aspects: genetics because he had trouble with ratios, physiology because his experiments never seemed to work, ecology because the lectures of Dr. *X* were dull. A greater merging of these branches of biology will help to create an atmosphere in which ecology or genetics could no more be left out than the cell theory or water and carbon dioxide. The greater maturity of the branches of biology means that the presentation of conclusions of general significance is less dependent on an explanation of techniques; there is therefore less chance that a student will fail to appreciate important conclusions because of his difficulties with the way in which the conclusions were reached. Biology can thus be presented as a subject which has matured to the point that every branch has some bearing on every other branch; the student can be brought up to feel that the physiologist who knows nothing of genetics, the taxonomer who is unacquainted with the science of ecology and the biochemist who is ignorant of evolutionary theory are biologically uneducated.

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3 : 5-DIHALOGENO-4-HYDROXYBENZONITRILES AS HERBICIDES

3 : 5-Dihalogeno-4-hydroxybenzonitriles : New Herbicides with Molluscicidal Activity

2 : 4-DINITRO-6-METHYLPHENOL (DNC) is a herbicide with high contact phytotoxicity which has been used in agriculture for many years, especially for the destruction of broad-leaved weeds in cereal crops. The activity of this molecule is specifically related to the presence of $-NO_2$ groups in the 2- and 4-positions to the –OH group though the 6-methyl grouping can be replaced by hydrogen or certain other alkyl groups without appreciable loss of phytotoxicity.

I have investigated the capacity of DNC and other aromatic nitro compounds to form intermolecular complexes with amines and hydrocarbons[1,2]. In the first of these investigations[1] it was established that the $-NO_2$ groups in 1 : 3 : 5-trinitrobenzene can be replaced by –CN without destroying the capacity to form molecular compounds, though the effect of the $-NO_2$ group in promoting compound formation was found to be greater than that of –CN. It was concluded from this work that the inductive effects exerted by these groupings in the benzene ring are similar in magnitude.

Such considerations led me to make a systematic investigation of the effects on herbicidal action of replacing the $-NO_2$ groups in DNC by –CN. A number of derivatives of 2- and 4-hydroxybenzonitrile were therefore synthesized and their activity as weed-killers was assessed by standard methods. In general, poor performance only was shown by derivatives of salicylnitrile; but a number of compounds derived from 4-hydroxybenzonitrile were shown to possess outstanding herbicidal activity. The most promising of these, first tested in June 1959, was 3 : 5-diiodo-4-hydroxybenzonitrile (later referred to as ioxynil).

The 3 : 5-dibromo analogue (broxynil) also showed high activity but the corresponding dichloro-derivative was much less active. The water-soluble sodium, potassium and ammonium salts of ioxynil and broxynil and certain of their esters were prepared during 1959–60 and tested against a range of crop and weed species. It was soon established that they are capable of destroying the tissues of many plants when applied as a spray at concentrations as low as 250 p.p.m. The effect is entirely that of a contact herbicide and no systemic activity has been observed. The compounds become inactivated by contact with soil. Against most plant species the phytotoxicities of ioxynil and broxynil are considerably greater than that of DNC; but, as with this compound, the differential wetting concept enables them both to be successfully used for destroying broad-leaved weeds in certain monocotyledonous crops. Ioxynil was tested for me by P. H. Rosher in Trinidad against a range of tropical crop and weed plants in December 1959. Most species were seriously affected or killed by a spray containing 1,000 p.p.m., grasses, millet and maize showing the least damage. Since that time a number of trials have been carried out by P. Cozens, Miss L. MacDonald and D. H. Bartlett at this College both with ioxynil and broxynil. The former has always proved to be the more effective compound. In two trials designed to examine their capacity for the destruction of potato haulm, both substances gave excellent results.

Investigations of the mode of action of these compounds are being carried out by my colleagues and me, and it has now been established by M. Kerr that the substances are strongly active in uncoupling oxidative phosphorylation within plant tissues. Since this property is shown also by DNC and by pentachlorophenol, both of which are good molluscicides, steps were taken to examine ioxynil and broxynil for their capacity to kill snails. This work was carried out for me by J. Duncan, of the Tropical Products Research Unit, Department of Technical Co-operation, who has consistently shown ioxynil to have an LC_{50} of about 0·5 p.p.m. and broxynil about 2 p.p.m. when tested as their sodium salts against *Australorbis glabratus*, a snail host of *Schistosoma mansoni*, the causative agent of intestinal bilharzia. Against another species, *Biomphalaria sudanica*, also a snail host of *S. mansoni*, the LC_{50} was $< 1{\cdot}0$ p.p.m. for ioxynil and $< 3{\cdot}0$ p.p.m. for broxynil. Ioxynil has also been shown in immersion tests to be some ten times more effective than metaldehyde against several mollusc species by I. F. Henderson and P. F. Newell at Rothamsted Experimental Station. The compound, however, has no attractant properties. A small-scale test of ioxynil for controlling water hyacinth (*Eichhornia crassipes*) has been carried out in Egypt with promising results. The destruction of this weed, which impedes water movement in the irrigation canals, is an urgent problem, and supplies of the compound have been sent to Egypt for further trials to be undertaken. The possibility of destroying water hyacinth and controlling the vector of bilharzia simultaneously with ioxynil would appear to warrant investigation.

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Herbicidal Action of 3 : 5-Dihalogeno-4-hydroxybenzonitriles

THE isolation of the plant growth regulator indolyl-3-acetonitrile from cabbages by Henbest *et al.*[1] in 1952 directed some attention on the role of the nitrile group, more particularly when it was later shown by a number of workers that this molecule was active *per se* and that activity was not solely dependent on the conversion of the nitrile into the carboxylic acid. Since then several herbicidally active nitriles have been described, for example, diphenylacetonitrile[2], triazine nitriles[3], and more particularly 2 : 6-dichlorbenzonitrile[4] (I). It seems clear that there is no rational or predictable relationship between