1,1 bis(*p*-chlorophenyl) ethane allows considerably more freedom in the rotation and oscillation of the benzene rings and does not fix the rings in restricted planes as it does in DDT and methoxychlor.

Hoskins and Craig (*8*) and Metcalf (*9*) have reviewed several theories on the relation of structure to the insecticidal activity of DDT. These theories, in general, attempt to tie the activity to particular solubilizing and toxophoric groups. We feel that the question should be evaluated from the standpoint of the molecule as a whole, taking into consideration properties such as molecular weight, solubility, polar groups, hydrogen bond acceptors (or donors), and molecular shape and dimensions.

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Results of a Preliminary Survey of Group Endings in Zoological Classifications above the Category of Genus

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Late in 1948 the author inquired of 27 North American ichthyologists in regard to fixing specific endings for various categories of classification. Replies were favorable. In order to obtain information on a broader basis, during the early part of 1949 specialists in the fields of carcinology, entomology, herpetology, ichthyology, invertebrate zoology, malacology, ornithology, mammalogy, paleontology, and parasitology were consulted. Entomologists and ornithologists have, to a certain extent, already adopted endings for various groups of classification. After discussions with about 20 specialists in the various fields, and knowing that, numerically, entomologists nearly equal the number of specialists in all other fields together, it was decided to follow the endings as already used by entomologists from superfamily down through subtribe, but to follow ornithologists for the ending of an order (-iformes) and for suborder (-oidei) as used by certain vertebrate zoologists, both minorities, for the purpose of stirring up discussions and inviting comments. The results were interesting and valuable.

The author sent a circular letter to more than 700 North American systematic zoologists on the mailing list of the Society of Systematic Zoology and received 445 ballots in return. This circular proposed to fix the endings of groups above the level of the genus, and results were as shown in Table 1.

The following information was summarized from comments received on about half of the ballots returned: "A wonderful idea and attempt to advance stability [uniformity] of zoological nomenclature;" "Leave nomenclature alone and get back to the study of specimens."

Order -iformes: "Too long; not widely used; preferable not to disturb ordinal and subordinal endings in such groups as entomology, mammalogy, and herpetology since these are so well known they are already fixed by usage; ordinal names should not be changed except for reasons of concept; let each group of specialists for each class of animals decide for itself what ending should be used." *Suborder*: Little or no comment. *Superfamily*: Little or no comment. *Supertribe, tribe, subtribe*: These categories are used

TABLE 1

Number of Votes Cast Concerning Proposed Endings Used in Groups of Classification

Field	Votes	Order -iformes	Sub-order -oidei	Super-family -oidea	Super-tribe -idi	Tribe -ini	Sub-tribe -ina	Type genus	Unanimous ballots	Total ballots returned*
Carcinology	For	12	17	19	18	19	19	16	11	23
	Against	11	6	4	5	4	4	7	2	
Entomology	For	51	73	155	140	154	127	80	41	159
	Against	106	84	3	13	4	15	68	2	
Herpetology	For	24	24	29	26	27	26	19	17	30
	Against	5	6	—	2	1	2	8	—	
Ichthyology	For	37	39	39	38	39	38	38	32	41
	Against	3	2	1	1	1	1	1	—	
Invertebrate zoology	For	30	31	36	38	38	37	30	25	50
	Against	12	17	12	9	9	10	12	7	
Malacology	For	10	11	16	13	13	13	10	7	17
	Against	7	6	1	3	3	3	7	—	
Ornithology	For	25	21	25	21	22	21	15	13	25
	Against	—	4	—	2	1	2	9	—	
Mammalogy	For	18	28	35	29	30	32	26	16	36
	Against	18	6	—	5	4	2	9	—	
Paleontology	For	10	10	20	19	17	14	12	7	29
	Against	17	17	7	8	10	13	15	5	
Parasitology	For	29	33	34	31	33	31	29	24	35
	Against	6	2	1	3	2	3	5	—	
Totals	For	246	287	408	373	392	358	275	193	
	Against	185	150	29	51	39	55	141	16	
Grand total		431	437	437	424	431	413	416	209	445
Percentage	For	57.1	65.7	93.3	88.0	91.0	86.7	66.1		
	Against	42.9	34.3	6.7	12.0	9.0	13.3	33.9		

* Some ballots did not have votes on every item.